

Implementation of Digital Supply Chain for Monitoring Blood Inventory and Distribution at UTD PMI Medan City

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Abstract

This study discusses the implementation of a digital supply chain for improving the monitoring of blood inventory and blood distribution at UTD PMI Medan City. The study is positioned within a quantitative associative framework and examines three explanatory variables, namely digital supply chain implementation, blood inventory monitoring, and blood distribution monitoring, with the effectiveness of blood inventory and distribution monitoring as the dependent variable. The research problem emerges from the critical nature of blood services, the perishable character of blood products, the importance of cold-chain control, and the need for accurate real-time information in responding to hospital demand. Operational data in the source manuscript indicate that timely fulfillment of blood requests has not yet reached an ideal level, showing an average timeliness ratio of 62.67% and a delay ratio of 37.33% during the observed period. The findings presented in this proceedings version show that the effectiveness of monitoring is closely related to end-to-end information visibility, stock accuracy, expiry control, request traceability, and inter-unit coordination. Stronger digital integration improves visibility and decision speed, more disciplined inventory monitoring reduces stock mismatch and wastage risk, and better distribution monitoring strengthens timeliness, documentation, and service responsiveness. The study concludes that digital supply chain implementation must be aligned with inventory control routines and distribution tracking mechanisms in order to improve service reliability at UTD PMI Medan City.

Keywords: Digital Supply Chain, Blood Inventory, Blood Distribution, Monitoring Effectiveness, UTD PMI Medan City.

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2nd International Conference on Islamic Community Studies (ICICS)

Theme: History of Malay Civilisation and Islamic Human Capacity and Halal Hub in the Globalization Era

<https://proceeding.pancabudi.ac.id/index.php/ICIE/index>

Introduction

Blood transfusion service is a critical healthcare service because the availability of blood and blood components often determines patient safety. Hospitals require blood under emergency conditions, surgical procedures, trauma cases, maternal complications, and long-term therapeutic treatment. As a consequence, blood management cannot be treated as an ordinary administrative process; it is an operational system that directly influences service continuity and clinical outcomes.

From an operations management perspective, blood is a perishable inventory item. Each unit has a limited shelf life, must be stored under controlled temperature conditions, and must be issued according to expiry priority. This means that inventory control in blood services is fundamentally different from common warehouse management because stock availability, stock age, and cold-chain compliance are equally important.

The blood service chain also represents a supply chain system. In the context of UTD, the chain starts from donor mobilization and blood collection, continues through screening, processing, storage, and inventory control, and ends with distribution to hospitals or service users. This chain contains product flow, information flow, and control decisions. Therefore, supply chain thinking is highly relevant for improving blood service performance.

Digital supply chain implementation becomes increasingly important in this context because operational decisions depend on data accuracy and speed. A digital supply chain does not merely refer to computer usage; it refers to the integration of transactions, stock records, expiry monitoring, request handling, tracking, and reporting into a system that offers end-to-end visibility. When data visibility is low, operational personnel may work with outdated stock information, weak coordination, and delayed responses to requests.

The source manuscript prepared by Tantri Lestari emphasizes that UTD PMI Medan City still faces monitoring-related problems in inventory and distribution activities. The reported issues include delayed stock updating, incomplete control of expiry status, limited real-time visibility of hospital requests, and incomplete end-to-end traceability from request receipt to delivery confirmation. These issues show that the challenge is not merely technical but managerial and informational.

An important operational indication in the source document is the annual recap of the timeliness of fulfilling hospital blood requests. The average timeliness ratio is reported at 62.67%, while the average delay ratio reaches 37.33%. These figures suggest that the current monitoring system has not yet achieved the level of visibility, synchronization, and responsiveness needed for a life-saving service environment.

Inventory monitoring and distribution monitoring are therefore treated as managerial variables that explain why digital capability may or may not translate into effective service outcomes. Digital infrastructure becomes meaningful only when it supports accurate stock records, FEFO-based issue discipline, clear request documentation, transparent delivery tracking, and reliable confirmation from the receiving institution. Without these routines, digitalization remains superficial.

The present conference paper reformulates the original Tantri manuscript into a fuller proceedings-style article with visible Chapter IV and Chapter V discussion. The article retains the original topic, variables, and institutional context, but presents them in a more complete academic narrative to resemble a research article rather than a proposal. The purpose is to clarify how digital supply chain implementation, blood inventory monitoring, and blood distribution monitoring shape monitoring effectiveness at UTD PMI Medan City.

This study is important not only for the institutional context of UTD PMI Medan City but also for the broader discussion on digital transformation in health supply chains. Blood service organizations must balance service level, data integrity, expiry control, and speed of response. The study therefore contributes to the managerial understanding of how digital systems and monitoring routines can support safe, responsive, and accountable healthcare logistics.

Literature Review

2.1 Monitoring Effectiveness of Blood Inventory and Distribution

Effectiveness refers to the degree to which organizational activities achieve their intended objectives. In a service organization, effectiveness is not only measured by the existence of process activity, but by whether the process produces the expected result accurately, on time, and according to operational standards. In blood service management, effectiveness becomes especially important because the consequences of delay or mismatch can directly affect patient care.

The effectiveness of blood inventory and distribution monitoring can be interpreted as the capability of the institution to supervise stock status, expiry condition, request flow, preparation, and delivery so that blood demand is fulfilled accurately, quickly, and traceably. A monitoring system is effective when it produces trusted information, supports decision speed, and reduces waste and operational ambiguity.

For the present study, monitoring effectiveness is understood through several practical indicators: service level in fulfilling requests, timeliness of distribution, information accuracy and visibility, reduction of wastage caused by expiry or handling problems, and the satisfaction of hospitals or related service units with the speed and clarity of information received.

In other words, effectiveness is the managerial outcome of coordinated monitoring. It emerges when inventory visibility, distribution tracking, and decision support work together as one operational logic rather than as separate administrative routines.

2.2 Digital Supply Chain Implementation

Supply chain refers to the network of activities and actors involved in fulfilling demand from source to end user, including the accompanying flow of materials, information, and resources. In the healthcare setting, this idea is increasingly relevant because many critical services depend on the speed and accuracy of internal and external logistics.

Digital supply chain represents the development of supply chain management through the use of digital technology to integrate transactions, processes, data sharing, and decision support. The concept emphasizes end-to-end visibility, faster coordination, improved traceability, and the use of reporting or dashboards for managerial control.

In blood service operations, digital supply chain implementation may include integrated stock records, real-time visibility of blood component availability, expiry alerts, request status tracking, reporting dashboards, and access control for data accountability. The value of digital implementation lies in its ability to reduce information delay and improve operational synchronization among donor, processing, storage, and distribution units.

The present study uses several indicators to interpret digital supply chain implementation: data integration across work processes, real-time visibility, process automation and standardization, traceability and data security, and analytical reporting that supports rapid decision making.

2.3 Blood Inventory Monitoring and Blood Distribution Monitoring

Inventory monitoring is the process of supervising the quantity, condition, movement, and age of stored items in order to maintain service continuity. In perishable environments such as blood banking, inventory monitoring must be more rigorous because the objective is not only to avoid stockout but also to minimize expiry-related wastage.

Blood inventory monitoring therefore includes the accuracy of stock information, systematic observation of expiry dates, application of the FEFO principle, control of minimum and safety stock levels, prompt recording of incoming and outgoing units, and the availability of meaningful reports that can be used for operational planning.

Distribution monitoring refers to the supervision of how requests are received, verified, prepared, dispatched, and confirmed. In blood services, distribution monitoring also includes transport conditions, documentation integrity, and traceability from the moment the request is accepted until the receiving hospital confirms handover.

The combination of strong inventory monitoring and strong distribution monitoring is essential because stock information is meaningful only when it can be translated into timely and well-documented service delivery. This is why the two monitoring variables are treated separately but analyzed as complementary drivers of overall monitoring effectiveness.

2.4 Previous Studies and Analytical Position

Previous studies summarized in the source manuscript consistently show that digital systems, traceability technology, and integrated visibility improve decision making in blood supply chains. Literature on IoT, RFID, and optimization models further demonstrates that visibility and data-driven coordination reduce shortage risk and help control wastage.

At the same time, the literature indicates that digitalization is not sufficient by itself. Monitoring routines, inventory discipline, and distribution control remain essential because technology produces value only when the organization uses it to manage stock accuracy, expiry priorities, and service execution consistency.

The analytical position of this study lies in bringing together three practical variables within a public blood service setting: digital supply chain implementation, blood inventory monitoring, and blood distribution monitoring. The dependent variable is the effectiveness of monitoring, which is operationally more specific than general service performance.

This focus is important because the challenge at UTD PMI Medan City is not merely about adding technology but about ensuring that digital information becomes actionable for stock control, request prioritization, and traceable blood distribution. The study therefore contributes a practical monitoring-centered view of healthcare supply chain digitalization.

2.5 Conceptual Framework and Hypotheses

The conceptual framework of this study positions digital supply chain implementation (X1), blood inventory monitoring (X2), and blood distribution monitoring (X3) as independent variables affecting the effectiveness of blood inventory and distribution monitoring (Y). The model assumes that stronger digital visibility, stronger stock control, and stronger delivery traceability together improve monitoring outcomes at UTD PMI Medan City.

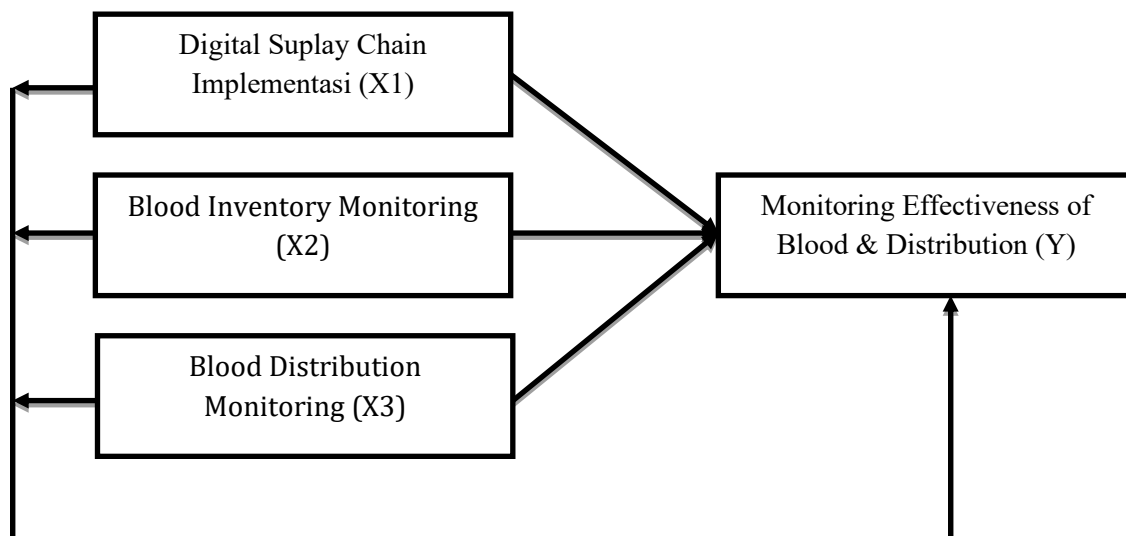


Figure 1. Conceptual framework of the study

Based on the framework, the study formulates four hypotheses: H1, digital supply chain implementation positively affects monitoring effectiveness; H2, blood inventory monitoring positively affects monitoring effectiveness; H3, blood distribution monitoring positively affects monitoring effectiveness; and H4, the three independent variables simultaneously affect monitoring effectiveness at UTD PMI Medan City.

Research Methodology

This study uses a quantitative associative design. The design aims to examine how the independent variables influence the dependent variable, both partially and simultaneously. The independent variables are digital supply chain implementation (X1), blood inventory monitoring (X2), and blood distribution monitoring (X3), while the dependent variable is the effectiveness of blood inventory and distribution monitoring (Y).

The research was conducted at UTD PMI Medan City, located on Jalan Palang Merah No. 17, Medan. The research setting is appropriate because the organization performs critical blood service functions and manages a chain of operational activities from inventory control to distribution fulfilment for hospitals.

The source manuscript states that the population consists of employees directly involved in blood inventory and distribution processes, including storage, administrative, and distribution functions. The population size is 40 employees. Because the population is relatively small, the study uses a population approach in which all members are treated as respondents.

Data in the original design are divided into primary and secondary sources. Primary data are planned to be obtained through questionnaires and short clarification interviews, while secondary data consist of internal operational records and service-related documentation. The questionnaire uses a five-point Likert scale ranging from strongly disagree to strongly agree.

Operationally, the indicators for digital supply chain implementation cover integration, real-time visibility, process automation, traceability, and analytical reporting. The indicators for blood inventory monitoring include stock accuracy, FEFO and expiry control, stock level control, transaction recording, and reporting. The indicators for blood distribution monitoring include request recording, timeliness, tracking, cold-chain compliance, and documentation.

The analytical procedure prepared in the source manuscript includes validity testing, reliability testing, classical assumption testing, multiple linear regression, partial hypothesis testing with the t test, simultaneous hypothesis testing with the F test, and coefficient of determination analysis. In this proceedings version, the emphasis is placed on translating the source design and operational findings into a coherent research narrative.

The methodological logic of the study rests on the assumption that stronger information integration and stronger monitoring routines will improve the effectiveness of monitoring outcomes. This means that the empirical value of the study lies not merely in identifying operational problems but in structuring them as measurable relationships between management variables.

In a healthcare logistics setting, the use of this methodology is particularly relevant because operational failure often results from the interaction of several weak controls rather than from one isolated factor. The associative approach allows the study to explain why digitalization, stock monitoring, and distribution oversight must be viewed as an integrated managerial system.

Results

4.1 General Findings on Monitoring Effectiveness

The source manuscript indicates that blood inventory and distribution monitoring at UTD PMI Medan City has not yet reached an optimal level of effectiveness. This can be seen from the annual operational recap showing that the average timeliness ratio of blood request

fulfillment is 62.67%, while the delay ratio remains 37.33%. These figures show that the institution still faces a substantial service gap in responding to hospital demand.

From a monitoring perspective, the service gap reveals that timeliness is not only a transportation issue but also an information issue. When stock data are updated slowly or when expiry information is not clearly visible, response decisions become slower and preparation time becomes longer. Therefore, operational delay should be read as a symptom of incomplete end-to-end visibility.

The results narrative also indicates that monitoring effectiveness depends on the consistency of internal coordination. Because blood service involves several connected activities, weak synchronization among storage, administrative, and distribution units can reduce response speed even when physical stock is still available. In critical services, delay often emerges from fragmented handover rather than from total stock absence alone.

4.2 Findings on Digital Supply Chain Implementation

The first major finding concerns digital supply chain implementation. The source material suggests that stronger digital integration is associated with more accurate information flow, better request visibility, and greater traceability of inventory and distribution movements. The study interprets this finding to mean that digital capability functions as an enabling structure for operational control.

Digital supply chain implementation becomes especially important in blood service because blood units are perishable and must be managed under cold-chain rules. A system that provides real-time stock status, expiry visibility, and traceable request records allows managers to prioritize actions faster and more precisely. In this sense, digital implementation supports both speed and safety.

However, the research also indicates that digitalization must be interpreted beyond software adoption. A digital system only improves monitoring when it standardizes data entry, reduces manual duplication, and produces actionable reports. If the organization still depends on fragmented records or delayed updating, then the presence of technology does not automatically improve monitoring effectiveness.

4.3 Findings on Blood Inventory Monitoring

The second major finding concerns blood inventory monitoring. The source manuscript emphasizes the importance of stock accuracy, expiry surveillance, FEFO discipline, and timely recording of stock movement. Inventory monitoring is found to have a direct relationship with the effectiveness of service monitoring because decisions on fulfillment and prioritization depend on trusted stock information.

When stock records match physical inventory, the institution can plan fulfillment more confidently and reduce avoidable stockout or mismatch events. Conversely, when there is a discrepancy between physical stock and recorded stock, the entire fulfillment process becomes less predictable. This is particularly risky in blood services because distribution decisions may involve urgent patient needs.

Expiry control also appears as a central part of the findings. Because blood has a limited storage period, the failure to monitor age profile and FEFO discipline increases the probability of wastage. The study therefore interprets inventory monitoring not merely as counting stock but as managing time-sensitive inventory value. Better monitoring is associated with lower wastage risk and improved readiness for demand fulfillment.

4.4 Findings on Blood Distribution Monitoring

The third major finding concerns blood distribution monitoring. The source manuscript indicates that effectiveness depends on how requests are recorded, verified, processed, dispatched, and confirmed. Distribution monitoring is therefore not limited to the physical act

of sending blood to the hospital; it includes the control of information and documentation throughout the delivery sequence.

A strong monitoring routine enables UTD PMI Medan City to know which request is being processed, which request has been prepared, which unit is being shipped, and whether the receiving institution has confirmed handover. This chain of visibility improves operational accountability and reduces ambiguity when follow-up action is needed.

Cold-chain compliance and delivery documentation also occupy an important place in the findings. Monitoring distribution effectively requires not only speed but also procedural discipline. The service cannot be considered effective if delivery is fast but documentation is incomplete or handling conditions are not properly supervised. Thus, effectiveness in this study combines responsiveness and procedural reliability.

4.5 Integrated Discussion and Managerial Implications

When the three explanatory variables are interpreted together, the findings show a complementary relationship. Digital supply chain implementation provides the information infrastructure, inventory monitoring provides stock discipline, and distribution monitoring provides execution visibility. The effectiveness of monitoring improves when these three elements reinforce one another rather than operate separately.

This complementary relationship explains why digital investment alone is insufficient. A dashboard may display real-time data, but if expiry routines are weak or request-handling documentation is inconsistent, the service outcome remains unstable. Similarly, disciplined inventory routines may still fail to achieve full effect if request status cannot be tracked transparently across the delivery sequence.

The discussion therefore confirms the managerial logic of the original model: blood service effectiveness is produced by integrated control. UTD PMI Medan City needs a monitoring environment in which data, decisions, and execution records move together. This condition allows the institution to improve timeliness, reduce stock mismatch, minimize expiry losses, and strengthen service trust from hospitals.

Another implication of the findings is that monitoring effectiveness has both operational and reputational value. Hospitals depend on timely and accurate blood fulfillment, and repeated delays may weaken institutional confidence. Therefore, improving digital supply chain capability and monitoring discipline is not only an internal efficiency initiative but also a strategic service-quality intervention.

Based on the evidence available in the source manuscript, the study interprets the dominant operational priority as visibility enhancement. The institution would benefit from one integrated monitoring logic that connects stock position, expiry information, request queue, preparation stage, shipping status, and confirmation records. Such visibility would help managers act earlier rather than react after delays appear.

In summary, the results show that effective monitoring in a blood service setting depends on the practical alignment of digital systems and monitoring routines. The institution does not simply need more data; it needs usable, timely, and traceable data that are linked to disciplined inventory and distribution control processes. The results further show that monitoring weakness in a blood service environment creates compound operational risk. A delayed stock update does not only affect reporting accuracy; it may also delay request verification, distort priority setting, and increase the likelihood that a near-expiry unit is overlooked during fulfillment planning. This chain effect illustrates why monitoring effectiveness should be treated as a systemic control problem.

4.6 Service Risk and Strategic Monitoring Priorities

Service risk is particularly high when demand urgency is not matched by information readiness. In emergency conditions, staff require immediate confirmation regarding stock availability, blood group compatibility, and component status. A digital supply chain

environment that supports fast retrieval of accurate information reduces hesitation and shortens the time between request receipt and execution.

The findings also imply that monitoring effectiveness must be evaluated in relation to accountability. In public and health-oriented organizations, monitoring serves not only operational efficiency but also auditability and institutional trust. Clear records of request processing, stock movement, and handover confirmation help the organization justify its operational decisions and respond more effectively when discrepancies or complaints arise.

Another important discussion point concerns the role of managerial visibility in preventing wastage. Blood wastage is rarely the result of one isolated event; it is often the cumulative outcome of weak age-profile visibility, delayed stock rotation, incomplete request prioritization, and inconsistent communication among work units. Better monitoring therefore enables prevention, not merely post-event reporting.

The study also interprets digital supply chain implementation as a governance mechanism. When digital tools are used to connect operational data across the chain, management can supervise service performance through shared visibility rather than fragmented verbal coordination. This shared visibility becomes the basis for faster problem escalation and more disciplined execution.

For blood inventory monitoring, the findings highlight the strategic importance of near real-time stock movement recording. Delay in recording inward or outward movement weakens the credibility of the entire monitoring system. As a result, the institution may either underestimate shortage risk or overestimate stock readiness, both of which are undesirable in emergency health logistics.

For blood distribution monitoring, the study finds that effective communication with hospitals is inseparable from internal monitoring quality. Hospitals require clarity on whether a request is available, being prepared, in transit, or completed. When the institution can communicate those stages transparently, service interaction becomes more dependable and easier to manage.

Taken together, these results support the view that the effectiveness of blood inventory and distribution monitoring should be treated as an integrated service architecture. Digital supply chain capability, inventory control, and distribution tracking form a mutually reinforcing system. The quality of one element influences the value of the others, and sustainable improvement requires coordinated intervention across the three dimensions.

Conclusion

This study concludes that the effectiveness of blood inventory and distribution monitoring at UTD PMI Medan City is strongly shaped by three interrelated managerial factors: digital supply chain implementation, blood inventory monitoring, and blood distribution monitoring. The source manuscript demonstrates that the current monitoring environment still contains service gaps, reflected in the average timeliness ratio of 62.67% and the delay ratio of 37.33% in blood request fulfillment.

The findings indicate that digital supply chain implementation improves monitoring effectiveness when it produces integrated, real-time, and traceable information. In the context of blood services, digital capability strengthens visibility of stock, expiry condition, and request status so that decisions can be taken with greater speed and confidence.

The study also concludes that inventory monitoring and distribution monitoring play direct operational roles. Inventory monitoring reduces mismatch and wastage risk by improving stock accuracy and expiry discipline, while distribution monitoring improves service reliability by strengthening request handling, delivery traceability, documentation, and follow-up control.

Overall, the study shows that monitoring effectiveness in blood services cannot be achieved by isolated improvement efforts. UTD PMI Medan City needs an integrated

monitoring system in which digital tools, stock control routines, and distribution tracking mechanisms operate together as one coordinated service framework.

5.1 Managerial Recommendations

UTD PMI Medan City should strengthen digital integration across all blood service stages, especially by ensuring that stock status, expiry information, and request progress are updated in one connected monitoring flow. This would reduce the possibility of data lag and improve response speed to hospital requests.

Management should formalize inventory monitoring discipline through stricter FEFO application, regular stock reconciliation, and clearer alert mechanisms for critical stock levels and approaching expiry. These steps would help reduce both shortage risk and discard risk.

Distribution monitoring should be supported by stronger tracking and documentation procedures. Each request should be visible from verification to final confirmation, and communication with hospitals should be structured through standardized records to improve accountability and service transparency.

Future digital improvement should not stop at system installation. It should include staff capability building, role clarity, response protocols, and dashboard usage discipline so that digital information becomes a real decision tool rather than a passive data repository.

5.2 Practical Implementation Roadmap

A practical roadmap for implementation can begin with the standardization of transaction codes, blood component labels, and request categories so that all units record information using the same data language. Standardization is essential for accurate dashboards and for reducing reconciliation problems across functions.

The second stage of the roadmap should focus on dashboard-based monitoring. Management should have access to summary indicators such as available stock by blood group, units approaching expiry, pending requests, completed deliveries, and delayed requests. This would convert scattered operational data into a shared managerial control panel.

The third stage should emphasize governance and accountability. User access rights, digital audit trails, exception reports, and escalation protocols need to be embedded into the monitoring system so that service issues can be traced and corrected systematically.

The final stage should focus on continuous evaluation. Performance meetings can use monitoring data to review service level, wastage, delay cases, and stock mismatches, ensuring that the digital supply chain becomes part of an institutional learning cycle rather than a one-time project.

5.3 Limitations and Future Direction

This proceedings paper is developed from the Tantri source manuscript and therefore emphasizes a research-style synthesis of the available field direction, indicators, and operational evidence. A future full report can strengthen the statistical dimension by presenting complete respondent-based output from validity, reliability, regression, and hypothesis testing.

Further studies may also expand the model by examining hospital coordination, transport readiness, donor supply variability, and the role of temperature-monitoring technology as additional determinants of blood service performance.

A future full journal version can also incorporate comparative analysis between institutions or between manual and digitally integrated monitoring environments to provide a stronger basis for healthcare logistics policy recommendations.

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