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The Analysis Of Blood Supply Chain Performance Based On Supply Chain Operation Reference Model And Causal Loop Diagram Approach

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ABSTRACT

This study evaluates the effectiveness of the blood supply chain and determines potential causes of substandard performance. Unfulfilled demand for blood at UDD PMI Indragiri Hilir in 2021 reached 970 bags or 14.1% of all orders. This paper is based on the SCOR Model, followed by an approach Cause Loop Diagram (CLD). The novelty of this research is applying the SCOR model to holistically measure the blood supply chain's performance and determine the leading causes of low performance. The total score performance is 77.78, which is a good category. The results show that five matrices fall into the low-performance. Based on CLD, potential root causes of the low performance of the supply chain with the CLD model are five low-performance matrices on production attributes influenced by voluntary and replacement donors, the number of donors, and blood tapping. Several things need to be considered to improve supply chain performance: determine inventory methods, reduce the capacity of blood in screening machines, and collaborate between regions.

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INTRODUCTION

The supply chain is a vital issue in the company's work processes, both service and goods companies. Problems that usually arise in the supply chain are choosing an accurate level of outsourcing, managing purchasing/supply of goods, managing suppliers, managing relationships with consumers, identifying problems, and responding to issues immediately [1]. The supply chain network must be optimized for enhanced competitiveness, which requires performance measurement. This aims to establish provisions and test the performance of management and related units in the company's organizational environment to contribute to the company's progress and glory in achieving its goals [2].

The blood supply chain is a complex system that includes numerous interrelated variables and a variety of stakeholders, including hospitals, blood banks like PMI, and donors [3]. The core problem of the blood supply chain system is that supply does not match the increasing demand [4]. The condition of Indonesia's population growth is constantly increasing, but from time to time, the number of blood donors has decreased [5]. Self-efficacy, attitude, individual moral standards surrounding blood donation, and subjective norms are the factors thatdetermine whether or not someone plans to donate blood (perceived social support) [6]. UDD PMI Indragiri Hilir is one of the health facilities that organizes blood donors in Riau. One of the worst consequences of the unavailability of blood is death [7]. The problem that occurs a lot at PMI UDD in Indragiri Hilir is that the demand for and availability of blood is uncertain and difficult to control. In 2021, there were 970 defected blood bags out of all production, namely 9327 bags; because many of the machines used were not suitable, and the blood could not be used because the blood bags were defected.

Based on interviews and observations, the inexistence of supply chain management causes blood bag damage during processing and storage. As a result, it decreases the availability of healthy blood and causes difficulties in supplying blood from donors. The blood bag defect rate in 2021 is shown in Table 1. In addition, the phenomenon is that blood distribution is carried out in a closed system by UDD to BDRS (Bank Darah Rumah Sakit), or BDRS officers come to collect blood from UDD without involving the patient's family. As long as blood is transported, its temperature must be maintained according to standardization. Therefore, the presence of BDRS can help to keep blood temperature according to standards. However, at UDD PMI Indragiri Hilir, until now, the patient's family come by themselves to UDD to take blood.

Table 1. Defective Blood Bag

Month (2021)	January	February	March	April	May	June	July	August	October	November	December
Production of Blood (bag)	628	693	718	889	724	698	677	742	671	744	803
Blood defected (Bag)	17	9	25	63	31	13	18	25	30	52	27

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There appears to be a knowledge-practice gap in previous research. The SCOR model was developed by the supply chain council (SCC) to improve the organizational performance of a company [8] and was initially used in the manufacturing industry [9]. Many studies have successfully implemented the SCOR model in the industry. Research on the elevator manufacturing industry [10], the packaging manufacturing sector [11], and the area fertilizer industry [12] obtained supply chain performance results with good criteria (scores between 70-90). Anissa has measured sustainable supply chain performance using SCOR 11.0 based on economic assessments, employee welfare (social aspects) and liquid waste (environmental aspects) [13]. This study is also an improvement framework that is applied to the Batik industry with the MTO-MTS typology. The measurement of supply chain performance outside the manufacturing industry has also been applied but is more challenging than in the manufacturing industry.

In previous studies, many have integrated the SCOR model. Determination of supplier criteria with the AHP-SCOR Integrated Model (ASIM) by Nazim [14]. In addition, Ayyidiliz [15] metric model SCOR with Best worst method and Pythagorean fuzzy AHP method. Integration of SCOR and agent-based distributed models by long [16] and [17] integrated of SCOR and discrete event simulation in analyzing supply chain dynamics. So, this study tries to integrate the SCOR model and the Causal Loop Diagram approach in the service industry, which has never been done by previous researches.
Based on the description and problems presented, it is necessary to measure supply chain performance and determine the potential root causes of low supply chain performance. Utilizing the SCOR (Supply Chain Operation Reference) method, the blood supply chain's performance is evaluated. In contrast, the CLD (Causal Loop Diagram) approach is used to describe the potential root causes of the supply chain, which has performance measurement results in the low-performance category at UDD PMI Indragiri Hilir.

This paper is organized as follows: The Section on research method introduces the proposed methodology. It is followed by the Section on results and discussion, which highlights the important discussions about results.The conclusion is drawn in the last Section.

RESEARCH METHOD

The SCOR model categorizes many supply chain processes into six core processes: plan, source, make, deliver, return, and enable, which is a suitable method for measuring supply chain performance [18]. The SCOR model was developed to describe business activities connected to all stages so that customer demand can be satisfied based on the Supply Chain Council [19]. In addition, there are five criteria for reliability, responsiveness, flexibility, cost and assets-which are used to define metric attributes in performance measurement [20]. Identifying activities related to the blood supply chain at UDD PMI Indragiri Hilir is the first step in using the SCOR to measure the performance of the blood supply chain. Then design the SCOR matrix and determine the Key Performance Indicator Hierarchy. After that, calculate performance based on guidelines/references (SCOR).

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Table 2. Level of Performance Indicator with *Snorm De Boer* [22]

Value	<40	40-50	51-70	71-90	>90
Performance Indicator	Very Low	Low	Average	Good	Very Good

Performance measures usually produce weighted scores on several scales, as in the example where the reliability attribute is expressed as a %, and the responsiveness attribute contains time units. It is necessary to normalize the performance data to obtain the calculation results of the overall performance and simplify the measurement of each metric. Therefore, it is necessary to apply the *Snorm De Boer* equation to normalize data [21]. *Snorm De Boer* is normalized using the normalization formula for Larger is better: $Snorm$ = (Si - $Smin$) $Smax$ - $Smin$ x 100 and normalization for the properties of lower is better $Snorm$ = ($Smax$ - Si) $Smax$ - divided into several categories and transformed into values between 0 and 100, with the notation 0 representing the worst score and 100 representing the best score. The categories that apply to the normalization of *Snorm De Boer* are described in the following analysis, which shown in table 2.

Meanwhile, the CLD (causal loop diagram) in this study was used to determine the potential root causes of low blood supply chain performance. CLD describes a causal relationship from several aspects, entities, and variables. The relationship between 2 entities, such as A and B, influences each other and changes the value of one of the entities, then it is given an arrow link. CLD in research is adjusted to the actual situation in an event. So, CLD belongs to the category of qualitative modelling [23].

The research began with a preliminary study based on observations and interview results by UDD PMI leaders. The literature studies were based on journals, books, articles, and theses. Then determine the problems at UDD PMI Indragiri Hilir based on direct observation. After that, formulate the problem. At this stage, questions about research objectives have been identified. Setting goals is the next step, which must be completed to overcome all the problems discussed in the research. The data obtained are outlined in the implementation of the method. The data obtained will be processed using the SCOR and CLD.

Steps in using the SCOR to assess the supply chain functions at UDD PMI Indragiri Hilir, namely:

1 Identify activities related to the blood supply chain at UDD PMI, Indragiri Hilir.
2 Designing the UDD PMI SCOR matrix for Indragiri Hilir.
3 Determining the Key Performance Indicator Hierarchy
4 Calculating performance based on the Supply Chain Operation Reference (SCOR) guidelines
5 Determining the level of performance categories based on *Snorm De Boer* Normalization

The stages of applying the Causal Loop Diagram (CLD) method in measuring the performance of the blood supply chain at UDD PMI Indragiri Hilir:

1 Designing a Causal Loop Diagram based on a low level of performance.
2 Providing performance improvement recommendations at low performance

RESULT AND DISCUSSION

Performance Measurement of the Blood Supply Chain Using the SCOR Model

This study uses the SCOR 12.0, which is structured in five main supply chain processes, namely plan (planning proce 208 source (procurement process), make (production process), deliver (distribution process), and enable (empowerment process). While the level is two steps in the core SCOR 12.0 process (including plan sourcing, plan creation, product stock sourcing, build to stock, and shipping stocked product), it is not the only step. Reliability, responsiveness, and asset management in SCOR are level three characteristics. The characteristics that will be measured at Level 4 in this measurement will be based on the KPI (Key Performance Indicator) provided by the UDD PMI leadership of Indragiri Hilir. Figure 1 displays the KPI hierarchy, while Table 3 displays the SCOR metric.

To avoid data duplication, reduce data complexity, and facilitate data analysis, the statistical data needs to be processed and filtered using the normalization process of *Snorm De Bour*. The SCOR model is used to measure supply chain performance before normalization. Normalization is needed to get the overall performance value because each metric has indicators with different weights and scales. Each category has a different color indicator: the “poor performer” category has a red indicator with values of no more than 50. The “moderate performer” group has values between 50 and 80 below the yellow indicator. In addition, table 4's "high performance" category is associated with a green indicator when the value exceeds 80.

Determination of Potential Root Causes of Low Blood Supply Chain Performance Using the Causal Loop Diagram (CLD)

Based on the results of data processing, 12 performance matrices are included in high performance. Then 11 performance matrices are included in the marginal performance. Then, 5 performance matrices are included in low performance. Root Cause Analysis in this study was carried out on 5 low-performance matrices. Figure 2 below is a Causal Loop Diagram (CLD) model, which is the root cause of low performance. Namely Production, Capacity Utilization Screening, Capacity Utilization for Blood Quarantine Storage Cabinets, Capacity Utilization for Healthy Blood, and Capacity Utilization Crossmatch.

Production is influenced by voluntary donors and substitute donors, which will increase the number of donors. Increased donors have a positive effect on blood tapping (AFTAP). Furthermore, the AFTAP blood affects the stock of screening reagents, where if the use of these reagents increases, it will increase the use of screening machines, and inversely if the use of screening machines increases, it will reduce the stocks of screening reagents. If this screening machine increases, it will increase quarantine blood, positively affecting blood production. The increasing number of quarantine blood will increase the use of blood quarantine machines. Healthy blood is affected by the increased amount of blood production.

Furthermore, the use of healthy blood cabinets also increases, but using it too long can reduce the quality of blood, which will cause expired blood and reduce the amount of healthy bloodstock. Besides, external factors that affect healthy blood are requests from the hospital or patients, which cause bloodstock to decrease. This demand also increases blood production. The increasing use of crossmatch tools is also influenced by the demand for blood by hospitals or patients, which causes the number of crossmatch reagent stocks to decrease.

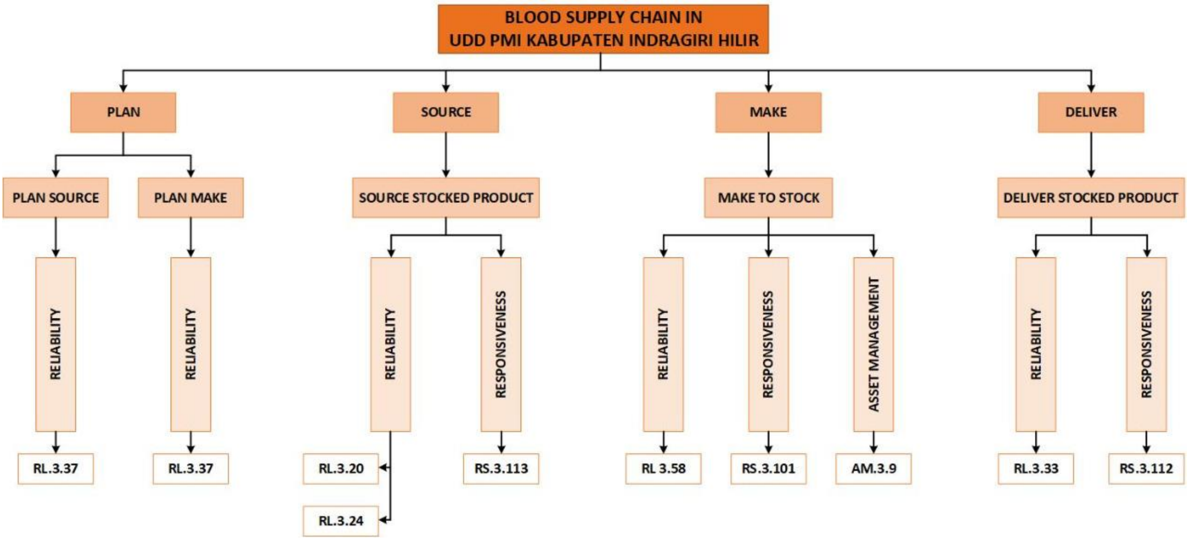

Figure 1. Key Performance Indicators in UDD PMI Indragiri Hilir

Analysis of Performance Measurement of the Blood Supply Chain Using the SCOR Model

First, consider the requirements for whole blood (WB), packed red cells (PRC), thrombocyte concentrate (TC), frozen fresh plasma (FFP), and liquid plasma. These blood substances are obtained from permanent donors or substitutes. The requirement to become a blood donor is that the donor undergoes several initial examination stages, namely blood type, blood HB, and disease. In addition, the doctor will confirm the initial examination results to ensure the donor is in good health before continuing the blood donation process (AFTAP). In the business process activities carried out, UDD PMI Indragiri Hilir runs the system with regulations originating from the central PMI, the Ministry of Health and BPOM as a source of guidance by UDD PMI Indragiri Hilir. As a result, the materials and consumables' specifications are in full compliance with the legislation and operational guidelines after the production of blood components.

The design of the performance measurement matrix is divided into two levels; the level 1 matrix is the four core processes of the SCOR model: plan, source, make, and deliver. The level 2 matrix is a process part of the SCOR process where in the Plan model matrix, there are two parts: plan source and plan make. In the source model matrix, there is a start stock product section. In the make model matrix, there is a make-to-stock section; in the deliver section, there is a return stock product. Furthermore, there are measurement attributes and a matrix in which there are 28 attributes of the attribute section under UDD PMI Indragiri Hilir.

There are 12 matrices for performance that fall into the high-performance category (colour green), 11 matrices for performance that fall into the medium-performance category (colour yellow), and 5 matrices for processing performance that fall into the low-performance category (colour red).

Details of the SCOR results shown in Table 4. These are low-performance attributes from section RS.3.101 MAKE Production, AM. 3.9

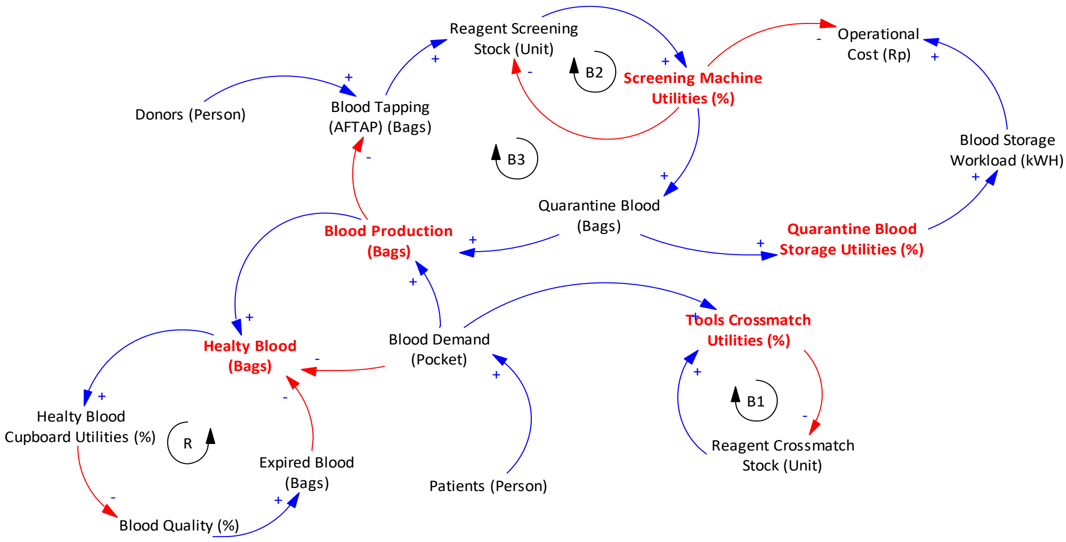

Figure 2. CLD model for low performance at UDD PMI Indragiri Hilir based on SCOR Model

Screening, AM. 3.9 Capacity utilization Blood Quarantine Storage Cabinet, AM. 3.9 Capacity Utilization for Healthy Blood, and AM 3.9 Capacity Utilization Crossmatch.

Analysis of Determination of Potential Root Causes of Low Blood Supply Chain Performance Using the Causal Loop Diagram (CLD)

The SCOR model shows that 12 performance matrices are included in high performance, 11 performance matrices are included in the marginal performance, and five performance matrices are included in low performance. Root Cause Analysis (RCA) uses the Causal Loop Diagram (CLD) model to determine potential root causes and provide input to improve the blood supply chain. RCA has determined the variables contained in CLD based on interviews with experts and literature information. Figure 2 shows that each performance is related to other performances based on the CLD model. In more detail, the availability of healthy blood is influenced by two variables: the amount of blood produced and the amount of demand for blood. Blood availability can be overcome by paying attention to the applied inventory method. Due to the nature of blood, which is very high in uncertainty, certain methods are needed to accommodate the required amount of healthy blood, such as Discrete Event Simulation [24] and Monte Carlo Simulation [25].

The next low-performance metric is blood production. This metric is influenced by the number of quarantine blood, which positively correlates with the screening machine utilities. Currently, the screening machine's performance is 65.26%, which is included in the unsatisfactory performance because the screening machine must be adjusted to test for diseases on blood bags. One way to increase the efficiency of the screening machine is to reduce the capacity in one run. It also reduces the waiting time in the screening process. The same thing is done with the crosstmatch tool to increase usage. It optimized AFTAP process activities to obtain an increased number of blood bags. Optimizing AFTAP process activities to obtain an increased number of blood bags, one way is to provide knowledge to potential donors about the positive impact of donating blood so that the number of donors also increases.

The observed shortage and damage of blood bags at UDD PMI Indragiri Hilir underline the urgency of addressing supply challenges. Collaborative efforts among UDD PMI units across regions offer a practical solution to counter shortages and enhance the overall efficiency and quality of the blood supply chain. Such collaborations provide an alternative source of supply during scarcity and facilitate knowledge-sharing, streamlined processes, and rigorous quality control measures, contributing to a more resilient and effective blood donation ecosystem.

It was stated that there was a shortage and many blood bags were damaged at UDD PMI Indragiri Hilir, so it is necessary to collaborate between UDD PMI for each region as an alternative when experiencing shortages. Good collaboration can help improve the availability and quality of blood and increase the efficiency of the blood supply chain.

CONCLUSION

This study uses the SCOR model to measure the blood supply chain's performance. The final value of the measurement is 77.78 (good category). However, several performance metrics are categorized as low (below 50), namely Production attribute (28.24), Capacity Utilization Screening (37.50), Capacity Utilization of Blood Quarantine Storage Cabinets (39.01), Capacity Utilization of Healthy Blood (44.44), and Capacity Utilization Crossmatch (33.3). So, it is necessary to improve the performance of the blood supply chain because it relates to one's health and life. Root Cause Analysis uses the CLD model to correct low performance by determining potential root causes. Several things need to be considered to improve supply chain performance, namely the need to determine healthy blood supply methods, reduce the capacity of blood in screening machines, and collaborate between regions.

In the future, Research in the service industry, particularly in blood management, holds promising avenues for exploration. Integrating a hybrid approach, combining system dynamics methodology with discrete event simulation, could yield a more robust framework for performance measurement simulations. The convergence of innovative methodologies and risk mitigation endeavors holds the potential to revolutionize the landscape of blood management research. This could pave the way for more efficient and effective performance measurement simulations, providing stakeholders with enhanced insights into the intricacies of the blood supply chain dynamics. Ultimately, the forward-looking integration of these strategies and methodologies is poised to drive the service industry, particularly blood management, toward a more optimized, adaptive, and sustainable future.

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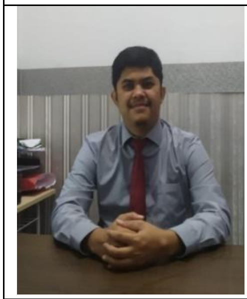	**M. Qurthuby** holds a Master of Engineering degree from Universitas Islam Indonesia in 2019. He is currently the head of the Industrial Engineering Department at Universitas Muhammadiyah Riau, Pekanbaru, Indonesia. His research includes Vendor Managed Inventory, Product Design and Development, Supply chain Engineering, and management. He can be contacted at email: qurthuby@umri.ac.id
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Apendix

Table 3. SCOR Metric for UDD PMI Indragiri Hilir

LEVEL 1	LEVEL 2	ATRIBUTE	DEFINITION	KEY PERFORMANCE INDICATOR
PLAN	sP2 - Plan Source	RL3.37 - Forecast Accuracy	percentage of accuracy in predicting sales requisitions	AFTAP Snack Screening Crossmatch
	sP3 - Plan Make	RL3.37- Forecast Accuracy	percentage of accuracy in predicting sales requisitions	Number of Blood Bags
SOURCE	S.S1- Source Stocked Product	RL.3.20 - % Orders/Lines Received On-Time to Demand Requirement	The number of raw materials suppliers can fulfill according to the time that can be promised (due date) to UDD but more to the quantity.	AFTAP Snack Screening Crossmatch
		RS.3.133 - Receiving Product Cycle Time	The time it takes for materials to arrive from when the order is placed.	AFTAP Snack Screening Crossmatch
		RL.3.24 - % Orders/ Lines Received Damage Free	Percentage of raw materials received without any damage due to shipping	AFTAP Snack Screening Crossmatch
MAKE	S.M2- Make To Stock	RL.3.58 - Yield	Comparison of the number of blood bags used and the number of successful blood bags	Screening Screening Production (Expired)
		RS.3.101 - Product And Test Cycle Time	The time it takes to complete quality control after the production process.	Production
DELIVER	Deliver Stock Product	RL.3.33 - Delivery Item Accuracy	Percentage of goods delivered by the order.	Order
		RS.3.112 - Receive, Enter and Validate Order Cycle Time	Total time required to process the request	Order Time
ENABLE	Manage Supply Chain Assets	AM.3.9 - Capacity Utilization	The actual output is how many products can be produced The maximum capacity is how many products can be made optimally from all available resources.	Screening Blood Quaratine Healthy Blood Fresh Frozen Plasma Tromocyte Concentrate Crossmatch

Table 4. Performance Category Level Based on *Snorm De Boer* (1)

PROCESS	PROCESS SECTION	CODE	ATRIBUTE	Min	Max	Actual Value	Characteristics	*Snorm*	Weight	Snorm x Weight	Performance Score	Value
PLAN	*PLAN SOURCE*	RL.3.37	AFTAP	25%	98%	70,61%	The bigger the better	62,26	0,25	15,56	61,90	67,83
			Snack	25%	98%	70,61%		62,26	0,25	15,56		
			Screening	25,87%	99,86%	64,71%		52,49	0,25	13,12		
			Crossmatch	13,01%	73,20%	48,36%		58,73	0,25	14,68		
	PLAN MAKE		Blood Bags	15,15%	99,06%	77,05%		73,77	1	73,76	73,77	
SOURCE	*SOURCE*	RL.3.20	AFTAP	100%	100%	100%	The bigger the better	100	0,1	10	100	97
			Snack	100%	100%	100%		100	0,1	10		
			Screening	100%	100%	100%		100	0,1	10		
			Crossmatch	100%	100%	100%		100	0,1	10		
	SOURCE	RL.3.24	AFTAP	100%	100%	100%	The bigger the better	100	0,1	10	92	
			Snack	98%	100%	99,61%		77,24	0,1	7,72		
			Screening	100%	100%	100%		100	0,1	10		
			Crossmatch	91%	100%	99,19%		90,71	0,1	9,07		
	SOURCE	RS.3.113	AFTAP	3	3	3	The smaller the better	100	0,1	10	98	
			Snack	7	7	7		100	0,1	10		
			Screening	7	8	7,08		91,67	0,1	9,16		
			Crossmatch	5	5	5		100	0,1	10		
MAKE	*MAKE*	RL.3.58	*Screening Production*	93%	99%	96,50%	The bigger the better	61,38	0,5	30,69	67	48
			Production *(expired)*	99%	100%	99,68%		73,15	0,5	36,57		
	MAKE	RS.3.101	Production	47%	75%	67,00%	The smaller the better	28,24	1	28,23	28,24	

Table 5. Performance Category Level Based on *Snorm De Boer* (2)

PROCESS	PROCESS SECTION	CODE	ATRIBUTE	Min	Max	Actual Value	Characteristics	*Snorm*	Weight	Snorm x Weight	Performance Score	Value
DELIVER	*DELIVER*	RL.3.33	Order	91%	97%	94,85%	The bigger the better	67,20	1	67,19	67,20	58,60
	DELIVER	RS.3.112	Order Time	52	125	88,5	The smaller the better	50,00	1	50	50,00	
ENABLE	*ENABLE*	AM.3.9	*Screening*	56%	81%	65,26%	The bigger the better	37,50	0,16	6,00	47,24	47,24
			Blood Quarantine	70%	93%	78,71%		39,01	0,16	6,24		
			Healthy Blood	18%	27%	22%		44,44	0,16	7,11		
			Fresh frozen plasma	23%	97%	69,13%		62,54	0,16	10,00		
			Trombocyte concentrate	40%	97%	78,22%		66,63	0,16	10,66		
			Crossmatch	6%	15%	9%		33,33	0,16	5,33		