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An examination of the relationships between master production scheduling, total quality management, blood production and transfusion sustainability in Uganda: A SEM approach

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A B S T R A C T

The purpose of this study is to examine the relationships of master production scheduling (MPS), total quality management (TQM), blood production (BP) and blood transfusion sustainability in the blood bank sector of Uganda. This study considers MPS as an independent variable and examines its relationship with BTS through TQM and BP. Based on the dynamic capability theory, this study concurrently incorporates and considers TQM and BP as independent and serial mediators. Data was collected from 213 blood bank respondents using a self-administered questionnaire. Random simple sampling was used to draw the sample. SEM approach was used in the study to assess the model. The major findings are positive total effect relationship between MPS and BTS; BP was found to be an independent mediator, TQM was found not to be an independent mediator, and TQM and BP mediated the MPS and BTS relationship serially. The findings suggest that MPS is related to BTS through a serial mediation model with two mediators. Therefore, blood banks in Uganda need to pay attention to develop and maintain a better MPS program so that positive perceptions of blood transfusion can be attained. Future research should investigate the mediating effect of other TQM and BP dimensions in the link between MPS and BTS in other countries.

1. Introduction

Blood transfusion is necessary in addressing any blood shortages, illnesses and disorders in the human body (Lestari *et al.*, 2017; Seed *et al.*, 2018). As such, sustainable blood transfusion remains crucial in extending and improving life for many patients (Kruk et al., 2018; Mulcahy *et al.*, 2017). Robust sustainable blood transfusion system is one that performs well on blood products safety, blood products range, and timely delivery (Mulcahy *et al*., 2017). World Health Organization (WHO) Global report (2010) indicated that blood transfusion would drastically reduce the death figures of 1.2 million (m), 2.5m, 1m, 900,000, 132,500 people that emanate from road traffic accidents, cardiovascular disease, malaria, tuberculosis, and maternal complications respectively. In Sub-Saharan Africa, lack of safe and adequate blood products lead to about 300,000 pregnant women and 3m children below the age of 5 years dying annually (Checkley *et al.*, 2019). Uganda is not an exception as mothers and children are still dying due to lack of blood products. Safe, adequate and timely blood products are essential for and during transfusion (Checkley *et al.*, 2019; Thomas *et al.*, 2017). However, blood supply and quality complaints continue to dominate scholarly works globally (Dixon-Woods, 2019; Heffernan *et al.*, 2019; Shaer *et al.*, 2017; Yates *et al.*, 2017).

Presently, blood banks suboptimal operations result in unfavourable transfusion outcomes such as cancellation, postponement and death. Therefore, there is an urgent need to enhance blood bank programs to ensure BTS. Dhabangi *et al*., (2020)

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inform that leukocyte reduction improves blood transfusion safety. Blood safety and sustainability are global issues and using separated blood for specific patient needs support transfusion sustainability and resource constrained countries prefer unseparated blood (Cap *et al*., 2018; Uyoga & Maitland, 2019). Timely and safe blood products are essential during transfusion in Kenya county hospitals (Thomas *et al*., 2017). Replenishment stock levels, assigned inventory and simple perishable inventory management practices improve timely delivery of blood products (Pirabán *et al*., 2019). According to (Kyeyune-Byabazaire & Hume, 2019) lack of proper coordination between blood banks and hospital blood banks affect timely delivery of blood products in Uganda. Based on current literature, findings have underscored that BTS can be achieved when the MPS, TQM, and BP programs are integrated in the most productive manner. This gap needs to be addressed to provide more insights on BTS. In addition to the lack of BTS literature, the existing studies are skewed toward developing countries. This study responds to the call for more scholarly research in this field. Thus, the present study seeks to examine the mechanism through which MPS can foster BTS to counter the prevailing unfavourable transfusion outcomes.

This study novel contributions come from (a) proposing a new variable MPS (which has not been quantitatively examined before, (b) underscoring the complex interplay of the antecedents of BTS by conceptualizing the independent and serial mediation effect of TQM and BP between MPS and BTS relationship, and (c) developing a conceptual framework by identifying variables that are aligned with the blood transfusion sector.

2. Theoretical Background and Hypotheses Development

2.1 Conceptual Framework

The findings of related previous literature are used to develop a conceptual framework that shows the relationship between the four variables (Fig. 1). MPS is proposed as a key driver of BTS. TQM and BP are identified as the mediating mechanisms.

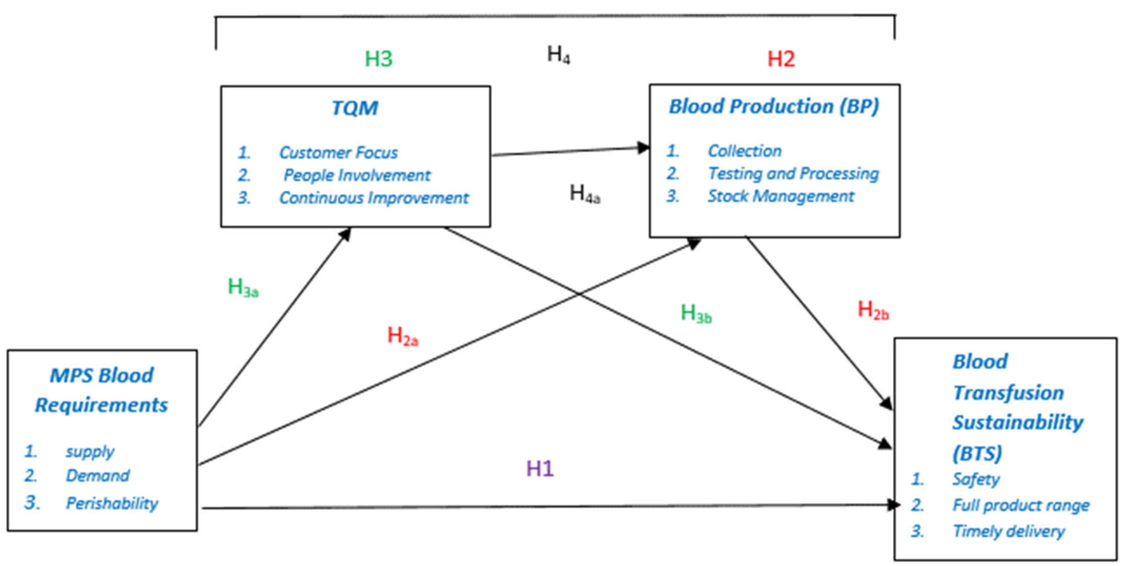


Fig. 1. Conceptual Framework

2.2 Hypotheses Development

2.2.1 Master production scheduling and blood transfusion sustainability

Some previous studies treated MPS requirements as independent variables and tried to establish a relationship with firm performance (Alfonso et al., 2015; Jonsson & Kjellsdotter Ivert, 2015; Osorio *et al.*, 2015). In this study, MPS was operationalized on supply, demand and perishability as critical requirements in achieving transfusion sustainability. Recently, blood banks have begun to realize that they too can benefit from implementing MPS initiatives. In order to achieve BTS, all national blood supply chain (BSC) critical activities including MPS should be coordinated (Barro *et al.,* 2018; Sibinga, 2017). Alfonso and Xiaolan, (2015) suggest that MPS requirements of demand and capacity increase BTS. Jonsson and Kjellsdotter, (2015) found out that MPS and organizational infrastructure result in more feasible plans for firms. MPS blood demand requirements such as aggregating hospitals blood demand and centralizing hospitals blood stock increased transfusion sustainability and resilience of transfusion services (Hosseinifard & Abbasi, 2018; Silva *et al.*, 2013). Effective blood donor scheduling and capacity planning are useful in blood collection systems (Alfonso & Xiaolan, 2015; Bas *et al.*, 2016). Perishability and limited shelf life add complexity and cost to blood stock management (Pirabán *et al.*, 2019). Mathematical demand forecast models have been empirically approved to address blood demand problems (Dharmaraja *et al.*, 2020; Lestari *et al.*, 2017). Thus, researchers claim that improving MPS actually enhances coordination, and therefore have a positive effect on firm performance sustainability. The above discussion clearly shows that there is a relationship between MPS and BTS. However, there is relatively less literature that uses descriptive surveys and quantitative methods in examining the relationship between MPS and BTS. Although MPS has not previously been quantitatively examined in the blood transfusion context, the available evidence provides sufficient basis to expect that MPS will be a positive driver of BTS. This study is again aimed to see the relationship that is also valuable particularly for practitioners, scholars and policy makers. As a result, the relationship of MPS on BTS will be empirically tested to help explain the relationship. Therefore, the following hypothesis is proposed.

H_1: *There is a positive relationship between master production scheduling and blood transfusion sustainability.*

2.2.2 Master production scheduling, blood production and blood transfusion sustainability

BP literature most often pointed out that BP is positively related with transfusion sustainability (Beliën, 2015; Fathian, 2019; Maeng *et al.*, 2018). Continual optimal function of blood banks improves transfusion sustainability (Jovanovi, 2013). According to (Silva *et al.*, 2013) quality of BP planning process affects efficiency of blood banks. The discussion has shown that previous studies support the relationship between MPS and BTS and the relationship between BP and BTS. The discussion provides an adequate basis to speculate that MPS will positively impact BP which will then impact BTS. Therefore, the author put forward the following hypotheses.

H2: *The relationship between master production scheduling and blood transfusion sustainability is mediated by blood production.*

H_{2a}: *There is a positive relationship between master production scheduling and blood production.*

H_{2b}: *There is a positive relationship between blood production and blood transfusion sustainability.*

2.2.3 Master production scheduling, total quality management and blood transfusion sustainability

Study of small and medium enterprises found that TQM practices were positively related to manufacturing performance for sustainable productive growth (Sahoo &Yadav, 2018). TQM practices promoted corporate sustainability (Nivasini, 2020). TQM had a positive effect on improving clinical laboratory services efficiency in Zimbabwe (Marufu *et al.*, 2014). The preceding discussion has shown that previous studies support the relationship between TQM practices and organization performance and sustainability. TQM partially mediated the relationship between differentiation strategy and performance improvement for manufacturing firms in Australia (Prajogo & Sohal, 2006). Although there is no a priori finding on the relationship between MPS and TQM, the preceding discussion provides adequate basis to speculate that MPS will positively impact BTS through TQM. Therefore, the author put forward the following hypotheses.

H_3: *The relationship between master production scheduling and blood transfusion sustainability is mediated by total quality management.*

H_{3a}: *There is a positive relationship between master production scheduling and total quality management.*

H_{3b}: *There is a positive relationship between total quality management and blood transfusion sustainability.*

2.2.4 Master production scheduling, total quality management, blood production, and blood transfusion sustainability

The complex nature of blood transfusion operations makes the existence of more intricate dynamics among MPS, TQM, BP and BTS variables by way of the indirect effects flowing between them. Due to this, the serial mediating effect of TQM and BP on the relationship between MPS and BTS was proposed. Reasons behind hypothesizing such serial mediating effects are: (a) MPS affects BTS, (b) MPS positively affects TQM (Phan, Nguyen, Nguyen, & Matsui, 2019), (c) TQM has a positive effect on BP (Marufu, Chimusoro, & Karodia, 2014) and (d) BP has a positive influence on BTS (Jersild, 2017). Due to these relationships, it is likely that in the blood transfusion sector TQM and BP mediate the relationship between MPS and BTS. However, to the knowledge of researchers no study has been conducted in this regard. This evidence further motivates the researcher to propose TQM and BP as potential variables between MPS and BTS. Therefore, the author put forward the following hypotheses.

H_4: *The relationship between master production scheduling and blood transfusion sustainability is serially mediated by total quality management and blood production.*

H_{4a}: *There is a positive relationship between total quality management and blood production.*

3. Methods

3.1 Research Instrument

A self administered questionnaire was used in the study to collect data from respondents. All items for the variables were measured using a Five-Point Likert Scale which ranged from strongly disagree (1) to strongly agree (5). Preliminary data analysis was done using SPSS-20 in order to address the problems of missing values, outliers and non-normality of the data. The model path analysis was done using SPSS AMOS23. Reliability and validity values were used to assess the measurement model while the hypotheses were tested using bootstrapping methods to examine the significance of the claimed relationships.

3.2 Sample Design and Data Collection

The target population of this research was the staff from regional and government university teaching hospital blood banks, and the respondents were selected using a simple random sampling method. The data was collected using a self administered questionnaire. A total of 213 usable questionnaires were used further for data analysis.

3.3 Analytical Methods

The collected data was analysed using SPSS AMOS23. The measurement model was estimated before the structural model. A confirmatory factor analysis (CFA) was employed to assess the measurement model and to test data quality, including reliability and construct validity checks. Structural equation modelling (SEM) was conducted to assess overall proposed model goodness of fit and test the hypotheses.

3.4 Ethical Statement

Ethical approval was sought and granted by appropriate institutions before conducting the study. Before data collection, all the study participants were informed that the study was for academic purposes only. Written informed consent was subsequently sought and obtained from participants. Every participant signed the official consent form before partaking in the study.

4. Results

4.1 Measurement Model

A measurement model was estimated using the maximum likelihood estimation method. The initial 11 items developed for measurement were subjected to CFA. Consequently, this measurement model was used for all further analyses. Fig. 2 presents the measurement model along with the item loadings.

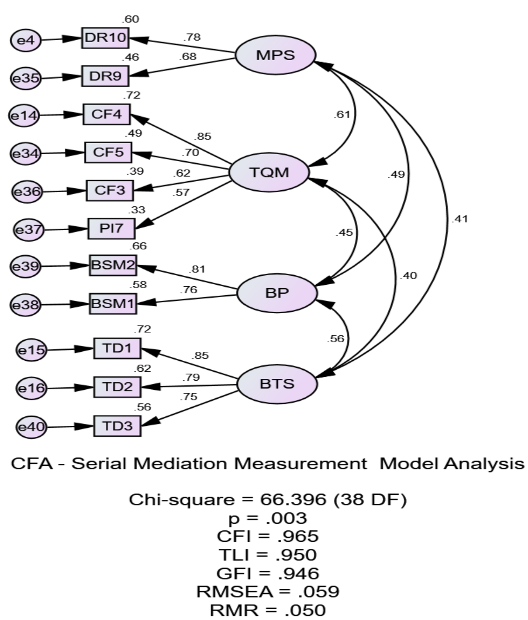


Fig. 2. CFA: MPS, TQM, BP and BTS Measurement Model Analysis

As shown in Table 1, the factor loadings were verified using Cronbach's Alpha, Composite reliability and Average Variance Extracted. According to (Hair *et al.*, 2014) the threshold for convergent validity measure is a standardized factor loading greater than 0.5; the values for composite reliability should be greater than 0.7 for all the items at 5% level of significance and the value for alpha should be greater than 0.7 an indication of high internal consistency among the measurement variables. However, one can accept AVE ≥ 0.4 (Fornell & Larcker, 1981) when the composite reliability (CR) is above 0.6. All factors values met the initial criteria and thus convergent validity was ensured. Discriminant validity in the study was assessed using Fornell and Larcker criterion. According to Fornell and Larcker criterion, discriminant validity is established when the square root of AVE for a factor is greater than its correlation within the other factors in the study. The correlations among factors were all positive with $p < 0.001$. The study proved to be valid and paved the way for the path analysis between MPS, TQM, BP and BTS.

Table 1
MPS, TQM, BP and BTS Constructs Reliability, Factor Loadings, Cronbach Alpha, and AVE

Items	Loadings	Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Master Production Scheduling (MPS)		0.690	0.6957	0.5345
DR9	0.681			
DR10	0.778			
Total Quality Management (TQM)		0.775	0.7480	0.4813
CF4	0.848			
CF3	0.623			
CF5	0.699			
PI7	0.574			
Blood Production (BP)		0.751	0.7640	0.6183
BSM1	0.763			
BSM2	0.809			
Blood Transfusion Sustainability (BTS)		0.830	0.8359	0.6300
TD1	0.846			
TD2	0.786			
TD3	0.746			

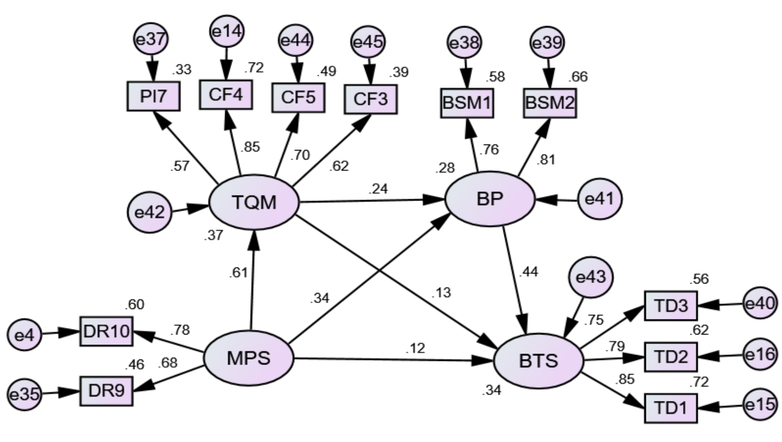
Table 2
MPS, TQM, BP and BTS Measurement Model – Discriminant Test (Fornell and Larcker criterion)

	MPS	TQM	BTS	BP
MPS	**0.731**			
TQM	0.612***	**0.694**		
BTS	0.413***	0.399***	**0.794**	
BP	0.489***	0.450***	0.555***	**0.786**

† $p < 0.1$ * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

4.2 Structural Model

The structural model was examined using the bootstrap technique to test the hypotheses. The goodness-of-fit statistics of the proposed model showed that the model reasonably fits the current data ($\chi^2/df = 1.747$, CFI = 0.965, TLI = 0.950, RMSEA = 0.059). The structural results of the proposed model are shown in Fig. 3.



CFA - Serial Mediation Structural Model Analysis

Fig. 3. Path Model (Coefficients and Model Fit Values)

4.2.1 Direct Effects

Simple regression was used to test the six direct hypotheses (H1, H_{2a}, H_{2b}, H_{3a}, H_{3b}, H_{4a}). The results of which are shown in Table 4. H1 proposed a positive relationship between MPS and BTS ($\beta = 0.120$; $p = 0.366$), which was not supported with mediators. H_{2a} proposed a positive relationship between MPS and BP ($\beta = 0.341$; $p = 0.034$), which was supported. H_{2b}, proposed a positive relationship between BP and BTS ($\beta = 0.439$; $p < 0.001$) and was supported. H_{3a} proposed a positive relationship between MPS and TQM ($\beta = 0.612$; $p < 0.001$), was supported. H_{3b} proposed a positive relationship between TQM and BTS ($\beta = 0.128$; $p = 0.312$) and was not supported. Finally, H_{4a} hypothesized a positive relationship between TQM and BP ($\beta = 0.241$; $p < 0.092$), which was not supported.

Table 1
Direct Effects

Relationship	Total Effect (TE) and Sig	Indirect Effect (IE) and Significance	Direct Effect (DE) and Significance with mediators	Remark
MPS → TQM	0.612 (0.000)		0.612 (0.000)	H_{3a}, supported
MPS → BP	0.489 (0.000)	*0.147 (0.062)*	0.341 (0.034)	H_{2a}, supported
MPS → BTS	0.413 (0.000)	*0.293 (0.009)*	0.120 (0.366)	H1, not supported
TQM → BP	0.241 (0.092)		0.241 (0.092)	H_{4a}, not supported
TQM → BTS	0.234 (0.113)	*0.106 (0.067)*	0.128 (0.312)	H_{3b}, not supported
BP → BTS	0.439 (0.000)		0.439 (0.000)	H_{2b}, supported

4.2.2 Indirect Effect (Mediation Test)

To check the meditation, bootstrapping was used to create a 95% bias-corrected confidence interval (C.I) to evaluate the significance of indirect effects if the C.I did not include zero. Table 5 reports the mediation results.

Table 2
Indirect Effects

Parameter	Direct Effect	Estimate	Lower	Upper	p	SE	CR	Mediation
MPS -- > BP → BTS	0.120 (0.366)	0.172	0.039	0.424	0.018	0.097	1.773	H2, Full
MPS → TQM → BTS		0.090	-0.106	0.277	0.262	0.100	0.900	H3, No
MPS → TQM-- > BP → BTS		0.074	0.003	0.223	0.045	0.059	1.254	H4, Full

The indirect effect through TQM as the sole mediator in the relationship between MPS and BTS revealed that TQM did not sufficiently explain the relationship: indirect effect ($\beta = 0.090$, $p = 0.262$, SE = 0.100, 95% C.I [-0.106, 0.277]). Thus, TQM independently did not mediate the relationship between MPS and BTS as zero falls within the lower and upper limit of the confidence interval. As such H3 hypothesizing the mediation effect of TQM on the relationship between MPS and BTS was not supported. BP as the sole mediator in the relationship between MPS and BTS revealed that BP did sufficiently explain the relationship: indirect effect ($\beta = 0.172$, $p = 0.018$, SE = 0.097, 95% C.I [0.039, 0.424]). Thus, BP independently did mediate the relationship between MPS and BTS as zero did not fall within the lower and upper limit of the confidence interval. As such H2 hypothesizing the mediation effect of BP on the relationship between MPS and BTS was supported. In contrast, when both TQM and BP were considered as mediators, they sequentially mediated the relationship between MPS and BTS significantly: indirect effect ($\beta = 0.074$, $p = 0.045$, SE = 0.059, 95% C.I [0.003, 0.223]), supporting H4. Furthermore, the direct effect of MPS on BTS was statistically insignificant ($\beta = 0.120$, $p = 0.366$), indicating full mediation of BP as independent mediator, no mediation of TQM as independent mediator and full mediation of TQM and BP when considered serial mediators.

5. Discussion and Conclusion

Based on the identified research gaps in the literature and the need to promote blood transfusion sustainability, a conceptual framework was proposed to theorize the relationship of MPS and BTS with TQM and BP as mediators.

H1, tested the relationship between MPS and BTS. The results of the regression analysis shows the hypothesized direct effect to be insignificant ($\beta = 0.120$; $p = 0.366$), not supporting H1. The findings of the current research are similar to previous ones (Chaimae & Adil, 2020). The findings confirm that scheduling and planning of blood collection is one of the most important problems at the operational and tactical level. The findings imply that by focusing on MPS, BTS can be improved for example timely delivery of blood products to healthcare facilities.

H2, suggested the relationship between MPS and BTS is mediated by BP. The indirect effect through BP as the independent mediator in the relationship between MPS and BTS revealed that BP sufficiently explained the relationship ($\beta = 0.172$, $p = 0.018$, SE = 0.097, 95% CI [0.039, 0.424]), supporting H2. The direct effect of MPS on BTS was statistically insignificant ($\beta = 0.120$, $p = 0.366$). Hence, independently BP fully mediated the relationship between MPS and BTS. These relationships had not been examined before in the context of the BTS. Furthermore, the total effect between BP and BTS was significant (β = 0.439; $p < 0.001$). The findings imply that BP, especially blood stock management is essential in ensuring BTS.

H3, suggested the relationship between MPS and BTS is mediated by TQM. According to the indirect results, the effect is insignificant (β = 0.090, p = 0.262, SE = 0.100, 95% CI [-0.106, 0.277]), not supporting H3. The direct effect of MPS on BTS was statistically insignificant (β = 0.120, p = 0.366). Hence, independently TQM has no mediating effect on the relationship between MPS and BTS as zero did fall within the lower and upper limit of the confidence interval. Although there was no priori basis for the hypothesis, the study expected a positive mediating effect of TQM on the relationship between MPS and BTS according to non-related studies (Prajogo & Sohal, 2006; Simani *et al.*, 2017). These relationships had not been examined before in the context of the BTS. As such, it is suggested that further studies should focus intensively on examining this relationship, for example considering TQM as an independent variable and conducting research in different countries.

H4, suggested the serial mediating role of TQM and BP and results indicated mediation of TQM and BP between MPS and BTS at 95% confidence interval. In contrast, when both TQM and BP were considered as mediators, they sequentially did mediate the relationship between MPS and BTS significantly. The indirect effect of TQM and BP between MPS and BTS revealed that TQM and BP sufficiently explained the relationship (β = 0.074; p = 0.045, SE = 0.059, 95% C.I [0.003, 0.223]), supporting H4. Furthermore, the direct effect of MPS on BTS was statistically insignificant (β = 0.120, p = 0.366), indicating full mediation. This novel relationship has not previously been examined. It appears that blood banks that implement MPS and TQM also report efficient BP and, in turn, seem to experience a higher level of BTS. Moreover, MPS and TQM make blood banks feel that they have a certain degree of autonomy to perform their tasks, and that they involve people and are customer driven. In sum, when staff understand that the blood bank is trying to help them to enhance their performance, they experience high motivation levels, which in turn lead to BP quality assurance. All of these process mechanisms have direct and indirect effects on BTS. These relationships had not been examined before in the context of the BTS, making the study worth unearthing the relationship, which, if found, could prove useful for practitioners, academicians and policy makers.

5.1 Theoretical Contribution

The study offers four key theoretical contributions. First, this study proposed a novel construct, i.e., MPS, to better explain the drivers of BTS in healthcare. By doing so, the study extends the limited blood transfusion literature, focusing on the relationship between MPS and TQM (β = 0.612; $p < 0.001$) and MPS on BP (β = 0.489; $p < 0.001$). The study responds to the call for more scholarly research on these topics in blood transfusion (Osorio *et al.*, 2015; Pirabán *et al.*, 2019; Torrado & Barbosa-Póvoa, 2022; Williamson & Devine, 2013). Second, the findings suggest that MPS is related to BTS through a mediation model with BP as mediator. This finding is relevant because no prior studies had examined the relationship. Third, the study proposes newer relationships that have not previously been examined, in the context of the blood transfusion. For instance, no prior studies have examined TQM and BP as a joint mechanism through which MPS can enhance BTS. Similarly, the relationship between TQM and BP (β = 0.241, p = 0.092) has not been examined. This is a remarkable contribution by the study since scholars have contended that proposing hitherto unexplored relationships constitute a noteworthy theoretical contribution. Fourth, very few studies have tested an integral model with two serial mediators using the SEM. No research to date has used this nascent methodology to identify the internal mechanisms between MPS and BTS. This approach can be seen as a strength of the study. Finally, the study contributes at the methodological level by theorizing and testing a serial mediation model to measure the sequential effect of TQM and BP on the relationship between MPS and BTS. By considering the sequential mediating effect of TQM and BP, the study underscores the joint role of TQM and BP in achieving BTS. No prior study until now has thus proposed and examined the sequential mediating effect of these variables on the relationship between MPS and BTS. Overall, the study provides a richer, deeper understanding of various blood bank programs ie MPS, TQM and BP as antecedents of BTS.

5.2 Managerial Implications

The results of this research also contribute to a more comprehensive understanding of the ways to achieve BTS in the healthcare industry. From a practical standpoint, it is essential for blood banks to discover what they can do to maintain and enhance high levels of BTS. Specific MPS, TQM and BP programs should be nurtured to foster BTS. One strategy is for blood banks to implement MPS blood demand requirements such as hospital transfusion practices and hospital blood stock management practices. The TQM customer focus and employee involvement elements to give attention include: use of customer complaints, systematic and regular customer satisfaction surveys, market research, and employee satisfaction surveys. Finally, BP areas to focus on include: blood stock management practices, blood stock management based on purpose. Given the budget constraints on blood bank operations, one must acknowledge that all investments in blood banks and in implementing MPS, TQM and BP should be optimized.

6. Limitations and Direction for future research

This study has some limitations, which can be seen as opportunities for future research. First, the cross-sectional research design limits the extent to which cause-effect relations can be inferred from the findings. The results should be interpreted considering this limitation and suggest longitudinal analysis to establish causality relationships. The second limitation has to do with the sampling method. The study's use of only staff directly involved in blood operations is not fully representative of blood banks. Generalization of the results is thus limited. Future research should consider more respondent size to obtain representative samples of blood banks staff. Third, the study collected self-report data from blood banks staff in Uganda. As such, the findings of the study may not be generalizable to other countries or sectors. However, the constructs and relationships explored in the study are relevant to other sectors, be it manufacturing or service. Future studies can thus replicate our model in different contexts to generate related findings. Finally, the present study argues that MPS leads to higher levels of BTS through TQM and BP in the transfusion sector; ignoring other factors thus keeping the scope manageable. It would thus be worthwhile to explore the role of other factors in enhancing BTS. For example, blood donor management, and hospital transfusion practices and how these relationships differ across countries. The results are limited to healthcare only.

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