Master Production Scheduling Requirements and Blood Transfusion Sustainability. Using SEM Approach

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Abstract

The purpose of the study is to find the effect of master production scheduling (MPS) requirements on blood transfusion sustainability (BTS). Data was collected from 213 respondents of regional and transfusing staff of government university teaching hospital blood banks using a self-administered questionnaire. Simple random sampling was used to draw the sample. Finally, a model including MPS requirements and BTS was validated with a path analysis. The results of this study showed a positive significant effect of MPS requirements on BTS with the prediction rate of 27.1% and in the 95% confidence level.

Key Words

Blood Bank, Blood Transfusion Sustainability (BTS), Master Production Scheduling (MPS), Structural Equation Modelling (SEM), Uganda

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). Sustainable blood transfusion is crucial in extending and improving life for many patients (Kruk et al. 2018; Mulcahy et al. 2017). World Health Organization (WHO) Global report (2010) indicated that blood transfusion would drastically reduce the death figures of people that emanate from road traffic accidents (1.2 million), cardiovascular disease (2.5 million), malaria (1 million), tuberculosis (900,000), and maternal complications (132,500). In Sub-Saharan Africa, lack of safe, timely and full product range of blood units lead to about 300,000 pregnant women and 3 million children below the age of 5 years dying annually (Checkley et al. 2019). Safe, timely and full product range of blood units are essential for both non-normal and normal healthcare for and during transfusion (Checkley et al. 2019; Thomas et al. 2017). World Health Organization recommend use of voluntary non-remunerated donors to achieve BTS in most parts of Africa through encouraging more voluntary non-remunerated blood donors (VNRDs), testing for transfusion transmissible infections (TTIs), as well establishing interventions for hospital best use of blood (Aneke and Okocha 2017). Mulcahy et al. (2017) suggested that robust blood transfusion system is one that scored high on the following three factors: safety levels, full range of blood units, and timely delivery such that patient health and scheduled transfusion services are not unduly compromised. However, globally failure to match blood supply to demand has continued to result into unfavourable transfusion outcomes like forced prioritisation, postponement, cancellation and death (Jenny et al. 2017; Kanagasabai et al. 2018; Opoka et al. 2018).

Therefore, there is an urgent need to examine MPS blood requirements to ensure BTS and save lives of patients (Hosseinifard and Abbasi 2018; Pitocco and Sexton 2005).

MPS is a time phased production plan (3-18 months) used to match supply to demand of specific end products at minimum cost in a changing environment (Kohneh et al. 2016). Blood banks operate in a stochastic environment and therefore expected to adapt and find unique avenues to optimize use of blood products and services (Barro et al. 2018; Evan et al. 2020; Sibinga 2017). Weimer et al. (2019) found that decline in funding strained the ability to maintain and improve blood transfusion safety in Sub-Saharan Africa. Blood safety and sustainability are global issues and using separated blood supported transfusion sustainability (Cap et al. 2018; Uyoga and Maitland, 2019). Thomas et al. (2017) study in Kenyan county hospitals found that transfusion delays were associated with poor outcomes. Pirabán et al. (2019) informed that replenishment stock levels, assigned inventory and simple perishable inventory management practices improved timely delivery of blood products. Kyeyune-Byabazaire and Hume (2019) study mentioned that lack of proper coordination between blood banks and hospital blood banks affected timely delivery of blood products in Uganda. Previous studies found out that there is positive relationship between MPS and organization sustainability (Edgar Alfonso, Xie Xiaolan, 2015; Hosseinifard and Abbasi, 2018; Jonsson and Kjellsdotter, 2015; Silva et al. 2013). However, a few studies have been conducted in Sub-Saharan Africa and Uganda in particular to examine the MPS blood requirements relationships with BTS. Therefore, this study will evaluate the effect of MPS blood requirements towards BTS in Uganda.

The study was conducted in Uganda. The Uganda blood transfusion services (UBTS) is built from coordinated activities of multiple stakeholder groups. All needed blood and blood products in Uganda is from VNRDs in the age range of 16-65 years, 73% being males, and 58% from repeat donors (Kyeyune-Byabazaire and Hume, 2019). UBTS, commissioned in 2003 is the semi-autonomous institution mandated by government to address the blood supply and blood demand for the welfare of Ugandans. The UBTS core functions are to regulate, efficiently and effectively manage the national blood production and timely provide information on blood availability. The UBTS supports and conducts research to improve blood production (BP), transfusion, monitoring and supervising national blood resources. The UBTS objectives are to develop a decentralized blood transfusion infrastructure; increase the national annual blood collection to meet transfusion needs; ensure safety of blood products; promote appropriate clinical and transfusion use of blood; and strengthen the institution capacity.

The UBTS headquarters at Nakasero Blood Bank act as a reference point for seven regional blood banks (Arua, Fort-Portal, Gulu, Kitovu, Mbale, Mbarara and Nakasero) and nine blood collection and distribution centres (Hoima, Masaka, Jinja, Kabale, Rukungiri, Lira, Angal, Soroti and Mengo Rotary). The UBTS network serves all hospitals mandated to administer blood transfusion that receive a non-cost recovery supply of blood, and Mulago and Butabika being the National Referral Hospitals. Of the blood units collected in Kampala (the capital city of Uganda) 30% of it is processed into blood products; reasons being blood bags used, low need for platelet concentrates, limited use of fresh frozen plasma and cryoprecipitate units. UBTS is undergoing the process for Africa Society for Blood Transfusion (AfSBT) SWAP accreditation so as to adhere to acceptable international quality requirements. In Uganda mothers and children are still dying due to blood shortage.

1.1 Objectives

The study was founded on three main objectives to be taken to reduce unfavourable transfusion outcomes. Firstly, the study looked at the direct relationship between MPS blood supply requirement and BTS. Secondly, the study assessed the relationship between MPS blood demand requirement and BTS. Thirdly, it assessed the relationship between MPS blood perishability requirement and BTS.

2. Literature Review

2.1 Master Production Scheduling (MPS)

MPS is a vital program when getting different end products from inputs. More than a hundred different products can be derived from donated blood (Osorio et al. 2015). MPS blood requirements such as aggregating hospitals blood demand and centralizing hospitals blood stock increased transfusion sustainability (Hosseinifard and Abbasi 2018). Effective blood donor scheduling and capacity planning are useful in blood collection systems (Alfonso and Xiaolan, 2015). Perishability and limited shelf life add complexity and cost to blood stock management (Pirabán et al. 2019). MPS blood requirements was used to map problems and improvement opportunities of Indonesia blood bank (Mansur et al. 2019). Literature review found out that MPS and descriptive research are minimally applied in blood transfusion, more so in Africa and Uganda. In this context, MPS blood requirements was operationalized on supply, demand and perishability as critical dimensions in achieving transfusion sustainability.

2.2 Blood Transfusion Sustainability (BTS)

In order to achieve BTS, all national blood supply chain (BSC) critical activities including MPS should be coordinated (Barro et al. 2018; Sibinga 2017). Robust blood transfusion system is one that scored high on three criteria: safety levels, full range of blood units, and timely delivery in order to optimize unfavourable transfusion outcomes (Mulcahy et al. 2017). The present study uses three dimensions safety, timely delivery and full product range of blood units to measure the BTS of Uganda.

2.3 Master Production Scheduling (MPS) and Blood Transfusion Sustainability (BTS)

MPS blood requirements of demand and supply planning increased BTS (Alfonso and Xiaolan, 2015). MPS methods and models result into feasible plans (Jonsson and Kjellsdotter Ivert, 2015). Blood service organizations resources are scarce and have to be efficiently utilized for enhanced sustainability (Dutta, 2019). Blood donor appointment scheduling balance blood production (Bas et al. 2016). High expiry and shortages at the blood transfusion unit affect BTS (Mansur et al., 2019). Blood shortage risk lives of patients in need of transfusion and subjects a lot of pressure on the system due to added complexity and cost to blood stock management (Hosseinifard and Abbasi 2018; Pirabán et al. 2019). Aggregating blood demand forecast and stakeholder collaboration increased sustainability and resilient of transfusion services (Silva et al. 2013). Mathematical demand forecast models have been empirically approved to address blood demand problems (Dharmaraja et al. 2020; Lestari et al. 2017). The above discussion clearly shows that there is a relationship between MPS blood requirements and BTS. Despite the importance of MPS blood requirements on BTS, there are still a limited number of studies in the area, especially in Sub-Saharan Africa. This study is one of the few studies conducted to examine relationship between MPS blood requirements and BTS especially in Uganda.

2.4 Conceptual Framework

Based on the existence literature, a conceptual framework has been proposed to understand the relationships between the MPS blood requirements and BTS in Uganda (Figure 1). The researcher proposed the following hypotheses.
H1: The MPS blood supply requirement on BTS has a positive and significant relationship.
H2: The MPS blood demand requirement on BTS has a positive and significant relationship.
H3: The MPS blood perishability requirement on BTS has a positive and significant relationship.

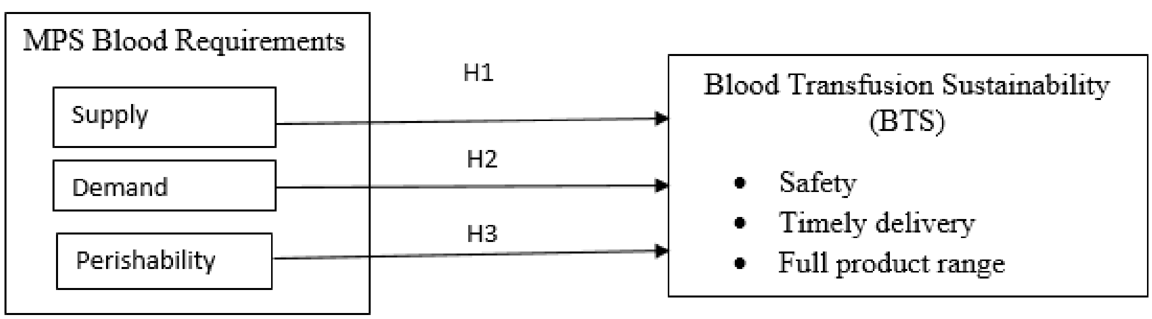

Figure 1. Conceptual Framework

3. Methodology

3.1 Research Instrument

A self administered questionnaire was used to collect data from respondents. MPS was measured using three factors and seven-items adapted from (Mansur et al. 2019). BTS was measured using three criteria suggested by (Mulcahy et al. 2017). A five-point Likert scale was employed in this study ranging from 5 (strongly agree) to 1 (strongly disagree).

3.2 Sample Design and Data Collection

The target population of this research was cold chain staff from regional blood banks and transfusing staff from government university teaching hospital blood banks, and simple random sampling method was used to select respondents. The data was collected using a self administered questionnaire. SPSS AMOS23 was used to analyse preliminary and main data. Assessment of the measurement model was made by considering reliability and validity values while the hypotheses were tested using bootstrapping method. A total of 213 usable questionnaires collected back were used further for data analysis.

3.3 Analytical Methods

The collected data was analysed using SPSS AMOS23 to develop measurement and structural models. 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 fit of the proposed model and test hypothesis.

3.4 Ethical Statement

This study obtained ethical approval from Mulago Hospital Research Ethics Committee (MHREC REC) under the protocal number MHREC-2022-081 and Uganda Council for Science and technology (UNCST). Information regarding the role of each participant was explained and respondents signed consent forms.

4. Results and Discussions

4.1 Measurement Model

A measurement model was estimated using the maximum likelihood estimation method. The initial 10 items developed for measurement were subjected to conformatory factor analysis (CFA). Consequently, this measurement model was used for all further analyses. Figure 2 presents the measurement model along with the item loadings.

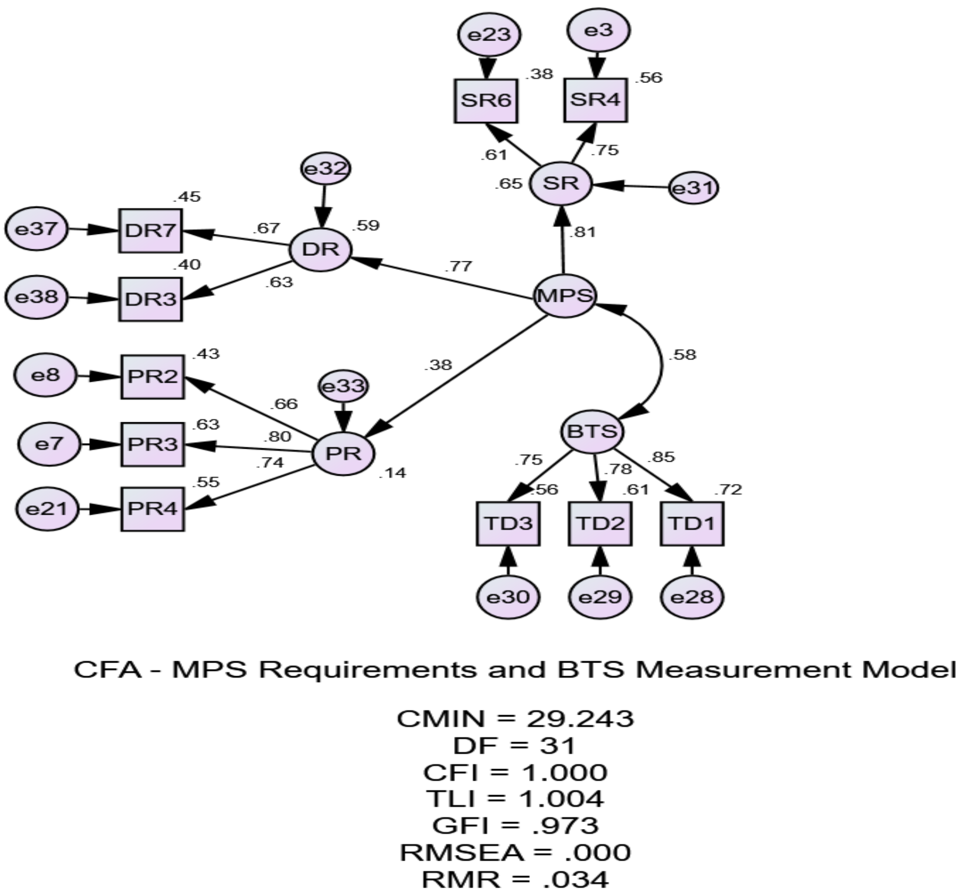

Figure 2. Measurement Model with Item Loadings

As shown in Table 1, the factor loadings were verified using Cronbach's Alpha, Composite reliability (CR) and Average Variance Extracted (AVE). According to (Hair et al. 2014) the threshold for convergent validity measure is a standardized factor loading greater than 0.5 for each item indicating the measurement items significantly defined the proposed latent variables; the values for composite reliability should be greater than 0.7 for all the items at a 5% level of significance and the value for Cronbach's alpha should be greater than 0.7 indicating high internal consistency among the measurement variables. However, one can accept AVE ≥ 0.4 (Fornell and Larcker, 1981) when the composite reliability (CR) is above 0.6. All the values met the initial criteria and thus convergent validity was ensured; Table 1.

Table 1. Validity and Reliability for Constructs

Items	Loadings	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Master Production Scheduling (MPS)		0.707	0.747	0.463
SR4	0.749			
SR6	0.613			
DR7	0.669			
DR3	0.632			
PR3	0.797			
PR2	0.655			
PR4	0.741			
Blood Transfusion Sustainability (BTS)		0.830	0.836	0.630
TD1	0.844			
TD2	0.779			
TD3	0.756			

The study assessed discriminant validity using Fornell and Larcker criterion and Heterotriat-Monotrait (HTMT) ratio. 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. To achieve discriminant validity, the HTMT ratios should be less than 0.85 (Henseler et al. 2015). Hence, discriminant validity was established and presented in Table 2 (Fornell and Larcker criterion) and Table 3 (HTMT ratio). The study proved to be valid and paved the way for the path analysis between MPS blood Requirements (independent variable) and blood transfusion sustainability (dependent variable).

Table 2. Convergent and Discriminant Tests (Fornell and Larcker Criterion)

	MPS	BTS
MPS	**0.680**	
BTS	0.579	**0.680**

Table 3. Convergent and Discriminant Test (HTMT ratio)

	BTS
BTS	
MPS	0.593

4.2 Structural Model

The structural model was examined using the bootstrap technique. The goodness-of-fit statistics of the proposed model showed that the model reasonably fits the current data. Chi-square value of the model (χ^2 = 29.243, df = 31) and other goodness of fit indices (RMSEA = 0.000; CFI = 1.000; GFI = 0.973) revealed that the model fit the data reasonably well. The structural results of the proposed model are depicted in Figure 3.

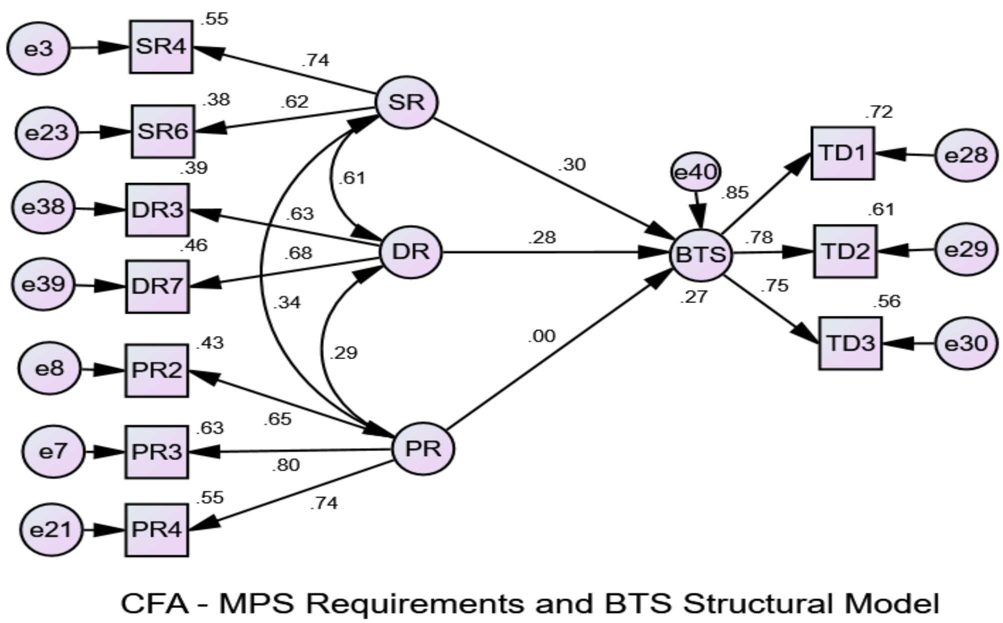

Figure 3. MPS Requirements and BTS Structural Model

The hypothesized relationship between MPS blood supply requirement (SR) and BTS was positive and significant ($\beta = 0.292$; $p = 0.042$); thus H1 was supported. Hosseinifard and Abbasi (2018) and Alfonso and Xiaolan (2015) support the findings. The path coefficient of the relationship between MPS blood demand requirement (DR) and BTS was also positive and significant ($\beta = 0.282$; $p = 0.050$); and thus H2 was supported. This study result is confirmed by (Silva et al. 2013). The path coefficient of the relationship between MPS blood perishability requirement (PR) and BTS was zero and insiginificant ($\beta = 0.003$; $p = 0.971$); and thus H3 was not supported. This study finding is congruent with (Pirabán et al. 2019). The summary of the results are presented in Table 4.

Table 4. Results of the structural model

Hypothesized Relationship	Standardized Estimates	t-value	p-value	Decision
SR ---> BTS	0.292	2.036	0.042	H1: supported
DR ---> BTS	0.282	1.957	0.050	H2: supported
PR ---> BTS	0.003	0.036	0.971	H3: not supported
R-Square				
BTS	0.271			
Model Fit				
	(CMIN/DF = **0.990**, GFI = 0.973, CFI = **1.000**, TLI = 1.001, SRMR = 0.043, RMSEA = 0.000, RMR = 0.033).			

The coefficient of determination is R-square. The R-square value represents the magnitude of the variance in the independent variable. The adjusted R-square for MPS blood requirement and BTS in this study is 0.271. Therefore, this study model can explain 27.1% of the variance in the dependent variable due to independent variable.

5. Conclusion

The study was founded on three main objectives. Firstly, the study looked at the relationship between MPS blood supply requirement (SR) and BTS. Secondly, the study assessed the relationship between MPS blood demand requirement (DR) and BTS. Thirdly, it assessed the relationship between MPS blood perishability requirement (PR) and BTS. The study concluded that MPS blood supply requirement had a positive and significant effect on BTS. The study also concluded that the effect of MPS blood demand requirement on to BTS was positive and significant. Finally, the study concluded that the effect of MPS blood perishability requirement on BTS was zero and insignificant. The overall effect of MPS blood requirements on BTS was positive and significant with the prediction rate of 27.1% and in the 95% confidence level. Additionally, this study was conducted in Uganda. Most of the studies focusing on BTS are mainly conducted from developed countries.

5.1. Managerial Implications

The study results indicate that better MPS blood requirements would help developing sustainable blood transfusion. It is evident that creating a dependable MPS is a substantial aspect of blood transfusion service. Jonsson and Kjellsdotter (2015) informed that MPS methods resulted into plans that are more feasible in uncertain environment. Blood banks and decision makers in Uganda should make an effort to develop positive intentions of timely delivery of blood products through a well-designed and maintained MPS blood requirements in order to save lives of patients in need of blood.

5.2. Limitations and Future Research

Although the results of the current study have shed light on several important issues, some limitations need to be considered in future research. This study has developed a model which focused on cold chain respondents from regional blood banks and transfusing staff from government university teaching hospital blood banks in Uganda. In future studies, other screening methods for a greater representative sample should be considered. Secondly, this analysis assessed MPS blood requirements and BTS on a few dimensions, the generalizability of the study is therefore restricted. Future studies may then use more robust models, and in other countries applying similar conceptual framework. Finally, the findings are focused on a cross-section analysis, which requires empirical testing to verify the relationship between MPS blood requirements and BTS for testing the findings of the study in the longitudinal analysis.

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