Connecting the dots: uncovering the relationships between challenges confronting Africa's organ transplant supply chain systems

Temidayo O. Akenroye

Department of Supply Chain and Analytics, College of Business Administration, University of Missouri – St. Louis, Saint Louis, Missouri, USA

Adegboyega Oyedijo

University of Leicester Business School, University of Leicester, Leicester, UK

Vishnu C. Rajan

VIT Business School, Vellore Institute of Technology, Chennai, India

George A. Zsidisin

Department of Supply Chain and Analytics, College of Business Administration, University of Missouri – St. Louis, Saint Louis, Missouri, USA

Marcia Mkansi

Department of Operations Management, University of South Africa, Pretoria, South Africa, and

Jamal El Baz

MADILOG, Ecole Nationale de Commerce et de Gestion, Ibn Zohr Univeristy, Agadir, Morocco

Abstract

Purpose – This study aims to develop a hierarchical model that uncovers the relationships between challenges confronting Africa's organ transplant supply chain systems.

Design/methodology/approach – Eleven challenges (variables) were identified after a comprehensive review of the existing literature. The contextual interactions among these variables were analysed from the perspectives of health-care stakeholders in two sub-Saharan Africa (SSA) countries (Nigeria and Uganda), using Delphi-interpretive structural modelling-cross-impact matrix multiplication applied to classification (MICMAC) techniques.

Findings – The findings reveal that weak regulatory frameworks, insufficient information systems and a lack of necessary skills make it challenging for critical actors to perform the tasks effectively. The interaction effects of these challenges weaken organ supply chains and make it less efficient, giving rise to negative externalities such as black markets for donated organs and organ tourism/trafficking.

Research limitations/implications – This paper establishes a solid foundation for a critical topic that could significantly impact human health and life once the government or non-profit ecosystem matures. The MICMAC analysis in this paper provides a methodological approach for future studies wishing to further develop the organ supply chain structural models.

Practical implications – The study provides valuable insights for experts and policymakers on where to prioritise efforts in designing interventions to strengthen organ transplantation supply chains in developing countries.

Originality/value – This study is one of the first to empirically examine the challenges of organ transplant supply chains from an SSA perspective, including theoretically grounded explanations from data collected in two developing countries.

Keywords Africa, Organ donation, Organ transplant supply chains, MICMAC analysis, Supply and demand, Health-care service, Developing countries

Paper type Research paper

1. Introduction

The shortage of donor organs represents one of the most challenging global problems today (INTERPOL, 2021; Lewis

et al., 2021). Since 2015, there has been a 7.2% increase in people needing organ transplants (Global Observatory on Donation and Transplantation, 2016). However, despite a global rise in the demand for organs, which can be ascribed to the prevalence of end-organ diseases such as chronic lung and heart diseases, as well as kidney and liver disorders (Parada-Contzen and Vásquez-Lavín, 2019), there are supply limitations (Bradford, 2021).

Effective organ transplantation programmes are crucial for the sustainability of health-care systems in developed and developing nations (Vanholder et al., 2021). For example, the average wait time for organ transplants in the USA is between two and six years. This issue results in the loss of over 10,000 lives each year (Beard et al., 2013). In developing countries like India, the low donation rate for organs, for example, is one factor that leads to the annual death toll of 500,000 people (National Health Portal, 2015). Over the past decade, many studies have identified challenges/constraints that may reduce the availability of high-quality organs for transplantation. This is due to a lack of regulatory or policy frameworks (Shroff, 2009), religious or cultural beliefs (Sharif, 2012), poor incentives systems (Parada-Contzen and Vásquez-Lavín, 2019), inadequate cold-chain facilities (Fisher et al., 2020), among other factors such as organ trafficking and tourism (Smith, 2012). However, many of these studies have examined such challenges individually without determining if the obstacles are interdependent.

Organ donation and transplantation involve a complex ecosystem with highly interconnected subsystems (Abbasi and Varga, 2022). Although specific challenges associated with organ transplant operations in a broader context have been examined in the relevant literature, little effort has been made to explore how these challenges intersect (Arora and Subramanian, 2019). It is only by bringing together the subsystems and treating them as interdependent parts of a complex system that such organisational systems can be improved (Ackoff, 1994; Baxter and Sommerville, 2011; Leavitt, 1965; McKay et al., 2021). Likewise, few studies have demonstrated how supply chain management practices improve organ transplantation by focusing on time, geographical location and allocations (Cole, 2021; Aleccia, 2020). Others have developed models to minimise organ transport time (Beliën et al., 2011) and effectively match organ demand with supply (Rabbani and Talebi, 2019). However, due to their greater emphasis on developed nations, these studies demonstrate that our understanding of organ donation and transplant supply chain issues are still limited.

More research is needed on how developing countries (e.g. in Africa), and particularly those in sub-Saharan Africa (SSA), can increase the supply of organs for transplantation. Developing countries, especially those in SSA, encounter unique challenges in their capacity to implement effective supply chain systems within the health-care sector (Yadav, 2015). Efficient and effective supply chains are vital for delivering safe, quality and affordable health services, and especially those in Africa (Yadav, 2015; Banda et al., 2021; Olutuase et al., 2022; Akenroye et al., 2022). Empirical research is needed to assist scholars and practitioners in gaining a better contextual understanding of the issues restricting organ donation and transplantation distribution networks in developing economies. Furthermore, a broader and more nuanced understanding of organ supply chain challenges would aid in illuminating and rethinking theoretical lenses and prioritising managerial actions to improve transplantation services. This is the issue we address in this paper.

The barriers hindering improvement in many supply chains, including health care, are found to be interrelated with distinct influencing characteristics (Vishnu et al., 2020). Here, influencing power means both driving power (potential to inflict other barriers) and dependence power (potential to get affected by other barriers). These characteristics ultimately determine the criticality and impact potential of the individual barriers. Hence, mapping the interrelationships and understanding their interactions is essential. Therefore, we pose the following research questions:

RQ1. What challenges exist in organ transplant supply chains, and how do these challenges interact?

RQ2. What is the potential impact of these challenges regarding their driving and dependence powers?

There are many reasons why we focus on Africa in this study. For example, Africa has the fewest transplants (Thomson, 2017), with only South Africa, Nigeria, Kenya, Ghana, Tanzania, Sudan, Seychelles, Namibia, Mauritius, Ivory Coast and Ethiopia performing organ transplants. This is a particularly pressing issue because the demand for organ transplantation has increased steadily without a corresponding increase in the number of organ donors in SSA countries (Damagum, 2022; World Health Organisation [WHO], 2020; West Cape Government, 2022). For instance, just 18% of families in South Africa authorised organ donation following a death (in a hospital) in 2017 (Thomson, 2017). In addition, the median number of kidney transplant facilities in Africa is 0.15 per million population (in comparison with 0.42 globally) due to the scarcity of transplant-related services (Oguejiofor et al., 2021).

Even though the organ transplant system is at the intersection of various disciplines, such as public health, logistics and information systems, this area has largely been neglected in mainstream supply chain management research. In contrast, it is generally assigned to disciplines with a solid clinical/medical science emphasis (Arshad et al., 2019; Ghose et al., 2021). Therefore, this study contributes to the supply chain management literature by creating a hierarchical model to reveal the complex interdependencies between organ transplant supply chain challenges with theoretically grounded explanations. For practitioners, the findings of this study provide unique insights and a deeper understanding of the types of challenges that exist in the organ transplant supply chain and how these challenges interact, particularly in developing countries. Furthermore, the findings of this study will generate new ideas for multi-stakeholder actions to improve the organ transplant supply chain and tackle pressing issues affecting people in need.

The rest of this paper is organised as follows. To answer our research question, we first conducted a literature review on the challenges affecting organ donation and transplantation processes, which are presented in Section 2. Section 3 describes the interpretive structural modelling (ISM) methodology and its application for identifying relationships between various organ donation and transplant supply chain challenges. Section 4 then discusses the findings. Finally, Section 5 presents our

conclusions, implications and limitations. The research implications are offered in a way that informs theory and practice. Ours is one of the first studies to investigate the interdependence of challenges in organ donation and transplantation supply chains, including theoretical explanations for the results. Through the developed ISM-based model, the study contributes to a better understanding of the issues that experts and policymakers can prioritise in the future for optimising organ transplant supply chains.

2. Literature review

2.1 Socio-technical systems theory

We adopt socio-technical systems (STS) theory in this study to advance explanations for the various challenges facing organ supply chains and how these challenges interact. While organ donation and transplantation can be technically challenging, they are also influenced by several interacting factors. The STS theory's framework on social, technical and environmental interaction may explain why certain behaviours emerge at different organ transplant supply chain stages. STS has been used in previous studies to understand issues such as behavioural constraints related to supplier integration (Kull et al., 2013), complexity and lean production systems (Soliman et al., 2018) and implementing intelligent supply chain control towers (Vlachos, 2021). In addition, other scholars have shown how socio-technical integration impacts supply chain sustainability practices (Shan et al., 2022) and supply chains as dynamic networks (Gattorna and Pasmore, 2022). However, previous studies have yet to consider a STS view of the organ donation and transplantation supply chain, which is what we focus on in this research. This is crucial because any action to address organ scarcity must consider how various social, cultural and technological factors interact to strengthen or weaken the supply chain.

2.2. A socio-technical system view of the organ donation and transplantation supply chain

A typical organ transplant supply chain consists of four generic phases: organ procurement, organ retrieval, distribution/delivery and transplantation (Akenroye et al., 2022). The first phase (i.e. organ procurement) refers to obtaining organs for transplantation by recruiting people willing to donate their organs (National Health Service [NHS], 2022). Even though most donors are deceased, people can donate organs while alive. Therefore, it is also critical for the organ procurement organisation to coordinate this procedure and assess the compatibility of the donor and recipient's health (National Health Service [NHS], 2022). Then, the organ retrieval procedure is performed as a highly complex and technically demanding surgical procedure. In addition to determining the suitability of the organs, the removal process eliminates significant adverse side effects from the donation that could harm the recipient. As part of the delivery process to the transplant centre, the organ is carefully packaged on ice and preserved with unique solutions. The organs retrieved for transplantation are cold-chain products that must be stored, packaged and transported according to strict quality and temperature standards. The final stage of transplantation involves placing a donated organ in a recipient. Overall, this is a challenging procedure that needs careful surgical planning, thorough screening and state-of-the-art medical equipment.

It is clear from the above process that the organ donation and transplantation supply chain requires not only highly regulated institutions (Ulasi et al., 2020) but also a variety of stakeholders ("actors") who have specialised knowledge (technical expertise) necessary for specific tasks to be completed (Mendes et al., 2012). To better understand how the organ donation and transplantation supply chain works and the factors that influence its operation, we adopt Bostrom and Heinen's (1977) STS theory. STS theory originates in the post-Second World War work of Eric Trist and other sociologists at the Tavistock Institute of Human Relations in England (Mujinga et al., 2019: Emery, 2016; Stranks, 2007). The theory contends that any organisation or a component comprises several "social" and "technical" subsystems, which must be managed as interdependent components of a complex system.

Figure 1 depicts the STS framework developed by Bostrom and Heinen to understand the interplay between four key elements of proactive change management: structure, task, technology and people. It illustrates that structures and people are social systems, while tasks and technology make up technical systems. Applying STS thinking also helps to identify areas of concern with large systems' operational and organisational aspects. For example, through the lens of STS, the actors of the social system of an organ transplant supply chain include individuals and stakeholder groups, such as professionals (clinicians and non-clinicians) involved in the organ donation, matching, retrieval, distribution and transplantation process. In addition, the institutional arrangements, such as formal work organisation, communication and authority structure, including norms, role expectations and behavioural patterns, constitute the structure of the social system (Lyytinen and Newman, 2008). For example, this relates to the institutional arrangements or regulations that govern organ sourcing by procurement organisations (Beyar, 2011), which is the transfer of organs voluntarily from potential donors to patients without jeopardising the recipients' post-transplant health.

When such institutional structures are not functioning correctly, they can raise transaction costs and encourage "opportunistic behaviour", such as organ commercialism (Danovitch, 2014), illegal trafficking, or organ tourism (Kassab and Rosen, 2019). When all of these factors are combined, they have the potential to cause a severe shortage of donated organs within a specific supply chain system. To address challenges and reconcile competing interests, the social system's structure may necessitate government-imposed remedies (Ogus, 2007) and collective actions (Klijn and Koppenjan, 2006) from supply chain actors. On the other hand, the technical system includes the techniques, processes and tools required for the implementation process. This relates to the availability of experts with the necessary skills, such as transplant clinicians/surgeons, logistics operators and social workers (Feldman et al., 2020), as well as the existing technology and infrastructure (Scalea et al., 2021), for successfully matching a donor with a recipient and performing an organ transplant. This includes tasks that meet organisational goals, objectives and stakeholder requirements (Lyytinen and Newman, 2008).

As was shown above, the STS involves complex and dynamic physical-technical systems in addition to networked interactions of interdependent actors. This demonstrates how different

Figure 1 Socio-technical systems perspective
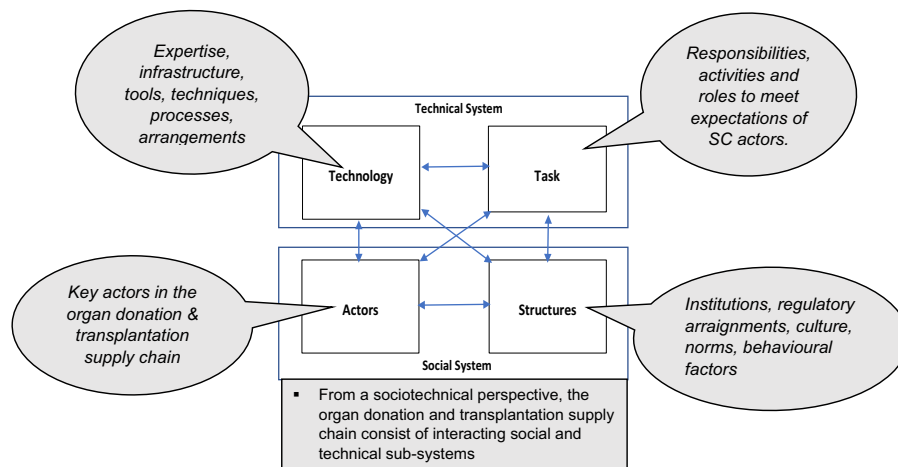
Source: Adapted from (Bostrom and Heinen 1977; Leavitt 2013)

variables may interact to affect the collaborative efforts of actors attempting to accomplish organ supply chain responsibilities.

2.3 Challenges associated with the organ donation and transplantation process

A comprehensive review of the literature uncovered eleven critical challenges to organ donation and transplantation, which are discussed below.

2.3.1 Lack of functional organ procurement network

Organ transplantation programmes are successful when potential donors are correctly identified, their health is assessed, and organs are matched and allocated to recipients (Beyar, 2011). The World Health Organisation (WHO) has established criteria and processes to monitor the effectiveness of the organ donation process (Beyar, 2011). However, evidence suggests inefficiencies in kidney allocation (Ross and Thistlethwaite, 2008), cadaveric organ procurement (Beard *et al.*, 2006) and circle-based liver allocation (Wood *et al.*, 2022). This issue has increased the rate at which organs are discarded and wasted in transplant centres (Stewart, 2021). To ensure allocation efficiency, an organ procurement organisation must collaborate with the National Transplant Programme to create a database of potential donors with strict medical evaluation requirements for matching organs to recipients based on various factors such as blood group, waiting period and donor hospital location (Beyar, 2011). However, most SSA countries lack a functional organ procurement network to support efficient organ sourcing and allocation (Kaze *et al.*, 2018).

2.3.2 Poor or non-existent organ transplant regulations

Organ donation and transplantation are highly regulated activities. However, few developing countries have a legal framework to monitor and govern the procurement and transplantation of human organs, cells and tissues (Ulasi *et al.*, 2020). Since such regulations do not exist, donation, retrieval, transportation and even transplant surgery may be susceptible to unethical practices. To ensure the safety and quality of organs, strong regulatory policies covering all steps of the transplantation process are imperative. This is also essential for maintaining clear rules for operating an organ donation registry,

stakeholder participation (Weimer, 2010) and ensuring governance and equity in organ transplantation practice (Hackmann *et al.*, 2022). In addition, many legal and ethical concerns about organ donation and transplantation will only be able to manage with a regulatory structure (Shroff, 2009), such as issues regarding incentives or compensation mechanisms for living organ donors.

2.3.3 Inadequate information system infrastructure

Data availability and accuracy concerns would make it difficult to maintain transparency and control over organ supply chain activities (Chavez *et al.*, 2020). Although studies show that digital technologies can assist developing countries (e.g. African countries) in achieving sustainable universal health coverage (Olu *et al.*, 2019), a weak data usage culture and inadequate information system architecture make the management of health supply chains in SSA more challenging (Kritchanchai *et al.*, 2018). Because so many parties are involved in the health supply chain and must cooperate and exchange information, insufficient information systems can make organ transplantation more difficult. Therefore, an effective data management system is required for the complete management of the transplantation process. In the absence of a robust digital backup system and data-driven decision-making (Massie *et al.*, 2014), health-care practitioners will find it challenging to manage national transplantation data sets (Howard and Byrne, 2007), ensure flawless organ matching and handle the flow of information between organ donation and transplantation (Molnar *et al.*, 2015).

2.3.4 Black market for donated organs

It is common knowledge that there is a flourishing international black market in human organs (Bowden, 2013; Yoon, 2018), particularly in developing countries. The WHO estimates 10,000 black market operations are taking place annually, in which illegally procured kidneys are traded (Iqbal and Khan, 2022; The Guardian, 2012). This often creates parallel supply chains to regulated organ transplantation programmes, putting potential donors through various risks, including slavery and other forms of abuse. Taylor (2006) argues that legalising such markets would increase the number of people being coerced

into selling their organs unwillingly. On the other hand, one could argue that the lack of adequate incentive structures and a stringent regulatory process is the root cause of black markets for human organs (Parada-Contzen and Vásquez-Lavín, 2019).

2.3.5 Lack of effective adequate cold chain system
Some pharmaceuticals and health-care commodities, such as blood and human organs, require a cold chain process to be stored and delivered to patients (Sharma *et al.*, 2021). Developing countries, especially those in Africa, are particularly deficient. The continent's medical cold chain cannot transport perishable items such as blood, organs and tissues to hospitals (Fisher *et al.*, 2020). As a result, if temperature monitoring and maintenance logistics systems are not sufficient to transport organs and tissues to hospitals on time, the safety and quality of organs and tissues will be jeopardised (Vreugdenhil *et al.*, 1991).

2.3.6 Lack of organ transport scheme
Every hour an organ is transported, its useful lifespan for the recipient decreases by an hour (Pullen, 2019). The lack of a sound organ transport system in some nations also increases transportation costs and time (Michel *et al.*, 2015). For example, in the USA, the current organ transportation system cannot handle the increased demand from new allocation policies (Pullen, 2019). Furthermore, as organ transportation is closely related to organ acceptance (Stewart *et al.*, 2016), difficulties encountered during transportation may impede the acceptance and transplantation of an organ, especially when imported organs such as kidneys and livers are involved (Wey *et al.*, 2018).

2.3.7 Lack of skilled labour
The establishment of a successful organ donation and transplant programmes requires a collaborative organisation involving many professionals (Spearman and McCulloch, 2014). These professionals include transplant physicians, anaesthetists, public health experts, logistics experts, transport experts, data analysts, radiologists, organ register coordinators and health economists. However, in SSA, there is a critical shortage of specialised health-care workers (Naicker *et al.*, 2010). For example, most cold chain products, such as blood and human organs, need more skilled and trained personnel familiar with advanced equipment and various IT systems. This includes a need for more knowledge about industry-specific inventory management and product handling practices, which necessitate specialised training (Kartoglu and Milstien, 2014).

2.3.8 Organ donor recruitment challenges
The fact that organ donation is still a heavily debated and contentious issue complicates organ procurement (Williamson *et al.*, 2019). Organ donation has religious supporters and opponents, depending on whether the donor is alive or dead (Sharif, 2012). Research on organ donation has revealed difficulties in engaging community groups, obtaining ethical clearance for sensitive experiments with the recently deceased and recruiting bereaved family members who were approached about organ donation (Noyes *et al.*, 2019). Due to this difficulty, organ donation campaigns have been challenging (Feeley and Kruegler, 2015). However, co-productive tactics can help to overcome this obstacle (Sharif, 2012).

2.3.9 Difficulties with matching donors and recipients
A critical aspect of the transplantation process is allocating organs efficiently between donor and recipient (Lee *et al.*, 2019). There are various criteria for successful matching, such as blood type, tissue type, patient medical urgency, proximity and compatibility (Lewis *et al.*, 2021). For example, if the donor and recipient are incompatible, the organ will be rejected by the recipient's body. In addition, unhealthy or people addicted to drugs or alcohol are also ineligible for lung transplants (Orens *et al.*, 2006). Some innovative online platforms have emerged to connect donors and recipients more effectively, including www. matchingdonors.com, which maintains the largest database of living charitable donors for kidney exchanges and receives between three and 26 new organ donor registrations per day (Matching Donors, 2023).

2.3.10 Organ transplant tourism
Transplant tourism is the movement of a recipient, donor, or both to a transplant centre in a foreign country (Shimazono, 2007). This has been reported in numerous nations and linked to organ trade/ "organ trafficking". It can also be thought of as buying an organ for transplant overseas and getting access to it while avoiding the laws, rules or procedures of any or all of the countries involved (Budiani-Saberi and Delmonico, 2008). Medical tourism, which involves the transportation of transplant recipients or donors across international borders (Hindi *et al.*, 2020), may not always be considered organ trafficking. Historically, developing countries such as India, Pakistan and Peru have been major organ exporters. Because of poverty, some individuals from these nations sell their organs to foreigners in developed countries such as the USA, the UK, Australia, Canada and Japan (Smith, 2012), resulting in organ shortages in their home countries.

2.3.11 Getting the consent of a potential donor
One of the most challenging aspects of organ donation is obtaining people's consent (Salim *et al.*, 2007). Obtaining the consent of a potential organ donor may be difficult in countries where there is no formalised framework or policy in place to guide organ transplantation practice. Because of this, it may become more challenging to receive organs on time for transplantation purposes. Previous studies have questioned whether presumptive consent is an ethically acceptable method of obtaining organs for transplant (Prabhu, 2019), as well as the opt-out and opt-in consent system for deceased organ donation (Ahmad *et al.*, 2019). In some developing nations, such as SSA countries, where there is no robust system or policy governing organ transplantation, it can be challenging to obtain the consent of a potential organ donor.

Table 1 summarises the link between the 11 challenges identified in the literature and the four-organ transplantation supply chain phases. Not all challenges are related to every stage of the transplant supply chain. For instance, the "delivery" and "transplantation" stages of the organ supply chain are more relevant to the lack of an efficient cold-chain system. However, all four stages have challenges with weak organ transplant regulation, inadequate information system infrastructure and a lack of skilled labour. The challenges listed in Table 1 need to be organised in order of importance or according to how frequently they have been found in the literature. This was done to safeguard the study's validity and lessen the possibility that it would be tainted by unintentional bias. As a result, there is less

Table 1 Challenges associated with organ donation and transplantation process

SN.	Hindering factors	Implications for organ supply	Influence on stages of organ transplant supply chain	Sources
C1	Lack of functional organ procurement network	Ineffective facilitation of organ sourcing and allocation	Sourcing and retrieval	Beyar (2011), Wood et al. (2022), Stewart (2021), Beard et al. (2006), Ross and Thistlethwaite (2008), Kaze et al. (2018)
C2	Organ transplant regulations are weak or absent	Concerns with organ procurement, supply and transplantation governance	Sourcing, retrieval, delivery and transplantation	Ulasi et al. (2020), Hackmann et al. (2022), Weimer (2010), Shroff (2009)
C3	Inadequate information system infrastructure	Transparency and management of the organ supply chain are hampered by a lack of available data	Sourcing, retrieval, delivery and transplantation	Chavez et al. (2020), Olu et al. (2019), Kritchanchai et al. (2018), Massie et al. (2014), Howard and Byrne, 2007; Molnar et al. (2015)
C4	Black market for donated organs	Alternative donor supply networks that are in direct competition with regulated transplantation programmes	Sourcing	Parada-Contzen and Vásquez-Lavín (2019), Bowden (2013), Yoon, (2018), Woan (2007), Morgan et al. (2005), Taylor (2006)
C5	Lack of effective cold-chain system	The safety/quality of organs will be at risk if cold-chain systems are not effective	Retrieval and delivery	Sharma et al. (2021), Fisher et al. (2020), Net et al. (2003), Vreugdenhil et al. (1991), Koizumi et al. (2015)
C6	Lack of effective organ logistics/transport scheme	Logistical problems can jeopardise organ transport and transplant equity	Delivery	Pullen (2019), Michel et al. (2015), Stewart et al. (2016), Wey et al. (2018)
C7	Lack of skilled labour	Inadequate skills in organ product handling procedures and inventory management techniques	Sourcing, retrieval, delivery and transplantation	Kartoglu and Milstien (2014), Spearman and McCulloch (2014), Naicker et al. (2010)
C8	Organ donor recruitment challenges	An insufficient supply of donors can be attributed to the difficulty of finding new ones	Sourcing	Williamson et al. (2019), Feeley and Kruegler (2015), Sharif (2012), Noyes et al. (2019)
C9	Difficulties with matching donors and recipients	The capacity of logistics to deliver organs to the appropriate individual at the right time can be hindered by challenges in pairing donors and recipients	Sourcing	Lewis et al. (2021), Lee et al. (2019), Orens et al. (2006), Matching Donors (2023), (2020)
C10	Organ transplant tourism	The high demand for organ transplants would seem to fuel "transplant tourism"	Retrieval, delivery and transplantation	Hindi et al. (2020), Shimazono (2007), Smith (2012), Budiani-Saberi and Delmonico (2008)
C11	Getting the consent of a potential donor	Affect the timely distribution and delivery of organs	Sourcing	Ahmad et al. (2019), Salim et al. (2007), Prabhu (2019), Shaw (2018)

chance that the participants will be affected by any implicit ordering or sequencing of the variables.

Due to the presumption that every organisation comprises interdependent subsystems, the next section will analyse these challenges using the ISM approach. Then, we will draw insights from the STS theory to interpret ISM findings and categorise the interaction patterns between the various organ supply chain challenges. In general, the STS framework's key dimensions can help to explain any emergent trend in the interconnections between the various challenges confronting the organ transplantation supply chain system.

3. Methodology

3.1 Interpretive structural modelling
This research aims to understand the challenges of the organ transplant supply chain and how they interact. We used the ISM method (Janssen *et al.*, 2018, 27) to reveal the contextual relationship among the challenges identified through a review of the relevant literature and the Delphi method (Kumar *et al.*, 2022; Naranjo *et al.*, 2023; Dalkey and Helmer, 1963). The Delphi method is a well-established approach for determining a consensus opinion among subject matter experts to respond to a research question. Using this method, participants are given the opportunity to review and consider their positions as a result of hearing other people's anonymous opinions. ISM involves those modelling activities in which the modeller intends to embody a geometric rather than an algebraic concept and in a describing form rather than calculate or measure quantitative outputs (George, 1980). Warfield (1974) extended structural modelling to ISM by including expert judgements as another dimension. In this context, interrelationships among the different elements in the system are determined by pairwise relationships, which are interpreted by an expert panel.

By using words and digraphs to model the interrelationships between elements, it is possible to interpret practical information that can be used to develop managerial measures to minimise the problem. As a result, we adopt the ISM technique by carrying out a series of clearly defined steps in the sequence discussed in subsequent sections below. Each step is significant and connected to the one before it.

3.2 Research setting
Our study focuses on Africa's organ donation and transplantation supply chain systems for several reasons. Firstly, research in supply chain management is still in its infancy in emerging economies such as Africa (Frei *et al.*, 2022; Oyedijo *et al.*, 2022). The African context also provides a rich and dynamic setting for investigating the organ donation and transplantation supply chain, as it currently faces numerous social, infrastructure and technical challenges (Oyedijo *et al.*, 2021; Oyedijo, 2022). Similarly, few studies have examined health-care supply chain issues related to organs, with most studies focusing solely on the business side.
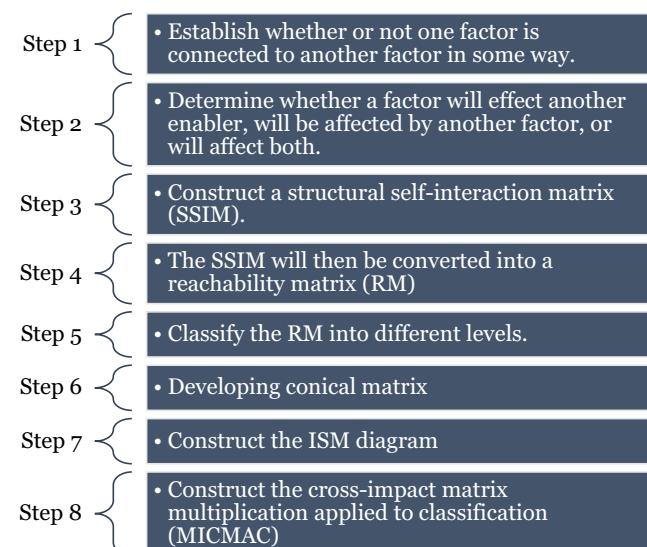
Our expert panel includes critical organ donation and transplantation stakeholders from Nigeria and Uganda. Nigeria is the world's seventh most populous country, while Uganda is the world's thirty-first and Africa's eighth most populous country (United Nations [UN], 2022). As a result, people in these areas are more likely to require organ transplants or organ

donations. Similarly, recent organ transplant issues have emerged in Nigeria and Uganda. Nigeria has one of the highest rates of organ-related disorders in SSA (Kaze *et al.*, 2018). For example, a former Deputy Senate President of Nigeria, Senator Ike Ekweremadu, was recently arrested and convicted for organ trafficking charges in London, in the first verdict of this kind under the Modern Slavery Act, after a 21-year-old refused to consent to surgery in a London hospital (BBC News, 2023; The Guardian, 2023). Following a public outcry in Uganda about selling organs and tissues from unwilling donors and reports of criminals using coercive power and deception to remove people's organs, the Ugandan Government recently passed a law to restrict the trade of human organs (Reuters, 2022). Therefore, conducting this study in these developing countries provides an opportunity to gain a deeper understanding of such a critical issue.

3.3 Data collection and interpretive structural modelling process used in this research
We implemented an integrated ISM and the cross-impact matrix multiplication applied to classification (MICMAC) approach to model and analyse dependencies among the challenges that impede the organ transplantation supply system. Table 1 lists the 11 challenges of organ donation and transplantation operations we used in our analysis. ISM is a well-structured interactive learning process commonly used to translate the judgements of a group of subject matter experts into an interpretive form, as shown in Steps 1–7 in Figure 2 below (Singh, 2011; Janssen *et al.*, 2018; Akenroye *et al.*, 2021). The ISM strategy was used to build a relationship model and identify the connections between driving forces (defined as a variable that influences another) and dependence (described as a variable being affected by another). MICMAC, on the other hand, divides interactions between variables and their drivers into four categories (Mandal and Deshmukh, 1994).

Figure 2 ISM key steps

Step 1	• Establish whether or not one factor is connected to another factor in some way.
Step 2	• Determine whether a factor will effect another enabler, will be affected by another factor, or will affect both.
Step 3	• Construct a structural self-interaction matrix (SSIM).
Step 4	• The SSIM will then be converted into a reachability matrix (RM)
Step 5	• Classify the RM into different levels.
Step 6	• Developing conical matrix
Step 7	• Construct the ISM diagram
Step 8	• Construct the cross-impact matrix multiplication applied to classification (MICMAC)

Source: Developed by the authors

Since this study aims to understand the perspectives of key stakeholders in SSA's health-care systems on organ supply chain challenges, we consulted 25 experts with at least 10 years of relevant experience from Nigeria and Uganda (two SSA countries). At the outset, we reached out to them by both email and phone. Using these communication modes, we could explain the study's goals and determine the participants' interest levels in the topic. Following a continuous conversation, 12 shortlisted experts agreed to participate in the consultation. In addition, we approached three academics in supply chain management, medicine and public health who agreed to join the study as research participants. A 15-member decision-making panel was then formed. Based on the literature, most ISM studies use a small group of experts (e.g. 5–11 people) from industry and academia to build contextual links (Purohit *et al.*, 2016; Panahifar *et al.*, 2015). The formulated ISM model was reviewed and validated using the Delphi technique (Naranjo *et al.*, 2023; Dalkey and Helmer, 1963). Thus, our team of 15 experts was well-suited for this analysis and developing the proposed ISM model. Table 2 contains brief biographies of the expert panel.

4. Data analysis and results

4.1 Steps 1–3: development of structural self-interaction matrix

The experts were told to follow Steps 1 and 2 during the consultation. Firstly, we explained the meaning of each of the 11 challenges identified in the literature to our experts. Then, we gave them four notations (V, A, X, O) to highlight the relationships between the challenges. Consequently, based on the census response from our experts, we gathered the contextual relationships to develop the structural self-interaction matrix (SSIM). For example, v means factor i impact factor j; A means factor i is influenced by factor j; X means both challenges influence each other and O means no relationship. Table 3 shows that the pairwise relationship between variables I and j) has been determined and depicted based on expert consensus. For example, the lack of a functional organ procurement network (B1) affects getting the consent of a potential donor (B11).

4.2 Step 4: the transformation of structural self-interaction matrix to reachability matrix

The initial reachability matrix is developed by transforming the data of each cell of SSIM in Table 3 into binary numbers "0 s" and "1 s", using the following rules according to Singh (2011):

- If the (i, j) entry in the SSIM is assigned with the symbol V, then the cell (i, j) entry becomes 1, and the (j, i) entry becomes 0 in the initial reachability matrix.
- If the (i, j) entry in the SSIM is assigned with symbol A, then the cell (i, j) entry becomes 0 and the (j, i) entry becomes 1 in the reachability matrix.
- If the (i, j) entry in the SSIM is X, both (i, j) entry and (j, i) entry cells become 1 in the reachability matrix.
- If the (i, j) entry in the SSIM is O, both (i, j) entry and (j, i) entry cells become 0 in the reachability matrix.

These above-listed rules were followed to develop the initial reachability matrix for the challenges of the organ donation and transplantation system, as shown in Table 4. The final reachability matrix (Table 5) is then achieved by incorporating transitivity (1^* entries are included) to fill any observed gap in expert views (opinions) gathered during the development of the structural self-instructional matrix. The matrix shows each factor's driving and dependence power in final reachability. Each challenge's driving power is reflected by the number of

Table 2 Profiles of selected experts

Expert	Type of organization	Designation	Relevance phase in the organ supply chain	Country	Years of experience
1	Ministry of health	Public health director	Donation (sourcing), retrieval, delivery and transplantation of organs	Nigeria	26
2	Health logistics services	CEO	Organ transportation/delivery	Nigeria	10
3	Public hospital	Transplant physician	Organ retrieval and transplantation	Nigeria	16
4	Private hospital	Family doctor	Organ retrieval and transplantation	Nigeria	24
5	NGO	Country representative	Organ donation	Nigeria	11
6	Kidney transplant center	Transplant physician	Organ retrieval and transplantation	Nigeria	20
7	University teaching hospital	Clinical immunologists	Organ donation (sourcing), retrieval and transplantation	Nigeria	14
8	University	Professor of medicine	Organ retrieval and transplantation	Nigeria	23
9	Blood transfusion services	Pathologist	Donation (sourcing), delivery and transplantation	Uganda	15
10	Public hospital	Cardiovascular surgeon	Organ retrieval and transplantation	Uganda	12
11	University teaching hospital	Renal unit, department of medicine	Organ retrieval and transplantation	Uganda	19
12	Medical laboratory	Cold chain expert	Organ transportation/delivery	Uganda	14
13	NGO	Country representative	Organ donation	Uganda	12
14	University	Health supply chain researcher	Organ transportation/delivery	Uganda	10
15	University	Professor of public health	Donation (sourcing), retrieval, delivery and transplantation of organs	Uganda	22

Note: CEO = Chief Executive Officer; NGO = Non-Governmental Organisation

Table 3 Structural self-interaction matrix

Barrier i ▼	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
C1. Lack of functional organ procurement network	V	V	V	V	V	A	A	V	X	A	
C2. Organ transplant regulations are weak or absent	V	V	V	V	A	V	V	V	A		
C3. Inadequate information system infrastructure	V	V	V	V	A	V	V	V			
C4. Black market for donated organs	A	V	A	A	O	O	O				
C5. Lack of effective cold-chain system	O	V	O	O	A	A					
C6. Lack of effective organ logistics/transport scheme	O	V	O	O	A						
C7. Lack of skilled labour	V	V	V	V							
C8. Organ donor recruitment challenges	A	V	X								
C9. Difficulties with matching donors and recipients	A	V									
C10. Organ transplant tourism	A										
C11. Getting the consent of a potential donor											

Table 4 Initial reachability matrix

Barrier	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	Driving power
C1	1	1	1	1	1	0	0	1	1	0	1	8
C2	1	1	1	1	0	1	1	1	0	1	1	9
C3	1	1	1	1	0	1	1	1	1	1	1	10
C4	0	1	0	0	0	0	0	1	0	0	0	2
C5	0	1	0	0	0	0	1	0	0	0	1	3
C6	0	1	0	0	0	1	1	0	0	0	1	4
C7	1	1	1	1	1	1	1	0	1	1	0	9
C8	0	1	1	1	0	0	0	1	0	0	0	4
C9	0	1	1	1	0	0	0	1	0	0	0	4
C10	0	1	0	0	0	0	0	0	0	0	0	1
C11	1	1	1	1	0	0	0	1	0	0	0	5
Dependence power	5	11	7	7	2	4	5	7	3	3	5	

Table 5 Final reachability matrix with transitive relationships

Barrier i ▼	1	2	3	4	5	6	7	8	9	10	11	Driving power
C1. Lack of functional organ procurement network	1	1*	1	1	1*	1*	1	1	1	1	1	11
C2. Organ transplant regulations are weak or absent	1	1	1*	1	1	1	1*	1	1	1	1	11
C3. Inadequate information system infrastructure	1	1	1	1	1	1	1*	1	1	1	1	11
C4. Black market for donated organs	0	0	0	1	0	0	0	0	0	1	0	2
C5. Lack of effective cold-chain system	1	1*	1*	1*	1	1*	1*	1*	1*	1	1*	11
C6. Lack of effective organ logistics/transport scheme	1	1*	1*	1*	1	1	1*	1*	1*	1	1*	11
C7. Lack of skilled labour	1*	1	1	1*	1	1	1	1	1	1	1	11
C8. Organ donor recruitment challenges	0	0	0	1	0	0	0	1	1	1	0	4
C9. Difficulties with matching donors and recipients	0	0	0	1	0	0	0	1	1	1	0	4
C10. Organ transplant tourism	0	0	0	0	0	0	0	0	0	1	0	1
C11. Getting the consent of a potential donor	0	0	0	1	0	0	0	1	1	1	1	5
Dependence power	6	6	6	10	6	6	6	9	9	11	7	

challenges that depend on it. The driving power represents the significance of a challenge, among others. Likewise, the dependent power of any challenge is the number of challenges it depends on. The dependent power symbolises a challenge's dependence. The reachability matrix (RM) output is then classified into levels to build the ISM diagram. We have captured all the transitive relations in Table 5 for computational purposes alone. Hence, while inferring the results of driving and dependence powers of an individual challenge in the subsequent section (see Step 7), our focus is on Table 4 results without transitive relations.

4.3 Step 5: classify the RM into different levels (level partitions)

We classify RM into levels to construct ISM's hierarchy. Warfield (1974) recommends evaluating the intersection between

reachability and antecedent sets for each variable. The reachability set contains all the challenges driven by another challenge, while the antecedent set contains the challenges that another challenge depends on (Zhang and Cao, 2018). Therefore, the intersection set contains the challenges that appear on both the reachability and antecedent sets. Following the steps taken by Cherrafi et al. (2017), we labelled the challenge with the same reachability and intersection sets as the top-level challenges. These challenges would not help to influence any other challenge above their level in the hierarchy. After identifying the "top-level factor", we separate them from the other reachability, antecedent and intersection sets. In Table 6, we present these variables together with their reachability set, antecedent set and top level. For example, it can be seen in Table 6 that "Organ transplant tourism" (C10) is found at the Level I. Therefore, this factor would be positioned at the top of the ISM model to be developed. To generate the digraph and the final ISM, this process is repeated continuously (i.e. using iterative level partitioning) to determine the subsequent levels of factor variables (Dwivedi et al., 2017).

4.4 Step 6: developing conical matrix
Finally, we developed the conical matrix from the final reachability matrix by reordering the challenges according to their level. This involves clustering all challenges on the same level across the rows and columns of the final reachability matrix. For example, C2 (Black market for donated organs) is found at Level II, while C8 (Organ donor recruitment challenges) and C9 (Difficulties with matching donors and recipients) are having Level III, and C11 (Getting the consent of potential donors) is position at Level IV. Following these rearrangements, the conical form of the final reachability matrix is generated and shown in Table 7. The digraph and ISM model will be developed from the conical form of the reachability matrix.

4.5 Step 7: construct the interpretive structural modelling diagram
Using the driving forces from Table 4 and the levels from Table 6, we constructed the ISM diagram shown in Figure 3. For a clear representation of the ISM digraph, we have used a coding scheme for the challenges of the organ supply chain (C1, C2, C3… C11). This indicates that among the 11 variables studied, C3 (Inadequate information system infrastructure) is the factor with the highest impact potential, followed by C2 (Organ transplant regulations are weak or absent) and C7

(Lack of skilled labour). As a result, any interventions to improve the supply chains of organ transplants in SSA should start with addressing these challenges, located at the base of the ISM diagram (Level V). Such interventions are also expected to have a positive cascading effect on minimising other challenges, especially the highly dependent ones. Regarding the dependency power, C10 (Organ transplant tourism) is found to be the after-effect of other challenges under investigation. It is a consequence of C4 (Black market for donated organs), C8 (Organ donor recruitment challenges) and C9 (Difficulties with matching donors and recipients).

4.6 Step 8: construct the matrix multiplication applied to classification
This section examines the driver and dependence power of the challenges associated with the organ supply chain system, which is the primary purpose of MICMAC analysis (Mandal and Deshmukh, 1994). These challenges are categorised into four different quadrants (Figure 4). The first quadrant is called the autonomous variables, which have weak driver power and weak dependence power. For example, Figure 4 shows that C11 (Getting the consent of a potential donor) is an autonomous variable because it has a driving power of five and a dependency power of seven. As a result, it occupies a corresponding position on the X and Y axis. The dependent variables are in quadrant two consisting of four challenges, namely, C4 (Black market for donated organs), C8 (Organ donor recruitment challenges), C9 (Difficulties with matching donors and recipients) and C10 (Organ transplant tourism). They all have extreme dependence but very weak driver power. In the third quadrant, linkage variables have strong driving power and dependence power out of the 11 variables, none falls in this quadrant. Finally, the fourth quadrant contains independent variables, which variables significantly drive the variable above them and affect the system. The challenges that fall in this quadrant are C1 (Lack of functional organ procurement network), C2 (Organ transplant regulations are weak or absent), C3 (Inadequate information system infrastructure), C5 (Lack of effective cold-chain system), C6 (Lack of effective organ logistics/transport scheme) and C7 (Lack of skilled labour). Not surprising to see these six challenges at the base of the ISM diagram (Figure 3), indicating their driving force over the entire system.

Table 6 Level partitioning

Barrier	Reachability set	Antecedent set	Intersection set	Level
C1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	V
C2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	V
C3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	V
C4	4, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 11	4	II
C5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	V
C6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	V
C7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	V
C8	4, 8, 9, 10	1, 2, 3, 5, 6, 7, 8, 9, 11	8, 9	III
C9	4, 8, 9, 10	1, 2, 3, 5, 6, 7, 8, 9, 11	8, 9	III
C10	10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	10	I
C11	4, 8, 9, 10, 11	1, 2, 3, 5, 6, 7, 11	11	IV

Table 7 Canonical form of the final reachability matrix

Barrier	C10	C4	C8	C9	C11	C1	C2	C3	C5	C6	C7	Driving power	Level
C10	1	0	0	0	0	0	0	0	0	0	0	1	I
C4	1	1	0	0	0	0	0	0	0	0	0	2	II
C8	1	1	1	1	0	0	0	0	0	0	0	4	III
C9	1	1	1	1	0	0	0	0	0	0	0	4	III
C11	1	1	1	1	1	0	0	0	0	0	0	5	IV
C1	1	1	1	1	1	1	1*	1	1*	1*	1	11	V
C2	1	1	1	1	1	1	1	1*	1	1	1*	11	V
C3	1	1	1	1	1	1	1	1	1	1	1*	11	V
C5	1	1*	1*	1*	1*	1	1*	1*	1	1*	1*	11	V
C6	1	1*	1*	1*	1*	1	1*	1*	1	1	1*	11	V
C7	1	1*	1	1	1	1*	1	1	1	1	1	11	V
Dependence power	11	10	9	9	7	6	6	6	6	6	6		
Level	1	2	3	3	4	5	5	5	5	5	5		

Figure 3 Interpretive structural model of organ supply chain challenges
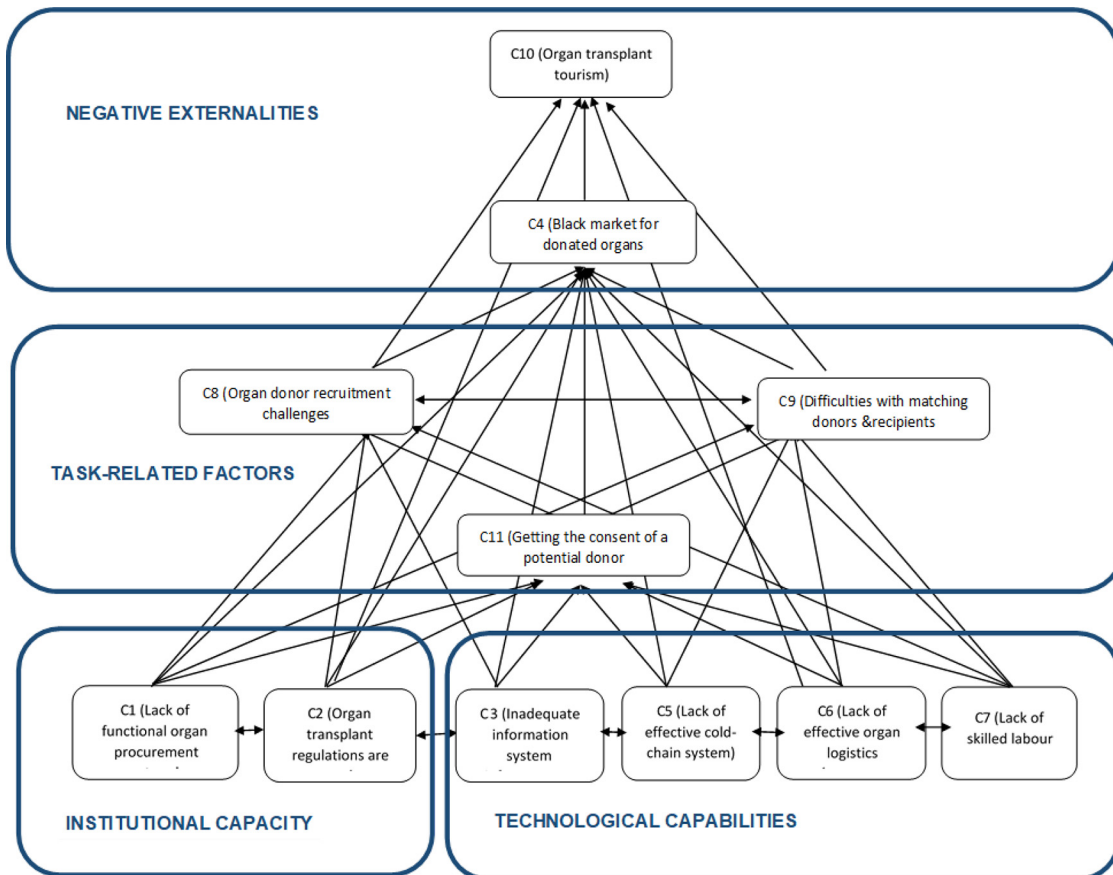

5. Discussion of findings

An efficient system for organ transplantation depends on the health supply chain running smoothly. However, there is a significant mismatch between the demand for and supply of organs for transplantation, resulting in the loss of lives and high socioeconomic costs. Previous studies have identified various challenges of the organ transplantation process based on our research question; however, the interactions between those challenges have yet to be examined from the perspectives of relevant stakeholders in SSA's health-care sector.

Figure 3 depicts the interaction of various variables identified in the literature as challenges to organ donation and transplantation (*addressing RQ1*). It reveals, for example, that a lack of a functional organ procurement network (C1), weak or absent organ transplant regulations (C2), inadequate information system infrastructure (C3), a lack of an effective cold-chain system (C5), a lack of an effective organ logistics/transport scheme (C6) and a

Figure 4 MICMAC analysis
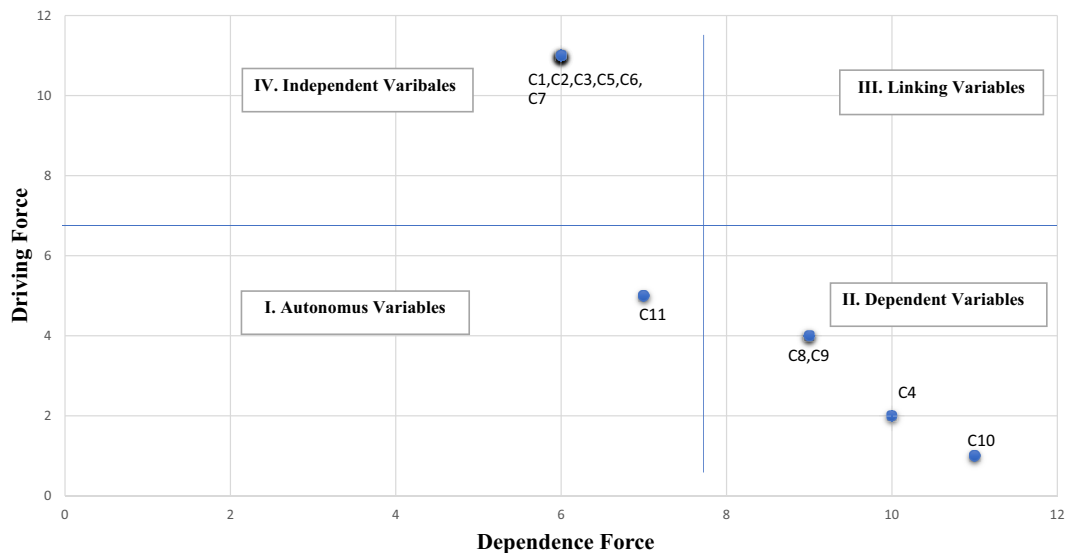
lack of skilled labour (C7) are all significant challenges to the organ transplant supply chain system in SSA and form the foundation of the ISM hierarchy model. These challenges are further classified as *institutional capacity* (C1, C2) and *technological capabilities* (C3, C5, C6, C7). Because these challenges have a high driving power but a low dependence power, they fall under the category of independent variables in the MICMAC results (Figure 4). Thus, showing the potential impact of these challenges in terms of their driving power and dependence power (*addressing RQ2*).

When we rank variables by their driving power, we see that inadequate information system infrastructure (C3), weak or absent organ transplant regulations (C2) and a lack of skilled labour (C7) are the three most influential factors (see the reachability Table 4). These three variables are the most important in exacerbating the problems in the organ transplant supply chain. This is not surprising, given that most SSA countries lack a robust regulatory framework (Oyedijo *et al.*, 2021; Oyedijo, 2022; Oyedijo *et al.*, 2022). The findings also support the widely held belief that Africa's health-care industry is suffering from severe skill shortages (Woodburn, 2013; Yadav, 2015) and that the logistics information systems that support the continent's supply chains are far from an optimum level (Lugada *et al.*, 2022). This implies that improvements to the relevant institutional and regulatory frameworks are required to optimise SSA's organ donation and transplant supply chains. If more digital technologies are used in the continent's health sector, organ transplant supply chain operations are more likely to be transparent and efficient. Such digitalisation efforts can assist stakeholders in the health-care sector in effectively acquiring, sharing and using information.

Other challenges, which we classified as *task-related factors*, will also be mitigated as institutional and technological capacities improve. The factors comprise difficulties in obtaining consent from a potentialr donor (C11), finding organ donors (C8) and matching donors with recipients (C9). However, the interaction effect of these task-related challenges gives rise to some *negative externalities*, such as the illegal market for donated

organs (C4) and organ transplant tourism (C10). These are found at the very top of the hierarchical structure, made possible by applying the ISM technique. They represent unintended consequences of inefficient allocation and distribution of organ products in the system. This implies that if domestic organ transplant operations were strengthened to support the efficient allocation of donated organ products, black markets and organ trafficking/tourism would not have emerged. Although the unmet need for organ transplantation in SSA is unknown, 643 organ transplants were performed in 2016, far fewer than in other WHO regions (World Health Organisation [WHO], 2020). Donors in organ trafficking are often from poor and developing countries like Nepal, India, Bangladesh, Egypt and, recently, Nigeria (Euronews, 2022; Warsi, 2023). When the supply of donated organs is insufficient to meet the demand in these countries, the market fails, giving people the incentive to engage in other unethical behaviours. For example, the prolonged nature of organ shortages can lead to the creation of black markets in any country (Danovitch, 2014).

It is also important to note that the organ transplant supply chain involves numerous stakeholders, many of whom have competing priorities. Suppose this process/relationship is not adequately managed, supply chain actors may engage in opportunistic behaviour to pursue self-interest outcomes (Kelly *et al.*, 2018), jeopardising the equitable allocation of donated organs. With the growth of a wide range of organ trade networks in recent years, reports of illegal human organ trafficking and tourism have reached an all-time high (Cole, 2021). While much effort has been invested in tackling this challenge, our model demonstrates that organ trafficking and tourism result from enduring institutional and technical weaknesses in developing countries. Thus, based on the MICMAC results (Figure 4), organ tourism is a dependent variable and an output of interactions between other underpinning issues. If the fundamental institutional and technical challenges at the heart of the ISM model are addressed and resolved, it will positively impact tackling organ trafficking and tourism.

The current methods of dealing with illegal organ trading are primarily reactive in nature (Human Tissue Authority [HTA], 2022). Thus, our finding suggests the need for a more proactive approach to prevent the issues (negative externalities) from emerging, particularly by strengthening the organ supply chain systems in developing countries. Based on our findings, the challenges positioned at the base of the ISM model in Figure 3 should be given the highest priority areas. Any intervention to tackle them would have a cascading effect on addressing the problem of organ trafficking/tourism and black markets. These are negative externalities caused by underlying structural and socio-technical weaknesses, yet they dominate the current organ shortage debate.

6. Conclusion

The supply chain for human organ donation and transplantation is one area where policymakers, regulatory bodies, scholars, medical practitioners, health-care services and the general public can all play a role in making the process more seamless. The issue is important considering that nearly every hour, a patient in the USA dies in the waiting room for an organ transplant (Degenholtz et al., 2019), and only 1 out of 100 people who die in the UK are usually able to be donors (National Health Service [NHS], 2022). Organ shortage is a global problem, but research on the human organ supply chain is still in its early stages (Cole, 2021; Akenroye et al., 2022; Misra et al., 2022). Even within the medical community, the emphasis has been on the medical aspects of the transplant procedure rather than attempting to understand issues holistically (Bruni et al., 2006; Misra et al., 2022). As a result, our research question, which asked what types of challenges exist in the organ transplant supply chain and how these challenges interact, is a step towards raising awareness of this critical issue and contributing to the health care and supply chain domains.

We discovered that the most critical challenges in SSA's organ transplant supply system relate to the structural dimensions of Bostrom and Heinen's socio-structural framework (weak organ transplant regulation and a lack of functional organ procurement organisations) and technology. These technological challenges can manifest in an inadequate information system, a lack of skilled labour, an effective cold chain system and a suboptimal organ logistics/transport scheme. Compared to social-structural challenges, task-related challenges have high dependence but low driver power. If not appropriately addressed, they can lead to inefficient allocation/distribution of donated organs, resulting in thriving black markets. As a result, research and practice should emphasise structural and technological issues, which have a more significant impact on SSA's organ transplant supply chain systems than actors' task-related factors.

6.1 Theoretical contributions

Previous research has not taken into account the socio-technical aspects of organ donation and transplant supply. Furthermore, understanding how these socio-technical subsystems interact to facilitate or inhibit the availability of transplantable organs has yet to be explored in previous studies. We used the ISM technique and MICMAC analysis to show the relative importance of subsystems (hierarchical structure of

interactions) beyond the STS theory's focus on interaction/interdependence alone. Our findings reveal the following:

- Weak regulatory institutions and inadequate information systems hinder supply chain actors' ability to carry out tasks effectively.
- Negative externalities can result from task-related difficulties (concerns about donor recruitment, consent and matching), causing the inefficient allocation of organ products within the system.
- Organ transplant tourism, one of the fastest-growing illegal activities globally, arises from (output of) the interaction effects of many variables but does not affect changes in as many others.

Based on these findings, any intervention developed to address the institutional capacity and technological capability (human and technical) is expected to have a positive ripple effect on the entire system. Therefore, this study adds to the relevant literature by understanding the challenges of organ transplant supply chains and establishing their contextual relationship to understand better the various areas where interventions can be developed to optimise the system. Furthermore, drawing from the STS theory, this research adds to the literature by offering a comprehensive interpretive structural framework which suggests new constructs on the interaction between different challenges of organ transplant supply chains, i.e. institutional capacity, technological capabilities, task-related factors and negative externalities (see Figure 3). Through this, the study adds to the findings of past studies concerning the uneven landscape of organ transplant supply chains (Cole, 2021), the factors influencing organ supply chains (Misra et al., 2022) and the design of organ transplant supply chains in uncertain environments (Goli et al., 2022).

Secondly, much attention has been paid in the literature to identifying and considering obstacles that impede organ donation and transplantation. Although many factors (challenges) have been identified, few studies have presented the challenges by category. Without a clear consensus on categorising the challenges, our study contributes to the literature using the ISM technique to determine the interplay between identified challenges in previous studies. Similarly, unlike previous studies on this topic (Zahiri et al., 2014; Kargar et al., 2020; Goli et al., 2022) that have primarily relied on mathematical models, our study uses the STS theory as a theoretical lens to determine if a helpful categorisation can be beneficial to improving organ transplant supply chain challenges.

Although much emphasis has been placed on the governance aspect of organ transplant supply chains in research (Chavez et al., 2020), efforts to improve this field will be limited if the social and technical elements are not adequately considered. As a result, to the best of our knowledge, our study is one of the first to empirically examine the challenges to organ transplant supply chains from an SSA perspective, including theoretically grounded explanations for the findings.

Thirdly, while the majority of the organ transplantation literature focuses on the demand side of the process, such as the prevalence of end-organ diseases (Parada-Contzen and Vásquez-Lavín, 2019), the increase in waiting time for transplantation (Beard et al., 2013), demand complexity (Rabbani and Talebi, 2019) and transactional costs associated

(Abouna, 2008), we develop an analytical model to synthesise the research findings and to uncover the relative importance and contextual interaction of the supply-side challenges. For example, Rabbani and Talebi (2019) highlighted geographical inequalities in organ location-allocation. However, our ISM model provides a more comprehensive view of this phenomenon by demonstrating that institutional weakness, a lack of information systems and a lack of skilled labour can all have spill over effects, i.e. black markets for organs and trafficking. These negative externalities constitute another type of inequality, which may cause market failure (Thorne, 1998) in the allocation/distribution of donated organs globally. Furthermore, the factors identified in previous research as issues in organ transplant supply chains were discussed in isolation; our study extends knowledge in this area by using MICMAC to deconstruct the variables identified in the previous literature to examine their driver power and dependence power, as well as to supplement a matrix of their relationship.

In addition, the findings emerging from this study have implications for the theory of constraints (Kim *et al.*, 2008; Rahman, 1998; Simatupang *et al.*, 2004), a technique used to determine the primary constraint to a system's optimisation and then sequentially improving that constraint to the point where it is no longer the limiting factor. For instance, given that our research has used the STS theory to shed light on an inherent interaction between challenges in organ supply chains, the theory of constraints can facilitate identifying the most significant system constraints and prioritising resource allocation to effectively and efficiently provide critical transplant services to those in need. Considering this, future efforts on how to combine the theory of constraints with the STS can provide better insights for researchers in overcoming key obstacles that prevent the realisation of the potential benefits of organ supply chain systems. In this way, the synergistic potential of these two theories can be better harnessed to help save the lives of those needing organ transplants.

6.2 Practical implications

The study contributions not only advance theoretical knowledge of the organ transplant process and supply field but they are also helpful for regulators, particularly policymakers, who want to strengthen the capacity of institutions and systems effectively, and people to improve both the operational and long-term performance of their organ transplant operations/services. This study's ISM-based model uncovered the interaction effects of variables impeding the organ transplant supply chain in SSA. However, now that we have a better understanding of how these challenges behave, public health professionals, clinicians, supply chain experts and regulators can implement solutions that will result in systemic change. Such solutions include a step-by-step reform of the organ transplant programmes, which can lead to the development of better institutional/regulatory processes for organ procurement, capacity building for improvement of organ handling/logistics practices and development of cold-chain systems to minimise waste.

In addition, digitalising the health supply chain can help to optimise organ donation and transplantation activities. Emerging technologies, such as big data analytics, advanced robotics, tracking and the Internet of Things, can be used to improve the use of data for decision-making and potentially help to solve current problems around matching donors with recipients, long waiting lists, as well as improving the traceability of donated organs (Ivanov *et al.*, 2019; Ben-Daya *et al.*, 2019). Thus, this study adds to organ donation and transplant operations by assisting health-care stakeholders in prioritising efforts and resources to design targeted interventions to strengthen organ transplantation programmes in developing countries. In addition, the findings can help policymakers develop better policies to help developing-country health programmes deal with the organ shortage crisis.

6.3 Limitations

This study has several research limitations. For instance, the model developed was based on expert opinions, which can be skewed. Nonetheless, we conducted a census among the participants to find common ground in their observation and ranking of the variables studied. In addition, while the findings are expected to have broader general applicability to human organ transplant programmes in SSA, more research in different regions of Africa, developing economies and organ-type contexts should be conducted to validate the proposed model. In those cases, factors can be added or removed as needed, depending on the context.

Overall, the paper sheds some light on the factors limiting the success of organ transplant operations in developing countries, thereby encouraging their optimisation. The proposed ISM-based model provides a realistic representation of the issues encountered while transferring an organ from a potential donor to a patient. This model, however, should be statistically validated. As a result, we encourage other scholars to use other methodological approaches, such as survey analysis to empirically validate the developed ISM model. Furthermore, to advance this research, ISM methodology can be combined with other multi-criteria decision-making methods, such as the Best Worst Technique, to validate the findings.

While this research provides exciting insights with the potential to impact human lives, it was conducted in African countries, which may be perceived as a parochial perspective limited by context. For example, the types of challenges that exist in the organ transplant supply chain in Africa (a developing economy) and how these challenges interact may differ from those found in developed markets. This point of view is essential, given that developed countries such as the USA and the UK also struggle with organ donation and transplantation systems. Consequently, it would be beneficial to broaden research on the organ donation and transplantation supply chain to developed countries and compare how these challenges interact in these different contexts. This could include a quantitative comparison of the data collected along the organ supply chain once many developing countries have established reporting systems for their respective governments. By better understanding organ transplant supply chains, future lives may be saved and improved.

References

Abbasi, M. and Varga, L. (2022), "Steering supply chains from a complex systems perspective", *European Journal of Management Studies*, Vol. 27 No. 1, pp. 5-38.

Abouna, G.M. (2008), "Organ shortage crisis: problems and possible solutions", *Transplantation Proceedings*, Vol. 40 No. 1, pp. 34-38.

Ackoff, R.L. (1994), "Systems thinking and thinking systems", *System Dynamics Review*, Vol. 10 No. 2-3, pp. 175-188.

Ahmad, M.U., Hanna, A., Mohamed, A.Z., Schlindwein, A., Pley, C., Bahner, I. and Jarmi, T. (2019), "A systematic review of opt-out versus opt-in consent on deceased organ donation and transplantation (2006–2016)", *World Journal of Surgery*, Vol. 43 No. 12, pp. 3161-3171.

Akenroye, T.O., Abubakre, A., Elbaz, J., Vishnu, C.R., Beka Be Nguema, J.N., Rana, G. and Falode, O. (2021), "Modeling the barriers to multi-stakeholder collaboration for COVID-19 pandemic response: evidence from Sub-Saharan Africa", *International Public Management Journal*, Vol. 25 No. 2, pp. 192-216.

Akenroye, T., Oyedijo, A., Elbaz, J. and Mkansi, M. (2022), "Human organ supply chains: current issues and potential solutions", *Logistics and Transport Focus*, Vol. 30 No. 10, pp. 50-52. October, 2022, available at: https://library.myebook.com/CILT/focus-october/4402/#page/51

Aleccia, J. (2020), "How lifesaving organs for transplant go missing in transit", Kaiser Health News website, available at: https://khn.org/news/how-lifesaving-organs-for-transplant-go-missing-in-transit/ (accessed 25th July 2022).

Arora, P. and Subramanian, R. (2019), "Improving societal outcomes in the organ donation value chain", *Production and Operations Management*, Vol. 28 No. 8, pp. 2110-2131.

Arshad, A., Anderson, B. and Sharif, A. (2019), "Comparison of organ donation and transplantation rates between opt-out and opt-in systems", *Kidney International*, Vol. 95 No. 6, pp. 1453-1460.

Banda, G., Mugwagwa, J., Wanjala, C., Mackintosh, M. and Kale, D. (2021), "Local manufacturing, local supply chains and health security in Africa: lessons from COVID-19", *BMJ Global Health*, Vol. 6 No. 6, p. 6362.

Baxter, G. and Sommerville, I. (2011), "Socio-technical systems: from design methods to systems engineering", *Interacting with Computers*, Vol. 23 No. 1, pp. 4-17.

BBC News (2023), "Ike ekweremadu: organ-trafficking plot politician and wife guilty", available at: www.bbc.co.uk/news/uk-england-london-65013545 (accessed 24th March 2023).

Beard, T.R., Kaserman, D.L. and Osterkamp, R. (2013), "The global organ shortage: economic causes, human consequences, policy responses", *The Independent Review*, Vol. 18 No. 2, pp. 296-298. Fall 2013

Beard, T.R., Kaserman, D.L. and Saba, R.P. (2006), "Inefficiency in cadaveric organ procurement", *Southern Economic Journal*, Vol. 73 No. 1, pp. 13-26.

Beliën, J., De Boeck, L., Colpaert, J., Devesse, S. and Van den Bossche, F. (2011), "Optimizing the supply chain design for organ transplants", Hub Research Paper (2011/01/Januari 2011).

Ben-Daya, M., Hassini, E. and Bahroun, Z. (2019), "Internet of things and supply chain management: a literature review", *International Journal of Production Research*, Vol. 57 Nos 15/16, pp. 4719-4742.

Beyar, R. (2011), "Challenges in organ transplantation", *Rambam Maimonides Medical Journal*, Vol. 2 No. 2, p. e0049.

Bostrom, R.P. and Heinen, J.S. (1977), "MIS problems and failures: a socio-technical perspective, part II: the application of Socio-Technical theory", *MIS Quarterly*, Vol. 1 No. 4, pp. 11-28.

Bowden, J. (2013), "Feeling empty: organ trafficking & trade: the black market for human organs", *Intercultural Human Rights Law Review*, Vol. 8, pp. 452-459.

Bradford, T.W. (2021), "We can fix this! Donor activism for non-profit supply generation", *Journal of the Academy of Marketing Science*, Vol. 49 No. 2, pp. 397-417.

Bruni, M.E., Conforti, D., Sicilia, N. and Trotta, S. (2006), "A new organ transplantation location–allocation policy: a case study of Italy", *Health Care Management Science*, Vol. 9 No. 2, pp. 125-142.

Budiani-Saberi, D.A. and Delmonico, F.L. (2008), "Organ trafficking and transplant tourism: a commentary on the global realities", *American Journal of Transplantation*, Vol. 8 No. 5, pp. 925-929.

Chavez, N., Kendzierskyj, S., Jahankhani, H. and Hosseinian, A. (2020), "Securing transparency and governance of organ supply chain through blockchain", *Policing in the Era of AI and Smart Societies*, Springer, Cham, pp. 97-118.

Cherrafi, A., Elfezazi, S., Garza-Reyes, J.A., Benhida, K. and Mokhlis, A. (2017), "Barriers in green lean implementation: a combined systematic literature review and interpretive structural modelling approach", *Production Planning & Control*, Vol. 28 No. 10, pp. 829-842.

Cole, H. (2021), "The organ supply chain: geography and the inequalities of transplant logistics", *Transactions of the Institute of British Geographers*, Vol. 46 No. 4, pp. 1008-1021.

Dalkey, N. and Helmer, O. (1963), "An experimental application of the Delphi method to the use of experts", *Management Science*, Vol. 9 No. 3, pp. 458-467.

Damagum, F. (2022), "Grey areas: organ transplantation in Nigeria", grey areas: organ transplantation in Nigeria, Daily trust, available at: https://dailytrust.com/grey-areas-organ-transplantation-in-nigeria/ (accessed 10th March 2022).

Danovitch, G.M. (2014), "The high cost of organ transplant commercialism", *Kidney International*, Vol. 85 No. 2, pp. 248-250.

Degenholtz, H.B., Creppage, K., DaCosta, D., Drozd, A., Enos, M., Himber, M. and Shaw, Y. (2019), "The patients save lives program to facilitate organ donor designation in primary care offices", *Progress in Transplantation*, Vol. 29 No. 3, pp. 204-212.

Dwivedi, Y.K., Janssen, M., Slade, E.L., Rana, N.P., Weerakkody, V., Millard, J. and Snijders, D. (2017), "Driving innovation through big open linked data (BOLD): exploring antecedents using interpretive structural modelling", *Information Systems Frontiers*, Vol. 19 No. 2, pp. 197-212.

Emery, F. (2016), "Characteristics of socio-technical systems", *The Social Engagement of Social Science, a Tavistock Anthology*, Vol. 2, pp. 157-186.

Euronews (2022), "Extreme poverty drives Afghans to sell vital organs to feed families", available at: www.euronews.com/2022/01/12/extreme-poverty-drives-afghans-to-sell-vital-organs-to-feed-families (accessed 25 February 2023).

Feeley, T.H. and Kruegler, J. (2015), "Promoting organ donation through challenge campaigns", *Progress in Transplantation*, Vol. 25 No. 2, pp. 176-181.

Feldman, A.G., Marsh, R., Kempe, A. and Morris, M.A. (2020), "Barriers to Pretransplant immunization: a qualitative

interview study of Pediatric solid organ transplant stakeholders", *The Journal of Pediatrics*, Vol. 227, pp. 60-68.

Fisher, A., Wallis, S., Hassall, O., Martin, R. and Bates, I. (2020), "Collaborations on blood transfusion research in Sub-Saharan Africa: who, what and where", *Vox Sanguinis*, Vol. 115 No. 3, pp. 221-232.

Frei, R., Ibrahim, S. and Akenroye, T. (2022), *"Africa and Sustainable Global Value Chains''*, Springer, Cham, doi: 10.1007/978-3-030-78791-2.

Gattorna, J. and Pasmore, W. (2022), "Supply chains as dynamic socio-technical systems", *Handbook of Theories for Purchasing, Supply Chain and Management Research*, Chapter 31 Edward Elgar Publishing, London, pp. 491-501.

George, G.L. (1980), "Structural modeling – a tutorial guide", *IEEE Transactions on Systems, Man and Cybernetics*, Vol. 5 No. 12, pp. 807-840.

Ghose, T.K., Deo, J., Dutt, V., Agarwal, R., Patel, B.B., Ganesh, M. and Singh, H. (2021), "Knowledge and attitude towards organ donation: a study among medical and nursing students of a medical college", *International Journal of Community Medicine and Public Health*, Vol. 8 No. 11, pp. 5398-5403.

Global Observatory on Donation and Transplantation (2016), "WHO-ONT (world health organization (WHO) and the Spanish transplant organization, organización nacional de trasplantes (ONT))", available at: www.transplant-observatory. org/ (accessed 10th October, 2022).

Goli, A., Ala, A. and Mirjalili, S. (2022), "A robust possibilistic programming framework for designing an organ transplant supply chain under uncertainty", *Annals of Operations Research*, Vol. 2022, pp. 1-38.

Hackmann, M., English, R.A., Kizer, K.W. and National Academies Of Sciences, Engineering, and Medicine. (2022), "Confronting and eliminating inequities in the organ transplantation system", *Realizing the Promise of Equity in the Organ Transplantation System*, National Academies Press, Washington, DC.

Hindi, Z., Congly, S., Tang, E., Skaro, A. and Brahmania, M. (2020), "Liver transplant tourism", *Liver Transplantation*, Vol. 26 No. 2, pp. 276-282.

Howard, D.H. and Byrne, M.M. (2007), "Should we promote organ donor registries when so few registrants will end up being donors?", *Medical Decision Making*, Vol. 27 No. 3, pp. 243-249.

Human Tissue Authority (HTA) (2022), "Organ trafficking: modern day slavery", available at: www.hta.gov.uk/ guidance-professionals/regulated-sectors/organ-donation-and-transplantation/living-organ-donation-2 (accessed 11th January 2023).

INTERPOL (2021), "North and West Africa: INTERPOL report highlights human trafficking for organ removal", available at: www.interpol.int/en/News-and-Events/News/ 2021/North-and-West-Africa-INTERPOL-report-highlights-human-trafficking-for-organ-removal (accessed 11th November 2022).

Iqbal, A. and Khan, A. (2022), "Killing prisoners for transplants: forced organ harvesting in China", *The Conversation, Published: July 28, 2022*, available at: https://theconversation.com/killing-prisoners-for-transplants-forced-organ-harvesting-in-china-16 1999 (accessed 30th July 2022).

Ivanov, D., Dolgui, A. and Sokolov, B. (2019), "The impact of digital technology and industry 4.0 on the ripple effect and supply chain risk analytics", *International Journal of Production Research*, Vol. 57 No. 3, pp. 829-846.

Janssen, M., Rana, N.P., Slade, E.L. and Dwivedi, Y.K. (2018), "Trustworthiness of digital government services: deriving a comprehensive theory through interpretive structural modelling", *Public Management Review*, Vol. 20 No. 5, pp. 647-71.

Kargar, B., Pishvaee, M.S., Jahani, H. and Sheu, J.B. (2020), "Organ transportation and allocation problem under medical uncertainty: a real case study of liver transplantation", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 134, p. 101841.

Kartoglu, U. and Milstien, J. (2014), "Tools and approaches to ensure quality of vaccines throughout the cold chain", *Expert Review of Vaccines*, Vol. 13 No. 7, pp. 843-54.

Kassab, H.S. and Rosen, J.D. (2019), "Human and organ trafficking", *Illicit Markets, Organized Crime, and Global Security''*, Palgrave Macmillan, Cham, pp. 111-135.

Kaze, A.D., Ilori, T., Jaar, B.G. and Echouffo-Tcheugui, J.B. (2018), "Burden of chronic kidney disease on the African continent: a systematic review and meta-analysis", *BMC Nephrology*, Vol. 19 No. 1, pp. 1-11.

Kelly, S., Wagner, B. and Ramsay, J. (2018), "Opportunism in buyer–supplier exchange: a critical examination of the concept and its implications for theory and practice", *Production Planning & Control*, Vol. 29 No. 12, pp. 992-1009.

Kim, S., Mabin, V.J. and Davies, J. (2008), "The theory of constraints thinking processes: retrospect and prospect", *International Journal of Operations & Production Management*, Vol. 28 No. 2, pp. 155-184.

Klijn, E.H. and Koppenjan, J.F. (2006), "Institutional design: changing institutional features of networks", *Public Management Review*, Vol. 8 No. 1, pp. 141-160.

Koizumi, N., DasGupta, D., Patel, A.V., Smith, T.E., Mayer, J.D., Callender, C. and Melancon, J.K. (2015), "Geographic variation in cold ischemia time: kidney versus liver transplantation in the United States, 2003 to 2011", *Transplantation Direct*, Vol. 1 No. 7, p. e27.

Kritchanchai, D., Hoeur, S. and Engelseth, P. (2018), "Develop a strategy for improving healthcare logistics performance", *Supply Chain Forum: An International Journal*, Vol. 19 No. 1, pp. 55-69.

Kull, T.J., Ellis, S.C. and Narasimhan, R. (2013), "Reducing behavioral constraints to supplier integration: a socio-technical systems perspective", *Journal of Supply Chain Management*, Vol. 49 No. 1, pp. 64-86.

Kumar, S., Raut, R.D., Narwane, V.S., Narkhede, B.E. and Muduli, K. (2022), "Implementation barriers of smart technology in Indian sustainable warehouse by using a Delphi-ISM-ANP approach", *International Journal of Productivity and Performance Management*, Vol. 71 No. 3, pp. 696-721.

Leavitt, H.J. (1965), "Applied organizational change in industry; structural, technological and humanistic approaches", in March, J.G. (Ed.), *Handbook of Organizations*, Rand McNally & Company, Chicago, pp. 1144-1170.

Leavitt, H.J. (2013), "Applied organizational change in industry: structural, technological and humanistic

approaches", in *Handbook of Organizations*, Routledge, London, pp. 2976-3045.

Lee, L.Y., Pham, T.A. and Melcher, M.L. (2019), "Living kidney donation: strategies to increase the donor Pool", *Surgical Clinics of North America*, Vol. 99 No. 1, pp. 37-47.

Lewis, A., Koukoura, A., Tsianos, G.I., Gargavanis, A.A., Nielsen, A.A. and Vassiliadis, E. (2021), "Organ donation in the US and Europe: the supply vs demand imbalance", *Transplantation Reviews*, Vol. 35 No. 2, p. 100585.

Lugada, E., Komakech, H., Ochola, I., Mwebaze, S., Olowo Oteba, M. and Okidi Ladwar, D. (2022), "Health supply chain system in Uganda: current issues, structure, performance, and implications for systems strengthening", *Journal of Pharmaceutical Policy and Practice*, Vol. 15 No. 1, pp. 1-11.

Lyytinen, K. and Newman, M. (2008), "Explaining information systems change: a punctuated socio-technical change model", *European Journal of Information Systems*, Vol. 17 No. 6, pp. 589-613.

McKay, S.C., Lembach, H., Hann, A., Okoth, K., Anderton, J., Nirantharakumar, K. and Hartog, H. (2021), "Health-related quality of life, uncertainty and coping strategies in solid organ transplant recipients during shielding for the COVID-19 pandemic", *Transplant International*, Vol. 34 No. 11, pp. 2122-2137.

Mandal, A. and Deshmukh, S.G. (1994), "Vendor selection using interpretive structural modelling (ISM)", *International Journal of Operations & Production Management*, Vol. 14 No. 6, pp. 52-59.

Massie, A.B., Kuricka, L.M. and Segev, D.L. (2014), "Big data in organ transplantation: registries and administrative claims", *American Journal of Transplantation*, Vol. 14 No. 8, pp. 1723-1730.

Matching Donors (2023), "Paired exchange program", available at: https://matchingdonors.com/life/index.cfm?page=p030 (accessed 15 November 2022).

Mendes, K.D.S., Roza, B.D.A., Barbosa, S.D.F.F., Schirmer, J. and Galvão, C.M. (2012), "Organ and tissue transplantation: responsibilities of nurses", *Texto & Contexto - Enfermagem*, Vol. 21 No. 4, pp. 945-953.

Michel, S.G., LaMuraglia Ii, G.M., Madariaga, M.L.L. and Anderson, L.M. (2015), "Innovative cold storage of donor organs using the paragonix sherpa pak^{TM} devices", *Heart, Lung and Vessels*, Vol. 7 No. 3, p. 246.

Misra, A., Saranga, H. and Tripathi, R.R. (2022), "Channel choice and incentives in the cadaveric organ supply chain", *European Journal of Operational Research*, Vol. 302 No. 3, pp. 1202-1214.

Molnar, A.O., Fergusson, D., Tsampalieros, A.K., Bennett, A., Fergusson, N., Ramsay, T. and Knoll, G.A. (2015), "Generic immunosuppression in solid organ transplantation: systematic review and meta-analysis", *BMJ*, Vol. 350 No. jun22 4, p. h3163.

Morgan, J., Wannemuehler, K.A., Marr, K.A., Hadley, S., Kontoyiannis, D.P., Walsh, T.J., Fridkin, S.K., Pappas, P. G. and Warnock, D.W. (2005), "Incidence of invasive aspergillosis following hematopoietic stem cell and solid organ transplantation: interim results of a prospective multicenter surveillance program", *Medical Mycology*, Vol. 43 No. Supplement 1, pp. S49-S58.

Mujinga, M., Eloff, M.M. and Kroeze, J.H. (2019), "Towards a framework for online information security applications development: a socio-technical approach", *South African Computer Journal*, Vol. 31 No. 1, pp. 24-50.

Naicker, S., Eastwood, J.B., Plange-Rhule, J. and Tutt, R.C. (2010), "Shortage of healthcare workers in Sub-Saharan Africa: a Nephrological perspective", *Clinical Nephrology*, Vol. 74, pp. S129-33.

Naranjo, F., Menor, L.J. and Johnson, P.F. (2023), "Lean supply chain management: a contextual contingent reconceptualization and Delphi method study", *International Journal of Operations & Production Management*, doi: 10.1108/IJOPM-07-2022-0436.

National Health Portal (2015), "Organ donation day", available at: www.nhp.gov.in/Organ-Donation-Day_pg (accessed 11th November 2022).

National Health Service (NHS) (2022), "Organ donation and transplantation", available at: www.nhsbt.nhs.uk/what-we-do/transplantation-services/organ-donation-and-transplantation/ (accessed 9th November 2022).

Net, M., Valero, R., Almenara, R., Deulofeu, R., López-Boado, M.A., Capdevila, L., Barros, P., Bombí, J.A., Agustí, M., Adalia, R. and Ruiz, A. (2003), "Hepatic preconditioning after prolonged warm ischemia by means of S-adenosyl-L-methionine administration in pig liver transplantation from non-heart-beating donors", *Transplantation*, Vol. 75 No. 12, pp. 1970-1977.

Noyes, J., Mclaughlin, L., Morgan, K., Roberts, A., Stephens, M., Bourne, J. and Walton, P. (2019), "Designing a co-productive study to overcome known methodological challenges in organ donation research with bereaved family members", *Health Expectations*, Vol. 22 No. 4, pp. 824-835.

Oguejiofor, F., Kiggundu, D.S., Bello, A.K., Swanepoel, C.R., Ashuntantang, G., Jha, V. and Board, I.A.R. (2021), "International society of nephrology global kidney health atlas: structures, organization, and services for the management of kidney failure in Africa", *Kidney International Supplements*, Vol. 11 No. 2, pp. e11-e23.

Ogus, A.I. (2007), "Regulatory arrangements and incentives for opportunistic behaviour", in Elger, T., Faure, M., Naigen, Z., (Eds), *Economic Analysis of Law in China*, Chapter 6 Edward Elgar, London, pp. 151-163.

Olu, O., Muneene, D., Bataringaya, J.E., Nahimana, M.R., Ba, H., Turgeon, Y. and Dovlo, D. (2019), "How can digital health technologies contribute to sustainable attainment of universal health coverage in Africa? A perspective", *Frontiers in Public Health*, Vol. 7, p. 341.

Olutuase, V.O., Iwu-Jaja, C.J., Akuoko, C.P., Adewuyi, E.O. and Khanal, V. (2022), "Medicines and vaccines supply chains challenges in Nigeria: a scoping review", *BMC Public Health*, Vol. 22 No. 1, pp. 1-15.

Orens, J.B., Estenne, M., Arcasoy, S., Conte, J.V., Corris, P., Egan, J.J., Egan, T., Keshavjee, S., Knoop, C., Kotloff, R. and Martinez, F.J. (2006), "International guidelines for the selection of lung transplant candidates: 2006 update – a consensus report from the pulmonary scientific council of the international society for heart and lung transplantation", *The Journal of Heart and Lung Transplantation*, Vol. 25 No. 7, pp. 745-755.

Oyedijo, A. (2022), "Firms from rich countries are taking factories home: what this means for Africa", *The Conversation*, Published: June 23, 2022, available at: https://theconversation.com/firms-from-rich-countries-are-taking-factories-home-what-this-means-for-africa-185456 (accessed 24th June 2022).

Oyedijo, A., Adams, K. and Koukpaki, S. (2021), "Supply chain management systems in Africa: insights from Nigeria", in Abugre, J.B., LC Osabutey, E., Sigué, S. (Eds), *Business in Africa in the Era of Digital Technology. Advances in Theory and Practice of Emerging Markets*, Springer, Cham, doi: 10.1007/978-3-030-70538-1.

Oyedijo, A., Francois Koukpaki, A.S., Kusi-Sarpong, S., Alfarsi, F. and Yang, Y. (2022), "Restraining forces and drivers of supply chain collaboration: evidence from an emerging market", *Supply Chain Management: An International Journal*, Vol. 27 No. 3, pp. 409-430.

Panahifar, F., Byrne, P.J. and Heavey, C. (2015), "A hybrid approach to the study of CPFR implementation enablers", *Production Planning & Control*, Vol. 26 No. 13, pp. 1090-1109.

Parada-Contzen, M. and Vásquez-Lavín, F. (2019), "An analysis of economic incentives to encourage organ donation: evidence from Chile", *Latin American Economic Review*, Vol. 28 No. 1, pp. 1-18.

Prabhu, P.K. (2019), "Is presumed consent an ethically acceptable way of obtaining organs for transplant?", *Journal of the Intensive Care Society*, Vol. 20 No. 2, pp. 92-97.

Pullen, L.C. (2019), "Tackling the growing problem of transporting organs", *American Journal of Transplantation*, Vol. Vol. 19 No. 6, pp. 1603-1604.

Purohit, B., Maneskar, A. and Saxena, D. (2016), "Developing a tool to assess motivation among health service providers working with public health system in India", *Human Resources for Health*, Vol. 14 No. 1, pp. 1-12.

Rabbani, M. and Talebi, E. (2019), "A comprehensive mathematical model for designing an organ transplant supply chain network under uncertainty", *International Journal of Engineering*, Vol. 32 No. 6, pp. 835-841.

Rahman, S. (1998), "Theory of constraints: a review of the philosophy and its applications", *International Journal of Operations & Production Management*, Vol. 18 No. 4, pp. 336-355.

Reuters (2022), "Ugandan lawmakers pass law to curb trade in human organs", available at: www.reuters.com/world/africa/ugandan-lawmakers-pass-law-curb-trade-human-organs-2022-09-29/ (accessed 23rd November 2022).

Ross, L.F. and Thistlethwaite, J.R. (2008), "Potential inefficiency of a proposed efficiency model for kidney allocation", *American Journal of Kidney Diseases*, Vol. 51 No. 4, pp. 545-548.

Salim, A., Brown, C., Inaba, K., Mascarenhas, A., Hadjizacharia, P., Rhee, P. and Demetriades, D. (2007), "Improving consent rates for organ donation: the effect of an inhouse coordinator program", *Journal of Trauma: Injury, Infection & Critical Care*, Vol. 62 No. 6, pp. 1411-1415.

Scalea, J.R., Pucciarella, T., Talaie, T., Restaino, S., Drachenberg, C.B., Alexander, C. and Scassero, M. (2021), "Successful implementation of unmanned aircraft use for delivery of a human organ for transplantation", *Annals of Surgery*, Vol. 274 No. 3, pp. e282-e288.

Shan, S., Shou, Y., Kang, M. and Park, Y. (2022), "The effects of socio-technical integration on sustainability practices: a supply chain perspective", *Industrial Management & Data Systems*, Vol. 122 No. 2, pp. 419-441.

Sharif, A. (2012), "Organ donation and Islam – challenges and opportunities", *Transplantation*, Vol. 94 No. 5, pp. 442-446.

Sharma, A., Abbas, H. and Siddiqui, M.Q. (2021), "Modelling the inhibitors of cold supply chain using fuzzy interpretive structural Modeling and fuzzy MICMAC analysis", *Plos One*, Vol. 16 No. 4, p. e0249046.

Shaw, D. (2018), "Presumed evidence in deemed consent to organ donation", *Journal of the Intensive Care Society*, Vol. 19 No. 1, pp. 2-3.

Shimazono, Y. (2007), "The state of the international organ trade: a provisional picture based on integration of available information", *Bulletin of the World Health Organization*, Vol. 85 No. 12, pp. 955-962.

Shroff, S. (2009), "Legal and ethical aspects of organ donation and transplantation", *Indian Journal of Urology*, Vol. 25 No. 3, pp. 348-355.

Simatupang, T.M., Wright, A.C. and Sridharan, R. (2004), "Applying the theory of constraints to supply chain collaboration", *Supply Chain Management: An International Journal*, Vol. 9 No. 1, pp. 57-70.

Singh, R.K. (2011), "Developing the framework for coordination in supply chain of SMEs", *Business Process Management Journal*, Vol. 17 No. 4, pp. 619-638.

Smith, A. (2012), "Medical tourism and organ trafficking", *African Journal of Hospitality, Tourism and Leisure*, Vol. 2 No. 1, pp. 1-9.

Soliman, M., Saurin, T.A. and Anzanello, M.J. (2018), "The impacts of lean production on the complexity of socio-technical systems", *International Journal of Production Economics*, Vol. 197, pp. 342-357.

Spearman, C.W.N. and McCulloch, M.I. (2014), "Challenges for paediatric transplantation in Africa", *Pediatric Transplantation*, Vol. 18 No. 7, pp. 668-674.

Stewart, D. (2021), "Moving toward continuous organ distribution", *Current Transplantation Reports*, Vol. 8 No. 4, pp. 1-13.

Stewart, D.E., Kucheryavaya, A.Y., Klassen, D.K., Turgeon, N., Formica, R.N. and Aeder, M.I.A. (2016), "Changes in deceased donor kidney transplantation one year after KAS implementation", *American Journal of Transplantation*, Vol. 16 No. 6, pp. 1834-1847.

Stranks, J.W. (2007), *Human Factors and Behavioural Safety*, Elsevier, Burlington, MA.

Taylor, J.S. (2006), "Black markets, transplant kidneys and interpersonal coercion", *Journal of Medical Ethics*, Vol. 32 No. 12, pp. 698-701.

The Guardian (2012), "Illegal kidney trade booms as new organ is 'sold every hour", available at: www.theguardian.com/world/2012/may/27/kidney-trade-illegal-operations-who (accessed 9th November 2022).

The Guardian (2023), "Nigerian politician, wife, and a doctor guilty of organ trafficking to UK", available at: www.theguardian.com/uk-news/2023/mar/23/nigerian-politician-wife-doctor-guilty-organ-trafficking-uk-ike-ekweremadu (accessed 24th March 2023).

Thomson, D. (2017), "Organ donation in South Africa-a call to action", *Southern African Journal of Critical Care*, Vol. 33 No. 2, pp. 36-37.

Thorne, E.D. (1998), "The shortage in market-inalienable human organs: a consideration of 'nonmarket' failures", *American Journal of Economics and Sociology*, Vol. 57 No. 3, pp. 247-260.

Ulasi, I., Ijoma, C., Ifebunandu, N., Arodiwe, E., Ijoma, U., Okoye, J. and Onodugo, O. (2020), "Organ donation and transplantation in Sub-Saharan Africa: opportunities and challenges", in Mihaylov, V. (Ed.), *Organ Donation and Transplantation*, IntechOpen, London.

United Nations (UN) (2022), "World population prospects 2022", available at: https://population.un.org/wpp/ (accessed 15th October 2022).

Vanholder, R., Domínguez-Gil, B., Busic, M., Cortez-Pinto, H., Craig, J.C., Jager, K.J. and Oniscu, G.C. (2021), "Organ donation and transplantation: a multi-stakeholder call to action", *Nature Reviews Nephrology*, Vol. 17 No. 8, pp. 554-568.

Vishnu, C.R., Sridharan, R., Kumar, P.R. and Kumar, V.R. (2020), "Analysis of the operational risk factors in public hospitals in an Indian state: a hybrid DEMATEL–ISM–PROMETHEE approach", *International Journal of Health Care Quality Assurance*, Vol. 33 No. 1, pp. 67-88.

Vlachos, I. (2021), "Implementation of an intelligent supply chain control tower: a socio-technical systems case study", *Production Planning & Control*, pp. 1-17.

Vreugdenhil, P.K., Belzer, F.O. and Southard, J.H. (1991), "Effect of cold storage on tissue and cellular glutathione", *Cryobiology*, Vol. 28 No. 2, pp. 143-149.

Warfield, J.N. (1974), "Developing interconnection matrices in structural modeling", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-4 No. 1, pp. 81-87.

Warsi, Z. (2023), "In Nepal's 'kidney valley,' poverty drives an illegal market for human organs", *PBS News Hour*, Published January 17, 2023, available at: www.pbs.org/newshour/world/in-nepals-kidney-valley-poverty-drives-an-illegal-market-for-human-organs (accessed 23rd March 2023).

Weimer, D.L. (2010), "Stakeholder governance of organ transplantation: a desirable model for inducing evidence-based medicine?", *Regulation & Governance*, Vol. 4 No. 3, pp. 281-302.

West Cape Government (2022), "Organ donation in South Africa", available at: www.westerncape.gov.za/general-publication/organ-donation-south-africa (accessed on 14th October 2022).

Wey, A., Salkowski, N., Kremers, W.K., Schaffhausen, C.R., Kasiske, B.L., Israni, A.K. and Snyder, J.J. (2018), "A kidney offer acceptance decision tool to inform the decision to accept an offer or wait for a better kidney", *American Journal of Transplantation*, Vol. Vol. 18 No. 4, pp. 897-906.

Williamson, L.D., Bigman, C.A. and Quick, B.L. (2019), "A qualitative examination of African Americans' organ donation-related medical mistrust beliefs", *Howard Journal of Communications*, Vol. 30 No. 5, pp. 430-445.

Woan, S. (2007), "Buy me a pound of flesh: china's sale of death row organs on the black market and what Americans can learn from it", *Santa Clara Law Review*, Vol. 47, p. 413.

Wood, N.L., VanDerwerken, D.N., Segev, D.L. and Gentry, S.E. (2022), "Logistical burden of offers and allocation inefficiency in circle-based liver allocation", *Liver Transplantation*, Vol. 29 No. 1, pp. 1-8, doi: 10.1002/lt.26527.

Woodburn, P.A. (2013), "Analysis of challenges of medical supply chains in Sub-Saharan Africa regarding inventory management and transport and Distribution", MSc Thesis (Unpublished), University of Westminster, London Westminster Business School.

World Health Organisation (WHO) (2020), "Regional Committee for Africa, 70. (2020). status of human organ and tissue donation and transplantation in the WHO African region: report of the secretariat. World health organization. Regional Office for Africa", available at: https://apps.who.int/iris/handle/10665/333715 (accessed 10th October 2022).

Yadav, P. (2015), "Health product supply chains in developing countries: diagnosis of the root causes of underperformance and an agenda for reform", *Health Systems & Reform*, Vol. 1 No. 2, pp. 142-154.

Yoon, S. (2018), "Black market trade of human organs in China and its implications for global Governance", *Illicit Industries and China's Shadow Economy*, Routledge, London, pp. 46-64.

Zahiri, B., Tavakkoli-Moghaddam, R., Mohammadi, M. and Jula, P. (2014), "Multi-objective design of an organ transplant network under uncertainty", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 72, pp. 101-124.

Zhang, Q. and Cao, M. (2018), "Exploring antecedents of supply chain collaboration: effects of culture and interorganizational system appropriation", *International Journal of Production Economics*, Vol. 195, pp. 146-157.

Further reading

Oglethorpe, D. and Heron, G. (2013), "Testing the theory of constraints in UK local food supply chains", *International Journal of Operations & Production Management*, Vol. 33 No. 10, pp. 1346-1367.

Corresponding author

Temidayo O. Akenroye can be contacted at: takenroye@umsl.edu