CRANFIELD UNIVERSITY

LULUK LUSIANTORO

# A COLLECTIVE MINDFULNESS PERSPECTIVE OF INFORMATION SHARING IN THE BLOOD SUPPLY CHAIN

SCHOOL OF MANAGEMENT
PhD in Logistics and Supply Chain Management

PhD
Academic Year: 2014 - 2018

Supervisor: Dr. Nicky Yates
Associate Supervisor: Prof. Liz Varga
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# ABSTRACT

**Purpose:** This thesis aims to determine and unravel the underlying mechanisms of how inter-organisational information sharing influences blood safety and availability in the dyadic blood supply chain in normal, high tempo, and emergency conditions.

**Design/methodology/approach:** Grounded in the critical realism paradigm and the perspective of high reliability theory particularly the collective mindfulness concept, this thesis uses an embedded multiple case study designed for theory elaboration. A combined retroductive-abductive and the basic qualitative description has been adopted as a research strategy. Two contrasting cases with three embedded cases for each main case are selected using convenient and context-based approaches, representing a centralised and tightly regulated blood supply chain in the UK as well as a decentralised and loosely regulated blood supply chain in Indonesia. The data are collected using the triangulation of semi-structured interviews, walkthroughs, and other supporting documents including artefacts and archives. Template analysis coupled with within-case and cross-case analyses are then used to analyse the data.

**Findings:** This thesis finds that inter-organisational information sharing influences blood safety and availability through the dynamic enactments of collective mindfulness principles that reflect the inter-organisational information sharing behaviour across the operational conditions. It also finds that the blood supply chain actors in the centralised and tightly regulated context are collectively more mindful when sharing information than those in the decentralised and loosely regulated context, so that more positive changes in the blood safety and availability performance are observed in the former compared to that in the latter context. Interestingly, whilst the data reveal an emerging mechanism of *heedful interrelating* across a range of operational conditions, this thesis also reveals the fact that inter-organisational information sharing does not necessarily lead to positive changes in blood safety and availability. In fact, negatively enacted collective mindfulness principles can lead inter-organisational information sharing to unimproved and even potentially worse blood safety and availability performance.

**Originality/value:** The primary contribution of this thesis lies in understanding the underlying mechanisms of how inter-organisational information sharing influences blood safety and availability in the dyadic blood supply chain across a range of operational conditions. Whilst offering practical and conceptually relevant knowledge to the blood supply chain literature, it informs the wider supply chain literature on the different collective mindfulness principles that make inter-organisational information sharing influence supply chain performance across a range of operational conditions. The use of the collective mindfulness concept offers a novel perspective that extends the current discussion on the effectiveness of that information sharing for supply chains.

Keywords: critical realism, high reliability theory, case study, theory elaboration, retroductive-abductive strategy, qualitative description, template analysis

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AR | Archive |
| ARTF | Artefact |
| BBTS | British Blood Transfusion Society |
| BC | Blood Centre |
| BDRS | Bank Darah Rumah Sakit – The Hospital Blood Bank |
| BSA | Blood Safety and Availability |
| BSC | Blood Supply Chain |
| BSMS | Blood Stocks Management Scheme |
| CIMO | Context Intervention Mechanism Outcome |
| CKD | Chronic Kidney Disease |
| CM | Collective Mindfulness |
| CR | Commitment to Resilience |
| DCMT | Document |
| DE | Deference to Expertise |
| DH | Department of Health |
| E | Emergency |
| EC | Embedded Case |
| ECR | Efficient Consumer Response |
| EDI | Electronic Data Interchange |
| EDN | Electronic Dispatch Note |
| ELA | European Logistics Association |
| EK | Excluding Keywords |
| ERP | Enterprise Resource Planning |
| FFP | Fresh Frozen Plasma |
| FIFO | First In First Out |
| H | Hospital |
| HBV | Hepatitis B Virus |
| HCV | Hepatitis C Virus |
| HD | Haemodialysis |
| HDFN | Haemolytic Disease of the Fetus and Newborn |
| HEV | Hepatitis E Virus |
| HI | Heedful Interrelating |

| | |
|---|---|
| HIV | Human Immunodeficiency Virus |
| HRO | High Reliability Organisation |
| HRT | High Reliability Theory |
| HT | High Tempo |
| ID | Identification |
| INT | Interview |
| IOIS | Inter-organisational Information Sharing |
| IT | Information Technology |
| ITS | Integrated Transfusion Services |
| KPI | Key Performance Indicator |
| LIMS/PULSE | Laboratory Information Management System |
| MC | Main Case |
| MHRA | Medicines and Healthcare products Regulatory Agency |
| MoU | Memorandum of Understanding |
| N | Normal |
| NAT | Normal Accident Theory |
| NBB | No Blood Bank |
| NBTC | National Blood Transfusion Committee |
| neg | Negative |
| NHS | National Health Service |
| NHSBT | National Health Service Blood and Transplant |
| OBOS | Online Blood Ordering System |
| OB-GYN | Obstetrics and Gynaecology |
| OSCM | Operations and Supply Chain Management |
| PBM | Patient Blood Management |
| PF | Preoccupation with Failure |
| PLT | Platelets |
| PMA | Product Movement Analysis |
| PMI | Palang Merah Indonesia – Indonesian Red Cross |
| pos | Positive |
| POS | Point of Sales |
| PPSC | Perishable Product Supply Chain |
| QM | Quality Management |

| | |
|---|---|
| RBC | Red Blood Cell |
| RBTC | Regional Blood Transfusion Committee |
| RFID | Radio Frequency Identification |
| RS | Reluctance to Simplify |
| SaBTO | Safety of Blood, Tissues, and Organs |
| SABRE | Serious Adverse Blood Reactions and Events |
| SC | Supply Chain |
| SCM | Supply Chain Management |
| SCRR | Supply Chain Risk and Resilience |
| SHOT | Serious Hazards of Transfusion |
| SLR | Systematic Literature Review |
| SMS | Short Message Service |
| SNBTS | Scottish National Blood Transfusion Service |
| SO | Sensitivity to Operations |
| SOP | Standard Operating Procedure |
| Sp-ICE | Specialist Services electronic reporting using Sunquest's Integrated Clinical Environment |
| SS | Search Strings |
| TLM | Transfusion Laboratory Manager |
| TP | Transfusion Practitioner |
| TQM | Total Quality Management |
| TV | Television |
| UK | United Kingdom |
| VANESA | Online Blood Stock, Usage, and Wastage Reporting System |
| VMI | Vendor Managed Inventory |
| WHO | World Health Organization |
| WT | Walkthrough |

# 1 INTRODUCTION

In this chapter, to give a general understanding of the research context, an introduction to the blood supply chain (BSC) is presented. Practical and research problems with identified research gaps are then described, followed a summary of the proposed research, findings and contributions. Finally, the structure of this thesis is outlined.

## 1.1 Introduction to the blood supply chain

Blood is a precious resource that is critical for the human body. It is administered to patients and separated into its constituent components, each of which has different properties. For example, red blood cells (RBCs) are very important for the treatment of all kinds of anaemia and to replace heavy blood loss in emergencies. RBCs contain haemoglobin, distributing oxygen to body tissues and carrying carbon dioxide back to the lungs as a waste product. Platelets (PLTs) help blood to clot and are critical to stop bleeding after injuries. Fresh frozen plasma (FFP) contains a large number of substances and proteins which are essential for medical procedures and help protect the body from infections (NHSBT, 2018a). Blood is also perishable. Whilst typical FFP has more than one year's shelf life, RBCs and PLTs, which have higher demand, only have 35 days and seven days of shelf life respectively. Special storage conditions and a coordinated supply chain (SC) are therefore required to keep them always in a high quality for patients (see Turnbull, 1989; Van Donselaar *et al.*, 2006).

In the United Kingdom (UK) particularly in England, for example, the supply of whole blood typically comes from voluntary donors who can regularly donate their blood every 12-16 weeks through dedicated blood donation centres or mobile blood collections. Once collected, the whole blood donations are transported to blood centres to be sorted and registered. They are then sent to the manufacturing area to be separated and extracted into component parts (i.e. RBCs, PLTs, FFP) and subsequently stored and quarantined in temperature controlled holding areas until all required testing is completed.

Meanwhile, the blood samples are tested to confirm the donors' blood groups, which are generally classified into eight specific groups: $O^+$, $O^-$, $A^+$, $A^-$, $B^+$, $B^-$, $AB^+$, and $AB^-$. The testing is also performed to screen for viruses and other infections to ensure that the blood donations are safe for transfusion to patients (NHSBT, 2018b). WHO (2017a) mandates that, prior to use, the blood should at least be screened for human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), and syphilis. The completed testing means that the blood components are safe, ready to be labelled, stored, and delivered to hospitals.

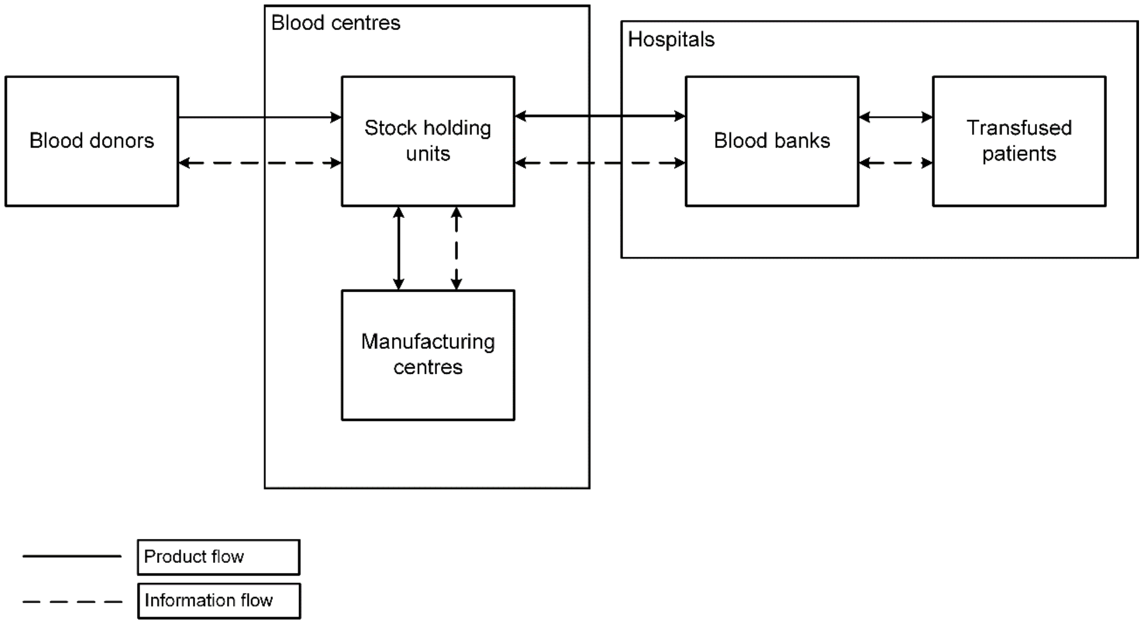


**Figure 1-1: General and simplified BSC processes**
**Source: adapted from NHSBT (2018b) and Dobbin *et al*. (2009)**

The management of blood products in hospitals follows several processes. Depending on the operational conditions, hospitals can place regular, *ad hoc*, or blue light (emergency) orders to replenish their stocks or obtain blood components as quickly as possible for patients in need. Grouping and testing are also conducted in hospitals to "cross-match" patients' blood groups with the blood taken from stock or urgently ordered from the associated blood centre. This ensures that the blood transfused to the patients is compatible, preventing serious reactions to transfusion, which could lead to fatal consequences. Blood products with quality issues or which cause incidents such as severe reactions to transfusion can be recalled and returned to the blood centre for further investigation. Figure 1-1 on page 2 illustrates the general and simplified BSC processes from donors to patients.

## 1.2 Practical problem in the BSC: research gap 1

Given the perishability and criticality of blood products for human life, ensuring blood safety and availability (BSA) remains a perennial challenge (e.g. Rautonen, 2007; WHO, 2017a; Williamson and Devine, 2013). Blood safety and availability are inseparable. Blood safety is a prerequisite of blood transfusion which should not be undertaken if the available blood is damaged and/or contaminated by infectious disease. Stockouts of blood products delay transfusions and operations affecting patients' lives, whilst outdated blood leads to wastage resulting in increased costs. Reliable operations are therefore required to ensure that blood products are always safe and available across a range of operational conditions, ensuring more lives are saved during normal, high tempo, and emergency operations whilst minimising wastage across the blood supply chain (BSC).

**Table 1-1: Prevalence of transfusion-transmissible infections in blood donations**

| Country classification | Measures | HIV | HBV | HCV | Syphilis |
|---|---|---|---|---|---|
| High-income countries | Median | 0.00% | 0.03% | 0.02% | 0.05% |
| | Interquartile range | (0.001% – 0.04%) | (0.008% – 0.18%) | (0.003% – 0.16%) | (0.005% – 0.26%) |
| Upper middle-income countries | Median | 0.08% | 0.39% | 0.21% | 0.31% |
| | Interquartile range | (0.006% – 0.2%) | (0.16% – 0.69%) | (0.05% – 0.42%) | (0.12% – 1.07%) |
| Lower middle-income countries | Median | 0.20% | 1.60% | 0.40% | 0.58% |
| | Interquartile range | (0.05% – 0.44%) | (0.94% – 4.13%) | (0.19% – 1.5%) | (0.18% – 1.47%) |
| Low-income countries | Median | 1.08% | 3.70% | 1.03% | 0.90% |
| | Interquartile range | (0.56% – 2.69%) | (3.34% – 8.47%) | (0.67% – 1.80%) | (0.31% – 1.88%) |

**Source: WHO (2017a)**

Concerning blood safety problem, World Health Organization (WHO) (2017a) reports that transfusion-transmissible infections, i.e. human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), and syphilis viruses, are still found in the blood donated all over the world with higher prevalence in low-income and lower middle-income countries (Table 1-1 on page 3). In some countries, this problem has been linked to the lack of regulation and compliance with the blood safety and quality standard (WHO, 2017a). This is indicated by the fact that only 68% of countries reporting to the WHO Global Database on Blood Safety have a national blood policy, whereas only 58% of reporting countries have specific regulation about safety and quality of the blood transfusion, consisting of 79% of high-income, 64% of middle-income, and 41% of low-income countries (WHO, 2017a).

Besides blood safety, blood availability also remains a persistent problem in some countries. The percentage of blood donation per population can be used as a proxy to indicate this problem. WHO (2017a) reveals that only 0.46% of the population in low-income countries and 0.78% of the population in lower middle-income countries donate blood. This percentage is far below their recommendation that to maintain blood availability, at least 1% of the total population of a country should regularly donate blood (WHO, 2017b).

Previous works have identified factors contributing to BSA problems from different angles. Figure 1-2 on page 5 shows the map of the contributing factors and how they are interrelated. The map was derived from a number of studies and reports that concern managing blood safety and availability across the BSC. The links between the contributing factors were established by matching the themes identified from the studies and reports. The factors can be further classified into five domains – donor management, blood management practices, patient blood management practices, cost-related factors, and information sharing. Donor management concerns managing donor-related activities upstream in the BSC. Blood management practices cover issues related to managing blood products across the BSC. Patient blood management practices deal with demand management of blood from patients. Cost-related factors cover any cost of providing blood safety and availability as well as the cost of implementing the information technology. Finally, information sharing facilitates the BSC actors to have visibility of activities and useful data across the BSC.

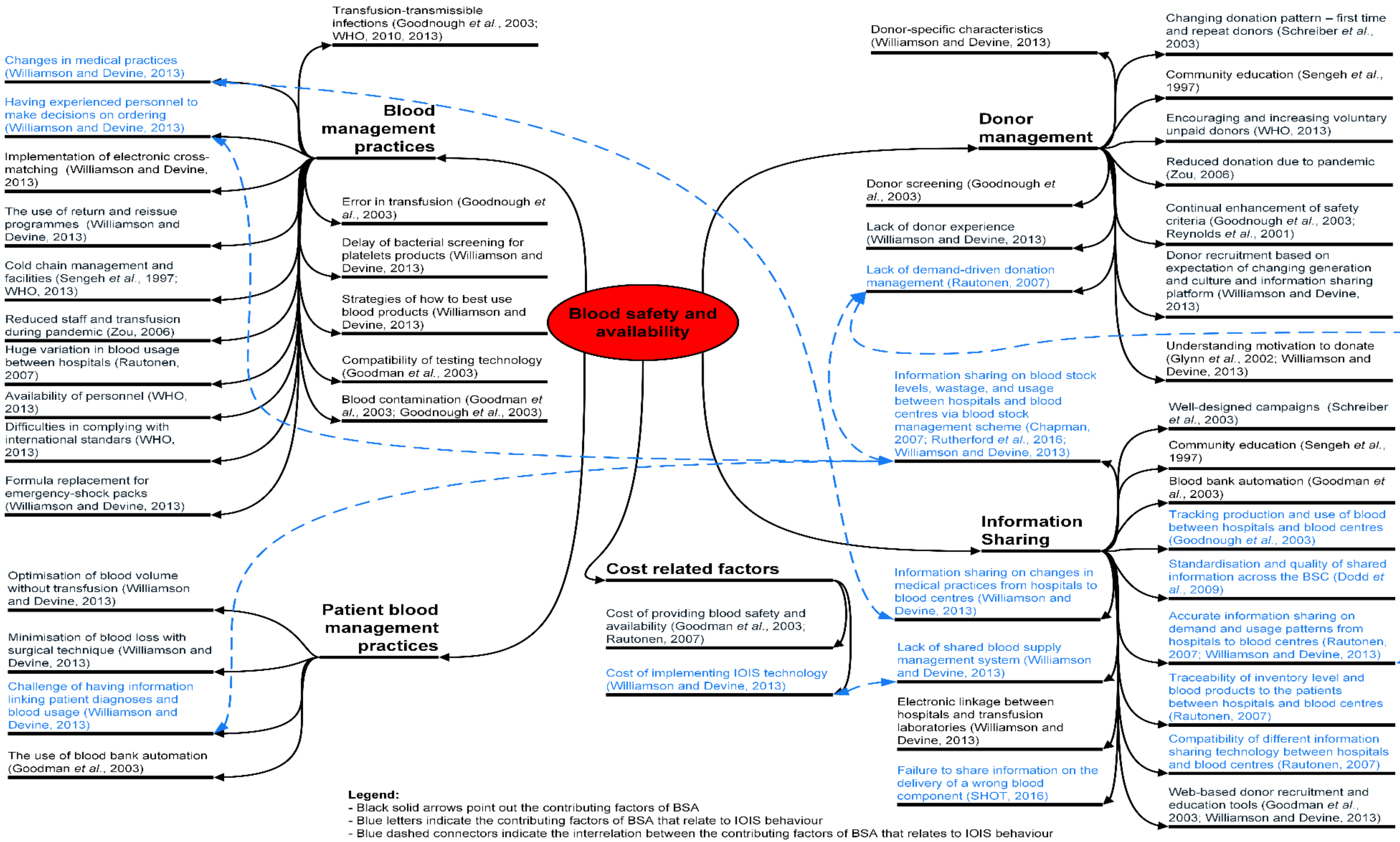


**Figure 1-2: Contributing factors of BSA problems**

Interestingly, despite the different angles to understand the BSA problems, the map shows the importance of inter-organisational information sharing (IOIS) as a common link between the contributing factors, thus it is the key to coordinating the BSC. Some previous examples of information sharing practices in the BSC context include sharing accurate information on demand, blood usage patterns, and inventory levels to maintain BSA across the BSC (Goodnough *et al*., 2003; Rautonen, 2007; Williamson and Devine, 2013). Sharing information on changes in medical practices and having real-time information linking patient diagnoses and blood usage can help the BSC actors understand the demand profile of blood products (Williamson and Devine, 2013). In addition, sharing information on blood inventory levels can help the BSC stabilise order patterns, and therefore improve blood availability and reduce wastage due to time expiry (Rutherford *et al*., 2016).

In fact, failure in IOIS is considered a notable incident in blood transfusion, which has been documented under the annual report of Serious Hazards of Transfusion (SHOT) – the UK independent and professionally-led surveillance scheme dedicated to document and share information on adverse events and reactions to blood transfusion from all healthcare organisations involved in blood transfusion. For example, a blood centre's failure to detect and share information with its associated hospital on the delivery of a wrong blood component caused serious harm in a patient receiving the wrong blood transfusion (SHOT, 2016). Improving IOIS practices is therefore necessary and is in line with WHO's (2017a) recommendations to improve BSA by integrating and coordinating blood transfusion services, monitoring the safety of transfusion processes, and reporting any adverse transfusion events across the BSC.

Despite the potential benefits, however, IOIS has attracted very little attention in the BSC literature, which has heavily focussed on inventory optimisation, supply management, and distribution scheduling of blood products (Beliën and Forcé, 2012). In addition, the relationship between IOIS and BSA across a range of operational conditions (i.e. in normal, high tempo, and emergency conditions) has not been explained in the BSC literature (see Beliën and Forcé, 2012). Further empirical research is therefore required to address this gap. A clear understanding of the relationship between IOIS and BSA will not only help the BSC actors address BSA problems, but also serve as a potential contribution to the BSC literature.

## 1.3 Lessons learnt from IOIS studies in supply chains: research gap 2

To address the above research gap, it is important to learn some lessons from inter-organisational information sharing (IOIS) studies in the wider supply chain (SC) literature. Despite the first work of relevance being undertaken by Forrester (1958), researchers are yet to reach a conclusive argument on the positive impacts of IOIS on SC performance. Whilst most studies agree that IOIS is beneficial for the SC (e.g. Cachon and Fisher, 2000; Fawcett *et al*., 2007; Lee *et al*., 1997, 2000; Lin *et al*., 2002; Sterman, 1989; Wu *et al*., 2014; Yu *et al*., 2001; Zhao *et al*., 2002), some studies reveal that IOIS does not necessarily improve SC performance (e.g. Cantor and Macdonald, 2009; Steckel *et al*., 2004; Zhao and Zhao, 2015) and that there is a lack of empirical evidence on the benefits of doing it for the SC (Kembro and Näslund, 2014). These contradictory arguments lead to a critical question: *how* does IOIS actually influence SC performance? In other words, what is it about IOIS which makes it influence SC performance?

The attempt to address the above question can be pointed to the work of Barratt and Oke (2007), Kochan *et al.* (2018), and Scholten and Schilder (2015), who posit that IOIS influences SC operational performance through the notion of visibility, which is characterised by the extent to which SC actors share or have access to quality information and to which the SC actors perceive the shared information as useful and meaningful. According to Barratt and Oke (2007), IOIS is only an activity; it is the high level of visibility in the SC that explains how IOIS leads to improved performance and therefore sustainable competitive advantage. Consequently, instead of merely sharing information, the SC actors should attempt to provide the high level of visibility as the co-action of IOIS (i.e. the action that happens together with the IOIS activity).

Zhao and Zhao (2015), however, suggest that visibility does not entirely explain how IOIS influences SC performance especially under unexpected conditions.

Providing access to quality and relevant information does not guarantee that SC actors will make sensible decisions and act according to expectation. They argue that mindfulness of SC actors may serve as a better mechanism to explain the phenomenon than visibility.

In general, mindfulness is about attentiveness to the organisational environment (Weick *et al.*, 1999). Mindful organisations are able to notice any changes in their environment and to swiftly and appropriately react to unexpected events that may affect them (Vogus and Sutcliffe, 2012). Zhao and Zhao (2015) argue that IOIS makes the SC actors mindful of their continuously changing environment, such as market demand. IOIS also allows them to pay more attention to their relationship with other SC actors and to the systematic performance across the SC (Zhao and Zhao, 2015). For example, continuous access to inventory information of other SC echelons increases the SC actors' attention to an unexpected operational condition, such as stockout. As a consequence, SC actors include the stockout of other SC echelons in their decision making process, making them aware that they should work together as a team to reduce the stockout (Zhao and Zhao, 2015).

In contrast, when the SC actors are mindless, sharing inventory information dictates their high expectation of suppliers' replenishment performance. Once the stockout occurs, the SC actors are disappointed and place large orders to their upstream suppliers without considering the costly backlogged stockout (i.e. stockout due to reserved or accumulated orders). When the large order is finally fulfilled, SC actors possess high stock levels, which triggers them to significantly reduce the subsequent order. This action induces significant oscillations and amplifications towards upstream in the SC, a phenomenon known as the bullwhip effect (Zhao and Zhao, 2015).

Whilst Zhao and Zhao (2015) seems to provide a plausible argument on the role of mindfulness as an underlying mechanism of *how* IOIS influences SC performance in a certain operational condition, further empirical investigation is still required to deeply understand the mindfulness-based mechanism across a range of operational conditions. Empirical research is also required to understand the mechanism in specific SC contexts, which may offer different insights into the IOIS phenomenon (Wong *et al*., 2011). Future research can address these gaps.

## 1.4 Summary of research gaps and proposed research

Blood safety and availability (BSA) remain perennial problems in the blood supply chain (BSC). Whilst some studies have suggested that inter-organisational information sharing (IOIS) can potentially improve BSA (e.g. Goodnough *et al*., 2003; Rautonen, 2007; Rutherford *et al*., 2016; SHOT, 2016; WHO, 2017a; Williamson and Devine, 2013), empirical research is currently lacking in its understanding of the relationship between IOIS and BSA across a range of operational conditions.

Meanwhile, the BSC literature can learn from the wider supply chain (SC) literature that SC actors do not necessarily gain benefits from IOIS (e.g. Cantor and Macdonald, 2009; Kembro and Näslund, 2014; Steckel *et al*., 2004; Zhao and Zhao, 2015) and further research is required to understand the underlying mechanisms of *how* IOIS influences SC performance. The BSC can further learn that there is a potential of using the concept of mindfulness to understand the mechanisms across a range of operational conditions (Zhao and Zhao, 2015).

This thesis seeks to address these two practically and conceptually relevant research gaps. Following up on Zhao and Zhao's (2015) work, high reliability theory (HRT) with its five core principles of collective mindfulness (i.e. *preoccupation with failure* (PF), *reluctance to simplify* (RS), *sensitivity to operations* (SO), *commitment to resilience* (CR), and *deference to expertise* (DE)) is elaborated to explain the underlying mechanisms of how IOIS influences BSA in normal, high tempo, and emergency conditions. HRT is chosen particularly to exemplify the underlying mechanisms required to ensure high reliability BSA performance in the unique context of the BSC. Whilst adding knowledge to the extant BSC and the wider SC literature, a clear understanding of the underlying mechanisms can help SC actors develop appropriate strategies to make impactful IOIS in the dynamic environment.

As recommended by Kembro and Näslund (2014), to obtain a better representation of IOIS as a “supply chain” phenomenon, multiple case study design is used to investigate the IOIS behaviour at the dyadic supply chain level. The co-actions of the IOIS behaviour (i.e. the actions that happen together with IOIS activities) are also investigated in order to unravel the underlying mechanisms. Two contrasting cases with three embedded cases for each main case were selected using convenient and context-based approaches, representing a centralised and tightly regulated BSC in the UK as well as a decentralised and loosely regulated BSC in Indonesia. The methodology used in this thesis is explained in detail in Chapter 4.

## 1.5 Summary of findings and contributions

This thesis finds that inter-organisational information sharing (IOIS) influences blood safety and availability (BSA) through the dynamic enactments of collective mindfulness (CM) principles across a range of operational conditions. It is also found that more CM principles are enacted in a centralised and tightly regulated blood supply chain (BSC) compared to those in a decentralised and loosely regulated BSC. This indicates that the BSC actors in the centralised and tightly regulated context are collectively more mindful when sharing information than those in the decentralised and loosely regulated context. By sharing information the BSC actors in the centralised and tightly regulated context attempt not only to respond to any changes in their operations, but also to address any potential and/or actual errors that lead to damaging BSA. This is contrary to IOIS in the decentralised and loosely regulated BSC, which tends to be more focussed on fulfilling immediate needs for BSA with a fire fighting mode of operations.

The data also reveals an emerging mechanism of *heedful interrelating* (HI) that is found across a range of operational conditions, particularly in the context of centralised and tightly regulated BSC. This emerging mechanism suggests that IOIS behaviour reflects the BSC actors’ mindfulness that their operations are likely to affect other actors across the BSC. In other words, they do not see their work as a silo activity. Instead, by sharing information they are mindful of their role in the BSC and see their work as a contribution to achieve the BSA performance of the whole BSC.

Finally, this thesis reveals an interesting fact, that IOIS does not necessarily lead to positive changes in BSA. In fact, negatively enacted CM principles can lead IOIS to unimproved and even potentially worse BSA. In the centralised and tightly regulated BSC, complacency towards the BSA performance can lead to ineffective IOIS, whereas, in the decentralised and loosely regulated BSC, lack of sensitivity to BSC operations can hinder IOIS from improving the BSA performance. A detailed description of these findings is presented in Chapter 5.

The primary contribution of this thesis lies in the understanding of the underlying mechanisms of how IOIS influences BSA in the dyadic BSC across a range of operational conditions. Its novelty lies in the use of the collective mindfulness concept to explain the underlying mechanisms. This thesis offers practically and conceptually relevant knowledge to the BSC literature. By showing the dynamic enactments of CM principles, this thesis informs the wider supply chain (SC) literature on what makes IOIS influence SC performance across a range of operational conditions. It also extends the current IOIS discussions and triggers a different way of thinking about the relationship between IOIS and SC performance.

## 1.6 Summary of disseminated works

Integrated parts of this thesis have been disseminated in various ways (see Table 1-2 on page 12). In 2018, a modified version of the systematic literature review of this thesis has been published in a special issue of the *International Journal of Physical Distribution and Logistics Management*. This article focusses on investigating the relationship mechanisms between inter-organisational information sharing (IOIS) and perishable product supply chain performance.

A modified version of this thesis was also presented at the 8$^{th}$ International Conference on Operations and Supply Chain Management (OSCM) 2018. The presentation focussed on the preliminary results of the data analysis. In addition, the pilot study of this thesis was presented on two separate occasions. It was first presented orally at the European Logistics Association (ELA) Doctoral Workshop 2016 and received constructive feedback from reviewers and other doctoral researchers. It was then presented as a poster at the British Blood Transfusion Society (BBTS) Annual Conference 2017. This is a practitioner conference and practical feedback including data presentation was received from some medical consultants.

**Table 1-2: List of published and presented works**

| Types of works | Published/ presented | Details | Notes |
|---|---|---|---|
| Modified full study | Published | Lusiantoro, L., Yates, N., Mena, C. and Varga, L. (2018), "A refined framework of information sharing in perishable product supply chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 48 No. 3, pp. 254-283. | Special issue: Structured literature reviews and meta analyses in supply chain management and logistics |
| Modified full study | Presented | Lusiantoro, L., Yates, N. and Varga, L. (2018), "Comparing information sharing behaviour in high and low reliability blood supply chains: does collective mindfulness matter?", paper presented at the 8th International Conference on Operations and Supply Chain Management (OSCM), 9th-12th September, Cranfield, UK. | Oral presentation of the preliminary results of the thesis |
| Pilot study | Presented | Lusiantoro, L., Yates, N., Cotton, S. (2017), "Information sharing: Keep mindful and save lives!", paper presented at the British Blood Transfusion Society (BBTS) Annual Conference, 13th-15th September, Glasgow, UK. | Poster presentation |
| Pilot study | Presented | Lusiantoro, L. (2016), "Towards high reliability supply chains: a closer look at inter-organisational information sharing in a perishable product environment", paper presented at the European Logistics Association (ELA) Doctoral Workshop, 22nd-25th June, Vienna, Austria. | The paper was among the 20 selected papers for oral presentation. Funding for participating in the workshop was granted by the Kuehne Foundation. |

## 1.7 Structure of the thesis

This thesis is organised as follows:

**Chapter 1:** In this chapter, a brief introduction to the blood supply chain (BSC) is presented. Practical problems of blood safety and availability (BSA) and inter-organisational information sharing (IOIS) in the BSC, together with lessons learnt from IOIS studies in the wider supply chain context are also presented. Finally, a summary of the proposed research, findings and contributions is presented in this chapter.

**Chapter 2:** This chapter covers the philosophical and theoretical perspectives underpinning the thesis. Critical realism is adopted as a philosophical perspective, whereas high reliability theory is elaborated as a theoretical perspective to understand the phenomenon of IOIS in the BSC.

**Chapter 3:** A systematic literature review (SLR) is presented in this chapter. The SLR focusses on reviewing the phenomenon of IOIS in perishable product supply chains, a research domain that shares many of the characteristics of the BSC. Accordingly, the research question and key definitions are specified, followed by the aim and objectives.

**Chapter 4:** This chapter presents the methodology used to answer the research question and to achieve the aim and objectives of the thesis. It covers research design and strategy, cases selection, data collection and analysis, as well as validity and reliability of the case study.

**Chapter 5:** This chapter presents the findings of the thesis. It covers the results of within-case and cross-case analyses including the IOIS behaviour and the enactments of collective mindfulness principles across cases.

**Chapter 6:** This chapter covers the discussion of the findings in relation to the theoretical perspective.

**Chapter 7:** This chapter concludes the thesis and presents its contributions to the BSC practices and to the relevant supply chain literature. This chapter also covers the limitations of the thesis as well as opportunities for future research.

# 2 PHILOSOPHICAL AND THEORETICAL PERSPECTIVES

In this chapter, the philosophical and theoretical perspectives underpinning this thesis are presented. Critical realism is adopted as a philosophical perspective, whereas high reliability theory and its central concept of collective mindfulness is elaborated as a theoretical lens, both of which serve as a foundation to unravel the underlying mechanisms of how inter-organisational information sharing influences blood safety and availability in the dyadic blood supply chain in normal, high tempo, and emergency conditions.

## 2.1 Critical realism as a philosophical perspective

Critical realism is adopted as a philosophical perspective underpinning this thesis. According to Blaikie (2007), critical realism as a research paradigm is embodied by depth realist ontology and neo-realism epistemology. Ontology answers the question "what is the nature of social reality?" (Blaikie, 2007:13), of which depth realist represents a stance that views the world as stratified reality. This ontology suggests that reality is stratified into three domains – empirical, actual, and real (Bhaskar, 1978). Empirical domain covers phenomena or events that can be observed or experienced. Actual domain includes events (empirical) and non-events triggered by underlying mechanisms which can be observed or experienced, or unobserved or unexperienced. Finally, the real domain represents processes or underlying mechanisms that generate those events (see Blaikie, 2007; Easton, 2010).

To illustrate this stratified view of reality, Adamides *et al.* (2012) provide a practical example using a bullwhip effect phenomenon in a wholesaler of a two stage supply chain. In this phenomenon, the wholesaler experiences excess stock after a shortage period (i.e. the empirical domain of reality). This excess stock is produced by a decision to order (more, less, or none) a certain amount of product to fill the stock (i.e. the actual domain of reality). This decision is produced as the outcome of mechanisms that are enacted in certain contexts or conditions. For example, when there is an increase in demand, independent of any arrivals backlog, the wholesaler orders larger amount of products from the manufacturer to fill the stock. Additional orders will result in overstock when the warehouse capacity is saturated. These underlying mechanisms represent the real domain of reality.

Epistemology answers the question “how can social reality be known?” (Blaikie, 2007:18). As the epistemological perspective to critical realism, neo-realism is not in full agreement with the central idea of empiricism (a positivism epistemology), that scientific explanation can be obtained by only establishing patterns, regularities, or constant conjunctions within the studied phenomena. Neo-realism argues that “establishing such regularities is only the beginning of the process. What is then required is to locate the structures or mechanisms that have produced the pattern or relationship” (Blaikie, 2007:22). Therefore, the aim of scientific enquiry based on critical realism is to explain observable phenomena by investigating their underlying structures or mechanisms (Blaikie, 2007). Pawson and Tilley (1997) describe the notion of underlying mechanism as:

> “To ‘generate’ is to ‘make up’, to ‘manufacture’, to ‘produce’, to ‘form’, to ‘constitute’. Thus when we explain a regularity generatively, we are not coming up with variables or correlates which associate one with the other; rather we are trying to explain how the association *itself* comes about. […] A mechanism is thus not a variable but an *account* of the make-up, behaviour and interrelationships of those processes which are responsible for the regularity.” (Pawson & Tilley, 1997:67, 68)

Critical realism provides a comprehensive alternative to positivism which argues that there are only empirical phenomena in which constant conjunctions between events happen; i.e. the happening of events is always followed by another event, such as liquid will change to gas when sufficient heat (constant temperature) is applied to a sufficient amount of water (Blaikie, 2007). Critical realism argues that there must be a theory explaining these constant conjunctions and underlying mechanisms of the relationship between events under particular conditions. In other words, critical realism offers a different way to understand what happens beneath the surface of observable inputs and outputs of the phenomena (Pawson and Tilley, 1997).

Critical realists accept the key assumption of positivism that the reality exists independently of observers. However, they acknowledge that this assumption is often valid in the natural sciences which operate within controllable and/or closed systems and is rarely observed in open social systems (Easton, 2010; Sayer, 1992). Blaikie (2007:16) emphasises that "social structures do not exist independently of the activities they influence or social actors' conceptions of what they are doing in these activities". Therefore, according to critical realism, "the world is socially constructed but not entirely so" (Easton, 2010:120). "The difference between critical realists and social constructionists lies in the acceptance of the possibility of knowing [independent] reality in the former case and its rejection in the latter who, in general, concentrate instead on uncovering the constructions [of reality] that social actors make" (Easton, 2010:123). The critical realists' acceptance of social constructionists' position in social research means that there is always an element of interpretation to understand the meaning of the studied phenomena (Sayer, 2000). This interpretation process can intervene between the empirical and actual domains of reality which "may not be observed at all or may be understood quite differently by observers" (Easton, 2010:123). Consequently, this interpretation process can potentially help explain the underlying mechanisms that operate in the real domain of reality.

Sayer (2000) argues that, compared to positivism and interpretivism, critical realism embraces flexibility in the use of a wide range of research methods. However, the particular choice of the methods should be driven by the nature of the research and what the researcher wants to learn from it (Sayer, 2000). In the supply chain management (SCM) literature, case study is increasingly used and regarded as a legitimate methodology for critical realism (Aastrup and Halldórsson, 2008; Adamides *et al.*, 2012). This is because case study can be used to understand the underlying mechanisms of a phenomenon (Aastrup and Halldórsson, 2008), which serves as an alternative for regularity-based causal explanations (e.g. surveys, statistical analysis) prescribed by positivism, which is believed to be the predominant philosophical stance in the SCM area (Aastrup and Halldórsson, 2008; Gammelgaard, 2004, 2017; Mentzer and Kahn, 1995). Moreover, case study represents "an empirical enquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context especially when the boundaries between phenomenon and context may not be clearly evident” (Yin, 2014:16). This is in line with the postulation of critical realism that advocates the importance of context to unravel the underlying mechanisms of the regularity of events (Denyer *et al.*, 2008; Pawson and Tilley, 1997).

Practically, the framework of critical realism paradigm can be understood using the trail of *context, intervention, mechanism,* and *outcome* (CIMO) logic (Denyer *et al.*, 2008; Pawson and Tilley, 1997). This logic asks a causality question: through which underlying mechanisms does intervention generate the outcome in the particular context? Denyer *et al.* (2008:396) suggest that this line of logic “contains information on what to do, in which situations, to produce what effect and offer some understanding of why this happens”. Therefore, CIMO is a useful logic to unravel the underlying mechanisms of a phenomenon.

According to Denyer *et al.* (2008), contexts can refer to internal and external environments as well as the nature of actors that influence changes in behaviour. Contexts include features such as age, competency experience, organisational power and politics, the nature of technical systems, organisational stability, and uncertainty and system interdependencies. Interventions are initial triggers that influence changes in outcomes, such as training, planning and control systems, leadership style, and performance management. Mechanisms are triggered by the interventions in certain contexts. For example, “empowerment [as a mechanism] offers employees the means to contribute to some activity beyond their normal tasks or outside their normal sphere of interest, which then prompts participation and responsibility, offering the potential of long-term benefits to them and/or to their organization” (Denyer *et al.*, 2008:397). Finally, outcomes can cover various changes as the result of interventions and mechanisms enacted in certain contexts, such as low error rates, cost reduction, or performance improvement. Denyer *et al.* (2008) illustrate the applicability of this logic using the following practical example:

> “If you have a project assignment for a geographically distributed team (class of contexts), use a face-to-face kick-off meeting (intervention type) to create an effective team (intended outcome) through the creation of collective task insight and commitment (generative mechanisms).” Denyer *et al.* (2008:396)

Embracing a critical realism paradigm and case study methodology, this thesis attempts to go beyond explaining a linear relationship between inter-organisational information sharing (IOIS) and blood safety and availability (BSA). Although most research in the general supply chain (SC) context shows that SC performance will increase by sharing information, i.e. showing a linear and positive relationship between the two variables (e.g., Cachon and Fisher, 2000; Fawcett *et al.*, 2007; Lin *et al.*, 2002; Wu *et al.*, 2014; Zhao *et al.*, 2002), they do not explain the mechanisms of how this relationship occurs. In fact, some research reveals that IOIS cannot guarantee improvement of SC performance (Cantor and Macdonald, 2009; Steckel *et al.*, 2004; Zhao and Zhao, 2015). These contradictory findings indicate that merely explaining the constant conjunction or regularities of the relationship between IOIS and SC performance is not sufficient, so the underlying mechanisms of the relationship need to be unravelled to offer a different perspective to understanding the IOIS phenomenon. The underlying mechanisms not only help the SC actors understand *how* IOIS actually influences SC performance, but can also help the SC actors develop appropriate strategies to make IOIS more effective.

To unravel the underlying mechanisms, high reliability theory (HRT) is adopted. The use of a theoretical lens in this thesis supports the critical realism stance that "it is unlikely to reveal completely and lead to a full understanding of any social situation [since] there can be no definitive criteria to judge the "truth" of a particular version" (Easton, 2010:123). Citing Woodside and Wilson (2003) and Woodside *et al.* (2005), Easton (2010:123) further emphasises that in critical realism, "[…] criticality within a discipline becomes essential since only by seeing the same data through the different theoretical lenses employed by different researchers can understanding of some of the features of the real world occur". The following section describes the theoretical perspective in detail.

## 2.2 High reliability theory as a theoretical perspective

This thesis focusses on elaborating high reliability theory (HRT), particularly its central concept of collective mindfulness, to explain how inter-organisational information sharing (IOIS) influences blood safety and availability (BSA) in normal, high tempo, and emergency conditions. HRT is chosen particularly to exemplify the underlying mechanisms required to ensure high reliability BSA performance in the unique context of the blood supply chain (BSC). In this section, HRT is briefly introduced to bring its relevance to this specific context. A comprehensive literature review of this theory is referred to the work of Lekka (2011).

### 2.2.1 Introduction to HRT

HRT originates from the study of organisations such as nuclear power plants, aircraft carriers, and air traffic controls – organisations which are characterised by their ability to sustain almost "error-free" performance over long periods of time (Robert, 1993; Sutcliffe, 2011). Such high reliability organisations (HROs) are generally defined as organisations that operate in complex, demanding, tightly coupled, and risky environments where failure may lead to fatal consequences. Thus, they strive to minimise errors and sustain excellent performance across a range of operational conditions, i.e. in normal, high tempo, and emergency conditions (Hopkins, 2007; La Porte and Consolini, 1998; Roberts, 1990; Roberts and Rousseau, 1989; Rochlin, 1993).

Roberts (1990) initially defines HROs by using a probability approach. She argues that:

> "[…] One can identify this subset [of organisations that have high safety records] by answering the question, "how many times could this organisation have failed resulting in catastrophic consequences that it did not? "If the answer is on the order of tens of thousands of times the organisation is "high reliability"" (Roberts, 1990:160)

However, this definition has been criticised as being too rigid on the statistical measure and cannot objectively determine organisations as high reliability. With this definition, some organisations that fail every minute or every day can still be categorised as HROs because their success rate is much higher than their failure rate. As an alternative definition, Rochlin (1993) suggests that HROs should be defined by the way the organisations enhance reliability performance. In other words, he advocates a process-oriented view of HROs as reliability-enhancing organisations:

> "What distinguishes reliability-enhancing organisations, is not their absolute error or accident rate, but their effective management of innately risky technologies through organisational control of both hazard and probability […]." Rochlin (1993:17)

This view of defining HROs is supported by Hopkins (2007), who suggests that researchers have changed direction from defining HROs with certain criteria that make organisations "high reliability" or "non-high reliability", to identifying practices that help organisations achieve and maintain highly reliable operations. As he suggests:

> "[the research] moves away from questions of just how safe does an organisation have to be before it can be considered an HRO, and it highlights instead what an organisation needs to do in order to reach the required end state" (Hopkins, 2007:6)

Embracing the process-oriented view of HROs, Weick and Sutcliffe (2007) suggest that HROs' ability to achieve high reliability performance is rooted in their informed culture that is defined by Goswami *et al.* (2009) as:

> "[…] an organizational culture that encourages reporting of errors and near misses, a culture that is just in terms of apportioning error when things go wrong, a culture that is flexible enough to be able to adapt to sudden and radical increases in pressure, pacing and intensity of organizational operations, and a culture that enables members of the organization to use lessons learnt from past experiences to guide present operations and assumptions." Goswami *et al.* (2009:6)

Informed culture encourages information sharing as a way to support collective organisational mindfulness, defined as "the extent to which an organization captures discriminatory detail about emerging threats and creates a capability to swiftly act in response to these details" (Weick *et al*., 1999; Weick and Sutcliffe, 2001; Weick and Sutcliffe, 2007 as cited in Vogus and Sutcliffe, 2012:723). Collective mindfulness is a dynamic social process comprising continuous actions, through extensive and real-time communication and interactions that reflect the shared behaviours of the organisational members to manage their interdependent operations (Vogus and Sutcliffe, 2012). This process is important because it enables the organisational members to engage in similar levels of perception and behaviours towards achieving high reliability performance (Vogus and Sutcliffe, 2012).

Collective mindfulness in HROs differs from its original concept of individual mindfulness, which is rooted in both Eastern and Western perspectives. From the Eastern perspective, individual mindfulness bases its concept on the Buddhism thought tradition that embraces awareness of and attention to present moments, i.e. the introspective and nonreactive awareness of body, feelings, consciousness, and mental objects achieved through meditation (Weick and Putnam, 2006). On the other hand, from the Western perspective mindfulness is defined as "a flexible state of mind in which we are actively engaged in the present, noticing new things and sensitive to context" (Langer, 2000:220). "People act less mindfully when they rely on past categories, act on "automatic pilot," and fixate on a single perspective without awareness that things could be otherwise" (Weick and Putnam, 2006:280). Instead of meditation, learning to switch modes from mindless to mindful and the process of noticing new things itself become the focus of the Western perspective of mindfulness (Weick and Putnam, 2006 in citing Langer, 2005).

Collective mindfulness was developed from the concept of individual mindfulness of the Western perspective (see Weick *et al.*, 1999). Morgeson and Hofmann (1999), Vogus and Sutcliffe (2012), and Weick *et al.* (1999), argue that individual mindfulness becomes collective mindfulness when there is an interaction between individuals to mindfully coordinate their actions. As such, the focus of collective mindfulness is not on what happens in the individual's mind (i.e. the intrapsychic process), but on the actions and interactions amongst individuals (Morgeson and Hofmann, 1999 as cited in Vogus and Sutcliffe, 2012). This is in line with the concept of "collective mind" that treats "mind" as activities or patterns of behaviour rather than as entities (Weick and Roberts, 1993). Collective mindfulness in an organisation is therefore a function of mindfully interacted behaviours carried out by members of the organisation rather than the intrapsychic process inside the head of each member of the organisation (Vogus and Sutcliffe, 2012).

## Table 2-1: Elements of collective mindfulness principles

| Collective mindfulness principles of HROs | |
|---|---|
| **Preoccupation with failure**<br>***Precaution***<br>• Treating any failure as a signal of system's health problems<br>• Identifying small errors or weak signals of failure anywhere<br>• Thoroughly analysing near misses<br>• Richly analysing and investigating any failure<br>• Treating near misses as a signal of danger rather than safety<br>• Frequently updating procedures after experiencing a near miss<br>• Avoiding complacency, inattention, and habituated routines<br>• Articulating mistakes they don't want to make<br>***Failure reporting***<br>• Reporting errors<br>• Learning from any reported failure<br>• Rewarding self-reporting errors<br>• Rewarding people for spotting errors<br>***Openness***<br>• Having a no blame culture<br>• Creating openness climate to report, discuss, and correct errors | **Sensitivity to operations**<br>***Transparency***<br>• Having a big picture of the operations by frequent interaction<br>• Having shared mental model and collective story building<br>• Having knowledge of interconnections within the system<br>• Having no fear, ignorance, or indifference to speaking up<br>***Regular interactions***<br>• Assessing situations with continual updates<br>***Real time interactions***<br>• Having real time status of activities and performance in the moment and in the near future<br>• Having access to relevant people and a variety of resources when unexpected events break out<br>***Ongoing operational adjustments***<br>• Ongoing small adjustments that prevent errors from cumulating<br>• Noticing anomalies while they are still tractable and can still be isolated<br>• Reducing the domino effect of an error<br>• Actively diagnosing of the limitations of current SOPs<br>• Actively monitoring appropriate actions indicated in the SOPs |
| **Reluctance to simplify**<br>***Redundancy***<br>• Having redundant systems as back-ups<br>***Scepticism***<br>• Making fewer assumptions and socialising people to notice more<br>• Having redundancy in the form of scepticism, making independent effort to confirm reports, cross checking, and having doubts that precautions are sufficient<br>• Having crystal clear information on anything<br>• Disseminating information to people who might not notice the errors<br>• Selecting new employees with non-typical previous experience<br>• Having training and re-training to be reluctant to simplify interpretation<br>• Having complex rather than simple SOPs which are subject to renewal, revision, and rejection to reflect new experience<br>• Encouraging unique information (anomalies) to be shared | **Commitment to resilience**<br>***Readiness***<br>• Developing capacity to cope with unexpected events after they have become manifest<br>• Devoting resources for training and re-training people to operate technical system<br>• Preparing for the inevitable events by expanding knowledge and technicality about the system and command over resources<br>• Developing repertoires of contacts used to respond to and solve problems<br>***Responsiveness***<br>• Managing (containing) fluctuations (surprises) in the system<br>• Responding to unexpected events as they occur<br>• Having the ability to bounce back from errors<br>• Accelerating feedback when unexpected events occur<br>***Recovery and growth***<br>• Having the ability to learn and grow from previous episodes of resilience |
| ***Checks and balances***<br>• Having diverse checks and balances using a range of meetings and committees<br>• Having frequent adversarial reviews (e.g. audits, accreditation visit, survey)<br>• Having frequent job rotation<br>• Having observable and continual renewal of formal agreements<br>• Having divergence in analytical perspectives on how to deal with something over theories, models, or assumptions<br>• Having mechanisms to manage conflicts or disagreements<br>• Having continuous negotiation, accomplishing trust and credibility | **Deference to expertise**<br>***Expertise-based decision making***<br>• Sharing information regardless of hierarchical rank<br>• Understanding anomalies by turning to others with expertise<br>• Enacting partial garbage can structure to allow more independent choice and decision making in the system – loosening the role of central decision maker and allowing decision making to migrate (rise or fall within the structure) along with problems to people with expertise and experience<br>• Having less orderly routines – orderly hierarchy can amplify errors<br>• Having flexibility with the enactment of organised anarchy when faced with dangers<br>• Committing to doing the job well<br>• Having a mind-set that structure is a variable while activity of structuring is a constant<br>***Collective decision making***<br>• Having collective rather than authoritative (top-down) decision making |

**Source: adapted from Weick and Sutcliffe (2015, 2007), Weick *et al.* (1999), and Lekka (2011)**

Collective mindfulness in HROs is often described in the form of *mindful organising*, which is the act of organising activities that constitute mindfulness (Vogus and Sutcliffe, 2012). Mindful organising can be observed, for example, from continuous and extensive real-time interactions and communication that occur in meetings, briefings, updates, and in teams' work to discuss any avoidable mistakes and to understand the big picture of operations within an organisation. In practice, collective mindfulness is manifested into the following five core principles of mindful organising (Weick and Sutcliffe, 2007, 2015). At a collective level, enacting and interacting with these principles means contributing to the process of achieving high reliability performance of an organisation. Detailed elements for each of the principle are presented in Table 2-1 on page 23.

1. *Preoccupation with failure* (PF). With this principle, HROs report errors and treat weak signals of failure and near misses as information about the system's health and try to learn from them, creating a climate of openness and no blame culture. In these organisations, near misses and incidents are thoroughly investigated to understand the lessons learnt, whilst procedures are frequently updated after experiencing near misses. People articulate mistakes they do not want to make and are rewarded for spotting errors.

2. *Reluctance to simplify* (RS). With this principle, HROs have redundant systems as back-ups. They encourage scepticism to avoid making assumptions on any information. They encourage error spotting and disseminate information to people who might not notice the errors. They have diverse checks and balances, and reviews to ensure the system's health.

3. *Sensitivity to operations* (SO). With this principle, HROs seek to understand the big picture of operations through transparency, and regular and real time interactions. They encourage speaking up, monitoring operations, and ongoing operational adjustments that prevent errors from cumulating.

4. *Commitment to resilience* (CR). With this principle, HROs embrace preparedness by developing capacity to cope with unexpected events. They

quickly respond to and accelerate feedback when unexpected events occur. They also develop repertoires of contacts to help solve problems during the events.

5. *Deference of problems to expertise* (DE). With this principle, when something out of ordinary happens, HROs share information regardless of hierarchical rank. They are aware that orderly hierarchy can amplify rather than minimise errors. Therefore, they embrace a flexible decision-making structure and encourage a collective rather than authoritative decision-making process. It means that even people working at the operational level can make important decisions when they have the related expertise to do so.

Weick and Sutcliffe (2007) further classify these collective mindfulness principles according to *when* they are supposed to be enacted. PF, RS, and SO are categorised under *the principles of anticipation* which are commonly identified in the normal conditions (i.e. when there are no unexpected events interrupting the operations). Whereas, CR and DE should be enacted once the unexpected events break out. For example when a wild fire becomes out of control and catastrophic, CR and DE should be enacted to contain its catastrophic impact. Therefore, CR and DE were categorised under *the principles of containment* which are commonly identified in emergency conditions.

Collective mindfulness is a central concept that characterises HROs. It also represents the underlying mechanisms by which HROs achieve their high reliability performance (see Lekka, 2011). The concept of collective mindfulness distinguishes HRT from similar studies under normal accident theory (NAT), quality management (QM), and supply chain risk and resilience (SCRR). Whilst studying the same type of organisations, NAT argues that accidents "normally" happen to any system in which elements were interactively complex and tightly coupled because of the combination of poor control and inability to comprehend what was happening (Perrow, 1984). NAT believes that "no matter how hard we might try, the characteristics of complexly interactive and tightly coupled systems will cause a major failure, eventually" (Perrow, 1994:216). According to NAT, accidents can be reduced by loosening the coupling and changing the system from complex to linear interaction (Perrow, 1984).

The pessimistic view of NAT raises a critical question: under which conditions will an interactively complex and tightly coupled system not fail? HRT addresses this question, offering a more optimistic view of capabilities to achieve highly reliable performance. Whilst recognising that errors in complex and tightly coupled systems are inevitable, HROs strive to prevent, anticipate, and minimise errors and sustain high levels of performance by enacting collective mindfulness principles across a range of operational conditions (Hopkins, 2007; La Porte and Consolini, 1998; Roberts, 1990; Roberts and Rousseau, 1989; Rochlin, 1993; Weick and Sutcliffe, 2007). Contrary to NAT, HRT argues that:

> "[…] interactive complexity and tight coupling may actually increase overall reliability. Complexity and tight coupling motivate designers to create more redundancy in a system, inspire operators to customize centralized decision premises, favor the development of multiple theories of system functioning, and encourage learning and discourage complacency." (Rijpma, 1997 as cited in Weick *et al*., 1999:34).

HRT also differs from the QM concept, including total quality management (TQM) and Six Sigma. QM suggests that quality is expected to improve following the implementation of QM programmes using pre-determined and standardised precepts (Antony, 2004; Schroeder *et al*., 2008). Unlike HRT, QM focusses on quality control and programme implementation with highly standardised routines under a stable (static) condition (Antony, 2004; Schroeder *et al*., 2008). As Sitkin *et al*. (1994) criticise:

> "Although the fundamental precepts advocated by founders of the quality movement can accommodate conditions of high uncertainty, the way that these basic TQM precepts have been articulated, extended, and applied has not reflected the distinct, learning-oriented requirements associated with higher levels of uncertainty". (Sitkin *et al*., 1994:537)

In addition, QM ignores complex and emergent problems due to its tight structure and preserved simplification (Sitkin *et al*., 1994), which focusses more on efficiency, rather than reliability (Weick *et al*., 1999). HRT criticises the idea of QM that repeatability of performance is often achieved by routines and the use of unvarying procedures, which do not reflect the mechanism of highly reliable performance under unforeseen conditions (Weick *et al*., 1999). HRT further suspects that failures of QM programmes often occur due to underdevelopment of collective mindfulness processes in the QM-adopting organisations (Weick *et al*., 1999).

Finally, HRT differs from SCRR. Supply chain resilience is the evolution of the supply chain risk management concept (Christopher and Peck, 2004; Hohenstein *et al*., 2015; Pettit *et al*., 2010). According to SCRR, the supply chain is vulnerable to the probability of "exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain" (Christopher and Peck, 2004:3; Hohenstein *et al*., 2015), so that the risks should be pre-identified through risk assessments (see Christopher and Peck, 2004; Pettit *et al*., 2010). As a consequence, SCRR emphasises the prepared risk mitigation, i.e. readiness of the capability to respond to big disruptive events such as fire at a major manufacturer facility, economic shocks, terrorist attacks or other major disasters such as floods, earthquakes, tsunamis, or nuclear power disasters (see Bhamra *et al*., 2011; Christopher and Peck, 2004; Hohenstein *et al*., 2015; Jüttner *et al*., 2003; Pettit *et al*., 2010; Ponomarov and Holcomb, 2009; Sheffi, 2005; Wilding, 2013).

Whilst HRT and SCRR share the same principles of readiness for, quick and flexible responses to and bouncing back from, serious disruptive events (see Hohenstein *et al*., 2015), HRT offers a more comprehensive mechanism of collective mindfulness to prevent and anticipate emerging operational errors/failures as well as to respond to unexpected events (Weick and Sutcliffe, 2007; Weick *et al*., 1999). In fact, resilience only represents one principle out of five collective mindfulness principles in HRT. In other words, HRT not only focusses on managing the big disruptive unexpected events, but also on small and weak signals of errors/failures and near misses which potentially lead to catastrophic consequences (PF principle) (Weick and Sutcliffe, 2007; Weick *et al*., 1999). This more subtle element of unexpected events is currently overlooked in the SCRR literature (see Hohenstein *et al*., 2015).

HRT and SCRR share the similar concept of redundancy and visibility of operations. However, redundancy in SCRR is focussed more on the physical elements of operations, such as transportation capacities, production slack, and multiple sourcing and supplier locations, to cope with disruptive events (Hohenstein *et al*., 2015). On the other hand, redundancy in HRT covers both physical and less physical, involving managerial or people elements of operations, such as scepticism and checks and balances to prevent errors as well as to ensure high reliability performance (RS principle) (Weick and Sutcliffe, 2007; Weick *et al*., 1999). The concept of visibility in SCRR refers to information sharing itself (Hohenstein *et al*., 2015), that is addressed in the principle of sensitivity to operations (SO) in HRT. However, SO not only covers visibility of operations, but also ongoing adjustments of operations to prevent errors from cumulating (Weick and Sutcliffe, 2007; Weick *et al*., 1999). In other words, SO also deals with what people managing the process will do with the information they have.

Whilst building human resources capabilities and experienced employees for crisis management are all important for both HRT and SCRR (Hohenstein *et al*., 2015), HRT emphasises sharing information with and deferring critical decisions to people with expertise regardless of the hierarchical structure (DE principle) (Weick and Sutcliffe, 2007; Weick *et al*., 1999). This notion of a flexible expertise-based decision making structure has not been addressed in the SCRR literature (see Hohenstein *et al*., 2015). In fact, similar to redundancy, the concept of flexibility in SCRR refers to the more physical elements of operations such as easy supplier switching, backup suppliers, and a flexible production system rather than the decision making structure (Hohenstein *et al*., 2015). In other words, HRT emphasises more the fact that the system is run by people who make decisions and have specific expertise in managing the process.

Finally, under the framework of SCRR, Pettit *et al*. (2010) argue that balanced resilience should be achieved when the level of capability and vulnerability matches. Tackling low vulnerability with high capability will potentially erode profitability, whereas handling high vulnerability with low capability will potentially result in excessive risk. This is contrary to the fundamental argument of HRT suggesting that collective mindfulness with a rich action repertoire (high level of capability) is required to tackle any error/failure in the system (regardless of the level of risk/vulnerability). According to HRT, this approach to reliability comes with a high cost of investment (e.g. time, energy, human resources), but potentially results in a more reliable system and sustained performance (Weick *et al*., 1999).

### 2.2.2 Limitations of HRT

Whilst HRT provides an interesting and compelling alternative towards understanding the notion of high reliability operations, it has several limitations requiring further research and elaboration (Lekka, 2011). First, current application of this theory is still mostly limited to distinctive types of organisation, such as nuclear power plants, air traffic controls, and aircraft carriers, which are considered to have minimum rates of error. Therefore, the application of this theory to the wider organisational contexts and industries remains a potential.

Moreover, whilst some researchers have seen the relevance of adapting HRT in the area, such as healthcare (e.g. Vogus and Sutcliffe, 2007a, b; Vogus *et al*., 2010), project/programme management (e.g. Denyer *et al*., 2011; Kutsch *et al*., 2013; Turner *et al*., 2016), and information systems (e.g. Butler and Gray, 2006), their research has been focussed on a single organisation as the unit of analysis. The elaboration of HRT in a research area such SCM may contribute to new insights on how HRT can be applied to address issues involving more than one organisation.

Second, HRT research lacks a theoretical framework, which explains why some HROs are able to sustain performance whereas others are not. In addition, more evidence is required to understand the relationship between collective mindfulness and safety performance. “Understanding the factors that facilitate the development of HRO [collective mindfulness] processes, as well as the links between specific HRO [collective mindfulness] processes and safety performance would help inform a more comprehensive approach as to how organisations can become more reliable or ‘mindful’.” (Lekka, 2011:19).

Third, whilst HRT offers a comprehensive approach towards error/failure prevention and anticipation as well as quick responses to unexpected disruptions, these mechanisms do not always work in certain environments (Lekka, 2011). Healthcare operations, for example, tend to have unpredictable and chaotic environments so that real-time error/failure prevention and anticipation can be difficult to apply (Blatt *et al*., 2006; Lekka, 2011). It is also argued that the ability to respond to unexpected disruptions in these environments may be dependent on relational factors such as culture and leadership in the organisation, which has not been adequately explored by HRT (Lekka, 2011). Further investigation is therefore required to understand the HROs' environmental conditions and the underlying mechanisms by which HROs operate to enable successful error/failure prevention and anticipation as well as quick responses to unexpected disruptions (Lekka, 2011).

In summary, despite its limitations, HRT offers a distinctive and useful concept of collective mindfulness as the underlying mechanism (see Denyer *et al*., 2008) that explains high reliability performance across a range of operational conditions. The elaboration of this theory in the wider contexts and industries including the BSC is therefore encouraged.

### 2.2.3 Blood supply chain and HRT

The blood supply chain (BSC) shares many of the characteristics of HROs. Perishability of blood products and uncertainty in both demand and supply add complexity to the supply chain (SC). The BSC requires stringent operations; blood products require temperature controlled facilities along with storage and transport processes that should comply with tight blood safety and quality regulations. Blood products must be delivered whenever needed in normal, high tempo, and emergency conditions through a series of continuous logistical processes from donors to patients, whereas failure to provide safe blood can lead to patients' death.

In normal conditions, some patients require blood for scheduled operations and treatments. The demand for blood is often unpredictable during high tempo conditions such as bank holidays or Christmas. This is coupled with the number of blood donors and therefore stock levels that tend to decrease. In emergency conditions such as major haemorrhages, terrorist attacks, or natural disasters, blood safety and availability (BSA) should not be compromised to fulfil immediate demand from the hospitals. Highly reliable operations are therefore required to ensure BSA and to potentially save lives across a range of operational conditions.

Whilst HROs have been dealing with a single organisational context requiring complex and tightly coupled interdependencies (Hopkins, 2007; Roberts, 1990; Weick and Sutcliffe, 2015), the BSC embraces a complex and tightly coupled structure involving more than one organisation, where inter-organisational information sharing (IOIS) is essential to coordinate the supply chain operations. In this inter-organisational context, catastrophic events can potentially happen, particularly when information sharing is difficult to achieve and the complex system is hard to comprehend (Turner, 1976; Weick *et al.*, 1999). Collective mindfulness amongst the BSC actors is therefore required to guide the coordination as one way to achieve and sustain high reliability performance.

Despite the similar characteristics between the BSC and HROs, there is limited research explaining the IOIS phenomenon in the BSC using the HRT perspective. A considerable amount of research, however, has adopted HRT in the healthcare context (see Baker *et al*., 2006; Frankel *et al*., 2006; Madsen *et al*., 2006; Reed McMillian and McEldowney, 2014; Roberts *et al*., 2005; Sutcliffe, 2011; Tamuz and Harrison, 2006; Vogus and Sutcliffe, 2007a; Xiao and Moss, 2001). Some researchers such as Vogus and Sutcliffe (2007a, b), and Vogus *et al*. (2010) for example use the five collective mindfulness principles of HRT to embrace safety practices in healthcare providers. Their research shows that collective mindfulness enables people in organisations to communicate safety problems, reduce errors, and to elaborate learning from failures resulting from their actions (Vogus *et al*., 2010). As such, the enactments of collective mindfulness principles have been associated with both lower medication errors and patient falls in hospitals (Vogus and Sutcliffe, 2007a).

In addition, the concept of collective mindfulness has been promoted alongside information sharing practices in the healthcare context. Faraj and Xiao (2006) for example coin the term *dialogic coordination practices* in the context of emergency treatments in a trauma centre. Dialogic coordination practices suggest that information sharing should reflect the time-critical, cross-boundary, and situated responses to address problems in the rapidly unfolding conditions (Faraj and Xiao, 2006). In this case, information sharing only is not enough; information sharing should represent the actors' continuous interactions, joint sensemaking, common responsibility, and cross-boundary interventions to ensure patients' safety (Faraj and Xiao, 2006). As such, dialogic approaches to coordination recognise that information sharing, action, and cognition are relational and highly situated (Faraj and Xiao, 2006). They are as much dependent on the people as the processes by which the information is shared. Such practices are highly significant to reduce the possibility of medical error and catastrophic outcome (Faraj and Xiao, 2006).

Faraj and Xiao (2006) provide clear examples from their data about medical practices in a trauma centre. When anesthesiologists find that a patient's condition is mysteriously deteriorating, they will consult the condition with their colleagues, speak up openly about the possible causes of the condition, and consult with those who might be more experienced in the organisation. When they see someone is doing something wrong or inappropriate, such as contaminating his/her gloves or gown, they will tell him/her so that they do not contaminate the patient's wound. These two examples represent Faraj and Xiao's (2006) descriptions of joint sense making and cross-boundary intervention respectively. In the collective mindfulness terminology, the first example can represent the principle of sensitivity to operations and deference to expertise, whereas the second example represents the principle of preoccupation with failure (see Weick *et al.*, 1999 which is also cited in Faraj and Xiao, 2006).

Whilst Faraj and Xiao (2006) imply the importance of collective mindfulness as an underlying mechanism that explains how information sharing influences performance, they focus on a single organisational rather than a supply chain context. In other words, there is a lack of attention towards investigating how collective mindfulness can explain the relationship between IOIS and SC performance in the healthcare context. This thesis can therefore add to this line of research.

### 2.2.4 Other related research adapting HRT

Whilst HRT is useful for some research in the healthcare context, the potential of adapting this theory has been proposed in some other areas that are closer to the IOIS context, such as information systems and supply chain management (SCM). Butler and Gray (2006) for example suggest that the collective mindfulness concept of HRT should be adapted to design reliable information systems. As they describe:

> "Mindfulness theories also have a variety of implications for the practice of designing information systems. First, designing reliable systems is more than a software engineering problem. If users contribute to, or undermine, a system's reliability, then designing reliable systems requires the development of technologies that promote mindful user behavior. Second, information systems embed and affect work practices. As a result, they can change an organization's ability to develop and maintain mindful approaches to its work and environment. Whether at the individual, unit, or organizational level, mindfulness theory raises questions about the principles and consequences of how systems are designed." Butler and Gray (2006:220)

Butler and Gray (2006) further argue that information systems that are designed to automate activities and simplify information can undermine collective mindfulness to detect unexpected variation and errors. Therefore, what is needed is information systems that can enhance reliability performance by encouraging individual, unit, or organisation to be collectively mindful to seek out multiple sources of information and to critically evaluate that information (see also Hedberg and Jonson, 1978). As they conclude:

> "Mindfulness theories do not imply that automation, routines, or technically reliable systems are undesirable. However, they do remind us that while it may seem costly, situated and active human cognition ultimately underlies an organization's ability to handle the unexpected situations that inevitably arise in modern IT-based business environments." Butler and Gray (2006:221)

Butler and Gray's (2006) study is useful for IOIS research and therefore this thesis because they highlight the importance of having reliable systems to share information. However, they build their argument based on a conceptual analysis and their focus is on a single organisational rather than a supply chain context. Empirical research is therefore required to support their proposal, particularly in the context of IOIS.

In addition, in the SCM context, an attempt to use HROs' mindfulness perspective has been suggested by Speier *et al.* (2011) to explain the relationship between IOIS and supply chain characteristics on product safety and security. Speier *et al.* (2011) find that firms with more vulnerable products, greater supply chain complexity, but a more mindful security culture, tend to share more security-related information than those firms with less vulnerable products, smaller supply chain complexity, but a less mindful security culture.

Whilst Speier *et al.* (2011) do not provide a deep explanation on the interrelation between informaton sharing, mindfulness, and product safety and security, they argue that more mindful firms are more likely to design an SC with greater visibility. Speier *et al.* (2011) measure information sharing as the capability of the firm's information system to deliver quality information (i.e. complete, timely, accurate, and actionable information) but mindfulness as the firm's interest in positioning security as a strategic goal to protect the firm's reputation and to gain competitive advantage. Interestingly, although they cited Weick and Sutcliffe's (2001) work on HRT, none of the five collective mindfulness principles of HRT was used to measure mindfulness in this research. This suggests that HRT as a theoretical lens has not been adequately elaborated to link collective mindfulness and IOIS in SCs.

## 2.3 Summary of the philosophical and theoretical perspectives

This thesis uses critical realism as a research paradigm to bring about the notion of underlying mechanisms to understand the relationship between IOIS and BSA. Critical realism offers a different perspective as an alternative for the conventional regularity-based causal explanations prescribed by positivism that is believed to be the predominant philosophical stance in the SCM studies. Instead of merely explaining the linear relationship between variables, critical realism builds on positivism by explaining how such relationship happens.

Moreover, this thesis contributes to the elaboration of HRT, particularly its central concept of collective mindfulness, by adapting it to explain the phenomenon of IOIS in the BSC. By doing so, this thesis attempts to extend the relevance of this theory from organisational to SC context. Whilst HRT reflects the unique context of the BSC that requires high reliability performance, this theory provides *a priori* knowledge as to how organisations achieve high reliability performance. This is useful due to the fact that the BSC also requires high reliability performance to ensure that blood is always safe and available whenever needed. This subsequently contributes a novel perspective to comprehensively understand the underlying mechanisms of how IOIS influences BSA. The elaboration of HRT in this thesis concurs with the recommendation of Kembro and Näslund (2014) and Kembro *et al*. (2014) for the use of theoretical perspectives to understand the phenomenon of IOIS in SCs.

The following chapter (Chapter 3) presents a systematic literature review, which not only brings about relevant SCM literature that informs this thesis, but also assesses whether the philosophical and theoretical perspectives applied in this thesis truly contribute to the novelty of this thesis. Subsequently, in Chapter 4, these perspectives are used as a foundation for developing the research methodology used in this thesis.

# 3 SYSTEMATIC LITERATURE REVIEW

This thesis is informed by three domains of literature (see the left circles in Figure 3-1) – inter-organisational information sharing in supply chains (IOIS-SC), the blood supply chain (BSC), and high reliability organisations (HROs). Whilst there is abundant research into IOIS in the IOIS-SC domain, research into IOIS is currently lacking in the BSC literature (see Beliën and Forcé, 2012). Similarly, this phenomenon is yet to be explored in the HRO's literature (see Lekka, 2011; Weick and Sutcliffe, 2015, 2007; Weick et al., 1999).

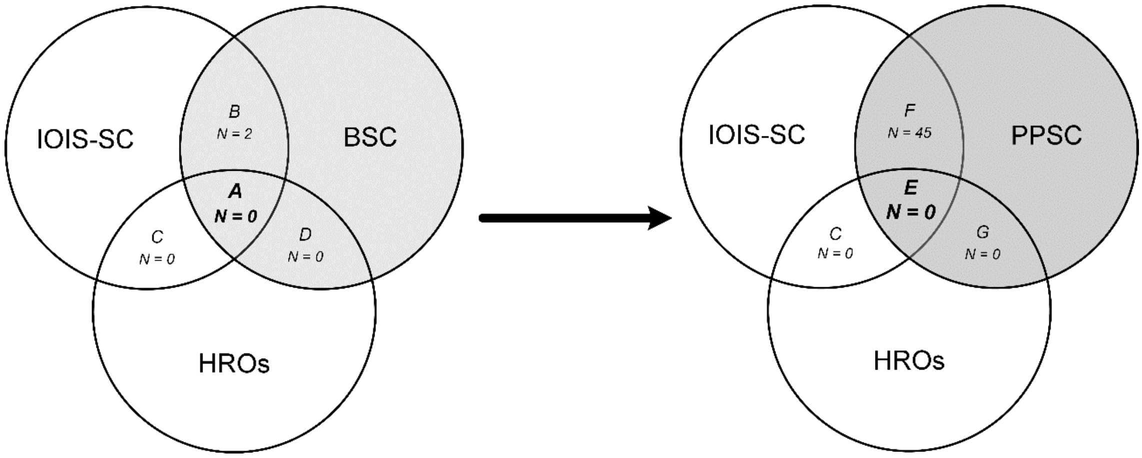


**Figure 3-1: Domains of literature informing the thesis**

A systematic search in four research databases, i.e. EBSCO, ABI/Inform, Scopus, and Web of Science, last conducted on August 2018, confirms this argument. Using the developed search strings (SS) and excluding keywords (EK) (see Table 3-1 on page 38; the process of developing the SS and EK is explained later in this chapter), the combination of the word "blood" (or "bloods"), IOIS (SS-1), supply chain (SS-2), and high reliability organisations (SS-4) finds no article in those databases (i.e. peer-reviewed academic journal articles written in English). This means that there is a research paucity in the intersection between the three domains of literature (area *A*, Figure 3-1). A research paucity is also found in the intersection between IOIS-SC and HROs (area *C*) and between BSC and HROs (*area D*), meaning that there is currently a lack of research using HROs' perspective to address IOIS-SC or BSC problems.

**Table 3-1: Search strings and excluded keywords**

| Code | Formula for search strings and excluded keywords |
|---|---|
| SS-1 | (data N4 share OR data N4 sharing OR data N4 shared OR data N4 exchang* OR data N4 flow* OR data N4 track* OR data N4 trace OR data N4 tracing OR data N4 traced OR data N4 transfer* OR information N4 share OR information N4 sharing OR information N4 shared OR information N4 exchang* OR information N4 flow* OR information N4 track* OR information N4 trace OR information N4 tracing OR information N4 traced OR information N4 transfer* OR knowledge N4 share OR knowledge N4 sharing OR knowledge N4 shared OR knowledge N4 exchang* OR knowledge N4 flow* OR knowledge N4 track* OR knowledge N4 trace OR knowledge N4 tracing OR knowledge N4 traced OR knowledge N4 transfer*) |
| SS-2 | ("supply chain" OR “supply network” OR "supply management" OR “supply chain management” OR logistic* OR “logistic* management” OR “demand chain” OR "demand management" OR “demand chain management” OR interorgani?ation* OR “interorgani?ation* system” OR “value chain” OR “value chain management” OR “cold chain” OR “cold chain management”) |
| SS-3 | (perish* OR deteriorat* OR spoil* OR decay* OR “short-lived” OR “short shelf life” OR “short life” OR perish* N4 product* OR perish* N4 item* OR deteriorat* N4 product* OR deteriorat* N4 item* OR spoil* N4 product* OR spoil* N4 item* OR decay* N4 product* OR decay* N4 item* OR food* OR “fresh food*” OR “agri-food*” OR agrifood* OR “agricultural product*” OR “fresh produce*” OR vegetable* OR fruit* OR poultry OR meat OR “diary product*” OR “bakery product*” OR vaccine* OR pharmaceutical* OR drug* OR vitamin* OR medicine* OR medication* OR blood OR bloods) |
| SS-4 | (“high* reliab*” N4 organi?ation* OR “high* reliab*” N4 organi?ing* OR “high* dependab*” N4 organi?ation* OR “high* dependab*” N4 organi?ing* OR “reliab* organi?ation*” OR “reliab* organi?ing*” OR “dependab* organi?ation*” OR “dependab* organi?ing*”) |
| EK | (logistic W1 regression*) |
| Notes | N4: finds the words if they are within four words of one another regardless of the order in which they are entered.<br>W1: finds the words if they are within one word of one another in the order in which they are entered. |

Despite the paucity of research in areas *A, C, and D*, this thesis finds a very limited number of relevant articles addressing IOIS in the BSC (area *B* – 2 articles). Amongst these articles are Grant (2010) and Katsaliaki and Brailsford (2007). Grant (2010) conducts an exploratory case study to investigate the integration of supply and marketing processes in the Scottish National Blood Transfusion Service (SNBTS). He finds that IOIS between SNBTS and hospitals helps the BSC reduce wastage, reduce unused blood, increase on-shelf availability, and reduce pressures in obtaining blood donations. Katsaliaki and Brailsford (2007) on the other hand use simulation modelling to analyse policies for managing a blood inventory system and suggest that sharing more frequent order information reduces the amount of expired stock in hospitals, whereas a more accurate sharing of order information leads to reduced outdates, shortages, and mismatched units in the hospitals. Given these findings, however, the mechanisms of how IOIS influences those BSC performance measures are not currently explained.

The limited insights on the IOIS phenomenon in the BSC means that more exploration is required to bring lessons learnt from other domains of literature, particularly the one that is close to the BSC context. This rationale leads this thesis to expand the systematic search process to the domain of the perishable product supply chain (PPSC), a discipline which shares many of the characteristics of the BSC (see the right circles in Figure 3-1 on page 37). In fact, researchers have long characterised blood as a perishable product that requires specialist inventory management, similarly to fruit, vegetables, poultry, meat, dairy products, and pharmaceuticals (e.g. Broekmeulen and Van Donselaar, 2009; Goyal and Giri, 2001; Kopach *et al.*, 2008; Nahmias, 1982; Raafat, 1991; Shukla and Jharkharia, 2013).

Like blood, the quality of perishable products deteriorates over time (Karaesmen *et al.*, 2011). These products have demand uncertainty, short biological life cycles, are not recyclable, directly affect human life, are susceptible to natural or artificial (cold chain) environmental conditions, and for which product safety and quality are paramount (e.g. Ferguson and Ketzenberg, 2006; Van Donselaar *et al.*, 2006). Some of these products are more vulnerable and susceptible to contamination by disease and damage from uncertain weather conditions, leaving a challenge to manage quality standards and product availability (Clements *et al.*, 2008). Specialist logistical processes and a coordinated supply chain are therefore required to maintain high quality and customer service levels in a short shelf life environment (Turnbull, 1989). These characteristics of the PPSC are therefore relevant to the BSC.

Whilst paucity of research is still found in the areas *E, C, and G* (see the right circles in Figure 3-1 on page 37) after expanding the research context, a considerable amount of relevant articles are found in the intersection between

IOIS-SC and PPSC (area *F* – 45 articles). This chapter therefore focusses on conducting an SLR in this area of research.

## 3.1 Research on the phenomenon of IOIS in the PPSC

This chapter focusses on investigating the phenomenon of IOIS in the PPSC in order to answer the following review question:

*How does inter-organisational information sharing influence the perishable product supply chain performance?*

By asking this question, this thesis seeks to understand how the extant PPSC literature explains the relationship between IOIS and PPSC performance. This understanding is very important as it can shape or confirm the novelty of the research proposed in this thesis, which seeks to investigate the underlying mechanisms of how IOIS influences blood safety and availability (BSA). In other words, the review question guides the SLR process to ensure that the formulation of the research question is well informed by the relevant literature. For this purpose, the review question is kept in a rather general form to acquire as many insights as possible from the extant PPSC literature.

### 3.1.1 Review method

A systematic literature review (SLR) is adapted to select, map, and assess the existing studies on IOIS-PPSC. The SLR was originally proposed in 2001 by the NHS Centre for Reviews and Dissemination; this method covers the identification of research areas, selection of studies, quality assessment, data extraction and data synthesis (Tranfield *et al*., 2003). SLR provides rigorous and transparent processes for conducting a review, the inclusivity of relevant studies, explanatory or interpretive findings, and heuristic outputs that lead to the next stage of research (Denyer and Tranfield, 2009). These processes distinguish SLR from other narrative-based literature review techniques that frequently lack rigour and audit trail, leading to biased results (Denyer and Tranfield, 2009).

While this method has been widely adopted across different disciplines ranging from medicine to management studies, research paradigm idiosyncrasies (i.e.

different ways of defining and understanding a phenomenon) need to be taken into account when applying the SLR to the supply chain management (SCM) context (Durach *et al.*, 2017). These idiosyncrasies reflect a complex range of theoretical perspectives, units of analysis, sources of data, study contexts, definitions and operationalisation of constructs, and research methods applied in SCM studies which make the retrieval, selection, and synthesis of SCM literature challenging (Durach *et al.*, 2017). Therefore, building on Tranfield *et al*. (2003), the aim of the SLR in SCM is to understand a supply chain (SC) phenomenon by addressing these idiosyncrasies in SCM studies. The following methods in conducting the SLR are adapted from Denyer and Tranfield (2009), Durach *et al.* (2017) and Tranfield *et al*. (2003).

#### 3.1.1.1 Development of inclusion and quality assessment criteria

To capture the phenomenon of IOIS-PPSC and to ensure the rigour of the SLR, this thesis developed inclusion and quality assessment criteria. In addition to the general search limitation to only retrieve peer-reviewed academic journal articles written in English, two sets of inclusion criteria were developed for (1) title and abstract screening and (2) full-text screening (Denyer and Tranfield, 2009), (see Table 3-2). For an article to be included, all the criteria listed in Table 3-2 should have "yes" answers.

**Table 3-2: Inclusion criteria for title, abstract, and full-text screening**

| Title and abstract inclusion criteria | Full-text inclusion criteria |
|---|---|
| - Peer-reviewed articles?<br>- Academic journal articles?<br>- Written in English?<br>- Purpose(s), finding(s), and/or implication(s) of the research talk about IOIS-PPSC?<br>- Perishable product context? | - IOIS focus (i.e. IOIS or traceability as the main construct/variable or as a key dimension of the researched topic)?<br>- IOIS at inter-organisational level?<br>- Unit of analysis covers dyadic or extended supply chain?<br>- Data collected from dyadic or extended supply chain?<br>- Perishable product context, i.e. addressing perishable products which have short biological life cycles, unrecyclable, directly affect human's life, and susceptible to natural or artificial (cold chain) environmental conditions where product safety and quality are paramount? |

As part of the inclusion criteria, some boundaries are developed to clarify the scope of the SLR. Considering rules for formulating a conceptual definition

(Wacker, 2004), this thesis defines IOIS as the *inter-organisational communication of meaningful data and/or explicit knowledge amongst supply chain actors.* In this definition, information can be defined as data (i.e. facts and messages) with relevance and purpose (Choo *et al.*, 2000; Davenport, 1997) and as explicit knowledge (e.g. advices, reports, standard operating procedures) that can be easily articulated and transferred across entities (Alavi and Leidner, 2001; Stenmark, 2002). This definition is in line with Kembro and Näslund (2014) who suggest that IOIS covers not only sharing information but also sharing data and knowledge. In fact, Stenmark (2002) argues that data, information, and knowledge are interwoven.

Whilst this thesis acknowledges the importance of intra-organisational IOIS (see Gimenez, 2006), the primary focus of this thesis is on IOIS at the SC level, i.e. IOIS including traceability across the PPSC (see Scholten and Schilder, 2015; Zelbst *et al*., 2010). This thesis adapts Harland's (1996) definition of "supply chain management" as the management of supply relationships between two or more organisations, excluding the internal supply chain and therefore internal IOIS. As a consequence, this thesis only selects articles examining IOIS in dyadic or extended SCs as the unit of analysis. Accordingly, this thesis also strictly selects articles that derive their analysis from data collected from two or more SC actors, which is in line with Kembro and Näslund's (2014) call to understand the IOIS phenomenon beyond the perspective of the focal organisation in SCs. This approach is also consistent with Durach *et al.*'s (2017) recommendation to maintain comparable units of analysis and units of data collection; avoiding bias in synthesising the literature.

To be relevant to the BSC context and in line with Wong *et al*.'s (2011) recommendation, the focus of this SLR is on perishable products which have specific logistical requirements. This includes products that have short biological life cycles, are not recyclable, directly affect human life, are susceptible to natural or artificial (cold chain) environmental conditions and for which product safety and quality are paramount. These products include, but are not limited to fresh produce, poultry, dairy products, bakery products, human blood, and pharmaceuticals. Although pharmaceutical products include those with relatively long shelf lives, this class of products is included in its entirety due to the products' criticality to human life and the requirement for specialist logistical processes to maintain product safety and quality (Papert *et al*., 2016). This thesis excludes product types such as newspapers and fashion products which have short shelf life cycles but are not perishable in the sense that is discussed in this thesis; their safety and quality do not deteriorate due to time or environmental factors, and they do not require specialist logistical or storage conditions.

Finally, this thesis selects articles which explicitly or implicitly relate IOIS to PPSC performance. Whilst specific measures such as product safety and quality are paramount for PPSC, a formal definition of PPSC performance is currently absent in the literature. Therefore, this thesis does not set specific criteria for the PPSC performance measures used in IOIS-PPSC literature. This avoids limiting the SLR to a very small number of articles which would reduce the potential lessons learnt gained from the literature.

Alongside the inclusion criteria, whilst the quality of the retrieved articles was ensured by limiting the search to peer-reviewed academic journals, explicit quality assessment criteria were developed to ensure rigour (Tranfield *et al.*, 2003) (see Table 3-3 on page 44). These criteria were adapted from the reviewer guidelines of highly respected journals in the fields of operations and logistics and supply chain management, including *International Journal of Physical Distribution & Logistics Management, International Journal of Operations & Production Management,* and *International Journal of Logistics Management* (Emerald Group Publishing Reviewer Guidelines, 2016). The articles were then judged against the criteria and were included for the next process when they met all the applicable criteria (see Tranfield *et al.*, 2003).

Whilst the quality assessment criteria were useful as a general guideline in assessing the articles, some articles need additional consideration. For example, using the classification of Pilbeam *et al.* (2012), this thesis treated studies using quantitative research techniques, such as mathematical modelling and simulation, as analytical rather than empirical research. For these articles, this thesis carefully examined the assumptions and limitations used to build the model. In fact, some of these articles call for further development and empirical testing of their model propositions; giving this thesis a legitimacy to treat the results of these articles as suggestive rather than conclusive.

**Table 3-3: Quality assessment criteria**

| Elements | Criteria |
|---|---|
| Introduction | Clear purpose |
| | Clear problem statement |
| | Clear context |
| | Clear description of findings of other research |
| | Description of general design/method |
| Research Method | Explain the data collection process |
| | Suitable research design to answer the research question(s) |
| | Sufficient information to replicate the research |
| | Identify the procedures followed and ordered in a meaningful way |
| | Explain methods in detail |
| | The sampling is appropriate |
| | Adequately describe the equipment and materials |
| | Describe the types of data recorded and precise measurements used |
| Findings | Clear description of findings in a logical sequence |
| | Appropriate analysis of the result |
| | Correct statistics |
| Discussion and Conclusion | Claims reasonably support the results |
| | Relate the results to expectations and to earlier research |
| | Support or contradict previous theories |
| | Explain the knowledge contribution |
| Relevant Contribution | Relevant contribution to theory |
| | Relevant contribution to practice |

**Source: Adapted from Emerald Group Publishing Reviewer Guidelines (2016)**

#### 3.1.1.2 Identification of literature through rigorous and structured searches

This SLR used four research databases – EBSCO, ABI/Inform, Scopus, and Web of Science – to retrieve relevant articles. This ensured the inclusion of all relevant articles and accommodated an inter-disciplinary view of the topic under review (Durach *et al.*, 2017). EBSCO and ABI/Inform provide literature focussed on business and management, including SCM, whereas Scopus and Web of

Science include literature from other relevant disciplines such as medicine and food science.

For each online database, search strings (a combination of keywords) and excluding keywords were developed in order to retrieve as many articles as possible related to IOIS, the SC, and perishability (see Table 3-1 on page 38 for examples). The search strings were designed to not only capture a specific phrase such as "information sharing", but also extended phrases such as "sharing perishable product information". To reduce bias, in line with Durach *et al.* (2017), suggestions from a panel of experts consisting of an information specialist, an expert in SLR, a practitioner, and two academics in the area of logistics and supply chain management were also incorporated into these search strings. To capture all relevant articles, this thesis did not limit the search by publication time.

#### 3.1.1.3 Identification of relevant studies based on inclusion and quality assessment criteria

By applying the inclusion and quality assessment criteria (see Tables 3-2 and 3-3 on pages 41 and 44 respectively), 1,032 titles and abstracts were retrieved from the databases and 297 duplicates removed using the "Remove Duplicates" tool in an Excel spreadsheet. Title and abstract screening (see the left column of Table 3-2 on page 41) was then performed for the remaining 735 articles, resulting in 170 relevant articles for full-text screening (see the right column of Table 3-2 on page 41). Following this second screening, 45 articles remained including six additional articles identified through cross-referencing. In total, 51 articles published in 33 peer-reviewed academic journals across a range of disciplines (see Table 3-4 on page 46) passed this quality assessment, and were ready for analysis. Figure 3-2 on page 47 illustrates this process.

The articles selected in this SLR date back to 2002 and have gained increasing attention to date. This is evident from the growing number of articles (73%) published in the last eight years (2010-2018). The highest proportion of the articles were published by journals in operations, logistics, and supply chain studies (43%) and food and agricultural studies (31%). The remaining articles come from journals in business and marketing studies (12%), information management (4%), environmental management (4%), and other areas (6%).

**Table 3-4: List of journals and the respective number of articles**

| Journal | Number of Articles | Journal | Number of Articles |
|---|---|---|---|
| **Operations, Logistics, and Supply Chain Studies** | | **Business and Marketing Studies** | |
| International Journal of Physical Distribution & Logistics Management | 5 | Business Strategy and the Environment | 1 |
| Supply Chain Management: An International Journal | 4 | International Marketing Review | 1 |
| Production and Operations Management | 3 | The Journal of Applied Business Research | 1 |
| Journal on Chain and Network Science | 2 | Business Process Management Journal | 1 |
| International Journal of Production Economics | 2 | Journal of Business & Industrial Marketing | 1 |
| Journal of Operations Management | 1 | Management Research Review | 1 |
| Annals of Operations Research | 1 | | |
| Interfaces | 1 | **Information Management** | |
| The International Journal of Logistics Management | 1 | Industrial Management & Data Systems | 1 |
| International Journal of Networking and Virtual Organisations | 1 | Journal of Global Information Management | 1 |
| Journal of the Operational Research Society | 1 | | |
| | | | |
| **Food and Agricultural Studies** | | **Environmental Management** | |
| British Food Journal | 5 | Journal of Cleaner Production | 1 |
| Computers and Electronics in Agriculture | 2 | Resources, Conservation and Recycling | 1 |
| International Food & Agribusiness Management Review | 2 | | |
| Journal of Food Engineering | 2 | **Others** | |
| American Journal of Agricultural Economics | 1 | Advanced Engineering Informatics | 1 |
| Advance Journal of Food Science and Technology | 1 | Rural Society | 1 |
| Food Control | 1 | Therapeutic Innovation & Regulatory Science | 1 |
| Comprehensive Reviews in Food Science and Food Safety | 1 | | |
| Meat Science | 1 | | |

The selected articles cover a range of research methodological approaches. Following the classification of Pilbeam *et al.* (2012), the methodological approaches were classified into empirical, analytical, and literature review studies. Empirical studies have dominated the field (71% of the articles) with case study (57%) and survey (10%) being the most prevalent methods used, followed by interviews (4%). Analytical studies make up the second biggest group (25% of the articles). Methods in this group include mathematical modelling and simulation (15%), model design and development (8%), and conceptual paper (2%). The remaining papers are literature reviews (4%).

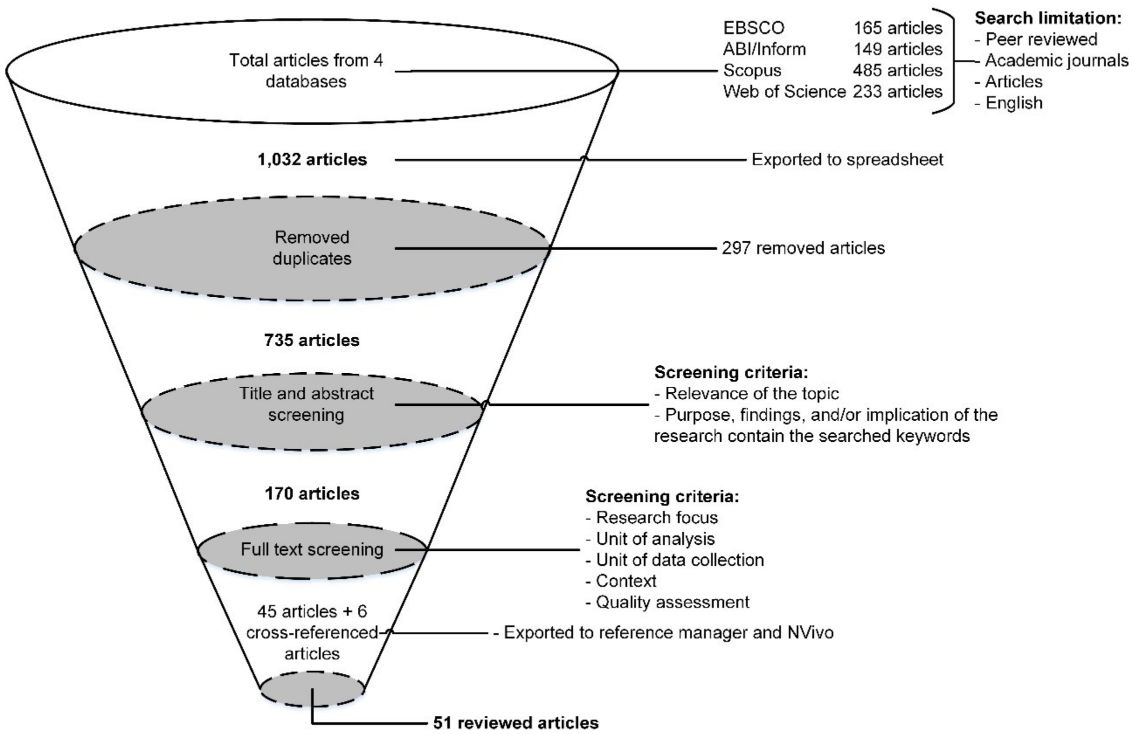


**Figure 3-2: Article collection protocol**

Various types of perishable products were addressed in the literature with food representing the biggest study (31%); followed by fresh produce (21%), meat (12%), pharmaceuticals (10%), agri-food (8%), fishery products (6%), blood (4%), and a combination of these products (8%). Interestingly, the reviewed literature highlighted very limited use of theoretical perspectives to study IOIS-PPSC. The result shows that only 10% of the selected articles adopt single or multiple theories including transvection theory, relationship marketing theory, multiscale decision theory, network theory, and transaction cost economics; the remaining extant research uses no theory at all. This alludes back to the fragmented PPSC literature, oriented towards problem solving rather than theory development (Shukla and Jharkharia, 2013).

**3.1.1.4 Coding and analysis method**

Fifty one articles were coded and analysed using template analysis. King (2012) defines template analysis as a style of thematic analysis of textual data that allows a flexibility of coding structure through the use of tentative *a priori* or initial codes, which allow researchers to focus on finding relevant information from the text. Template analysis allows these initial codes to evolve by inserting, deleting, or merging codes as new themes emerge from the text. These characteristics distinguish template analysis from other approaches, such as grounded theory and interpretative phenomenological analysis which offer a more inductive and rigid coding structure that is less flexible and more time-consuming when used with large data sets (King, 2012). Moreover, in line with the purpose of this SLR, template analysis fits with research that seeks to understand the mechanisms of the relationship between variables (King, 2012). This method has also been used previously in SCM research. Karatzas *et al.* (2007) for example, use this method to examine manufacturer-supplier relationships and service performance in a triadic supply chain, whereas Clegg and Wan (2013) employ template analysis to understand the relationship between different enterprise resource planning (ERP) systems in a Chinese manufacturing company.

The template analysis involved several processes. First, 51 screened articles were exported to NVivo 11 Plus. Each article was then read in detail. An *a priori* set of codes was developed to capture research questions, methodologies, findings, theoretical perspectives, logistics performance, types of perishable product, perishable product characteristics, unit of analysis, and unit of data collection. The first order coding process was then started to allow the collection of detailed information on explicit and/or implicit primary dimensions, secondary dimensions, antecedents, consequences, moderating dimensions, mediating dimensions, underlying mechanisms of IOIS, and perishable product-related performance. This terminology, henceforth referred to as *relationship* *mechanisms*, reflects the different ways IOIS is positioned amongst other distinctly defined constructs or variables in the IOIS-PPSC literature.

Primary dimensions refer to the main constructs or variables, whereas secondary dimensions or sub-dimensions represent supporting constructs or variables studied in the reviewed literature. Secondary dimensions can also represent measurement items used to define primary dimensions. The notion of primary and secondary dimensions is adapted from Watts *et al.* (1993) as cited in D'Souza and Williams (2000), which is in line with Podsakoff *et al.* (2006) who use the term "dimensions" to cover distinct facets of constructs with their specific measures or variables. This thesis adapts Bacharach's (1989) definition of a construct as "a broad mental configuration of a given phenomenon", whereas a variable is "an operational configuration derived from a construct". For example, performance is a construct, whereas product safety or quality is a variable representing performance. Therefore, a variable is the more concrete manifestation of a construct (Bacharach, 1989).

Antecedents in this study refer to interventions, drivers or determinants of primary dimensions; they are constructs or variables that trigger the existence of primary dimensions. Consequences are the implications or outcomes of primary dimensions. Moderating dimensions strengthen or weaken the relationship between primary dimensions and consequences, whereas mediating dimensions act as a bridge in this relationship. When mediating dimensions are taken away, the relationship between primary dimensions and consequences may not exist. Finally, underlying mechanisms of IOIS refer to mechanisms that produce the outcomes of IOIS, and explain how IOIS influences the outcomes. The notion of underlying mechanisms differs from mediating dimensions as they are not constructs or variables, but things that make up the relationship between constructs or variables. See the philosophical perspective section of Chapter 2 on page 14 in this thesis for further explanation of underlying mechanisms.

Following the first order coding, the second order coding process grouped the initial codes into categories and higher level themes. During the coding process, inputs from two academics in the area of logistics and SCM (including BSC) and information systems respectively are acquired to ensure the consistency and quality of the coding process. The diverse range of subject areas and methodological expertise of the academics reduced the risk of methodological or subject area bias. Finally, the "final" template (see King, 2012) consisting of the first and second order codes was analysed and interpreted.

### 3.1.2 Analysis and synthesis of literature

To understand how IOIS influences PPSC performance, this thesis unravels how the IOIS-PPSC literature addresses IOIS by mapping the relationship mechanisms that explicitly and implicitly relate IOIS to PPSC performance. Table 3-5 on page 51 shows the different relationship mechanisms that are reflected in the different positioning of the IOIS construct as an antecedent, primary dimension, secondary dimension, moderating dimension, mediating dimension, underlying mechanisms, and consequences of other constructs affecting the PPSC performance.

In row 1 of Table 3-5 on page 51, for example, this thesis identifies collaboration between buyers and suppliers as a central construct (i.e. primary dimension) which is explicitly addressed in the literature (Aggarwal and Srivastava, 2016). It then finds that collaboration is driven by the need to share vital information (Krishnakumar *et al.*, 2009); therefore IOIS is an antecedent of collaboration. It further identifies that collaboration can lead to supply chain efficiency and reduced waste (Aggarwal and Srivastava, 2016); therefore supply chain efficiency and waste are consequences of collaboration.

In row 3, this thesis identifies IOIS as a primary dimension explicitly linked to supply chain profitability as a consequence (Ferguson and Ketzenberg, 2006). In this row, it finds that the shorter the product shelf life, the stronger the impact of IOIS on profitability; therefore product shelf life is considered as a moderating variable (Ferguson and Ketzenberg, 2006).

**Table 3-5: Positioning of IOIS-PPSC constructs and variables**

| Explicitly or implicitly mentioned in the literature? | Antecedents (number of articles) | Primary dimensions (number of articles) | Secondary dimensions (number of articles) | Moderating dimensions (number of articles) | Mediating dimensions (number of articles) | Underlying mechanisms of IOIS (number of articles) | Consequences (number of articles) | Perishable product-related performance (number of articles) |
|---|---|---|---|---|---|---|---|---|
| Explicit | IOIS (5) | Collaboration (2), trust (1), innovation (1), transparency (1) | N/A | Technology adoption (1), information quality (1) | N/A | N/A | Profitability (2), SC efficiency (1) | Waste reduction (1), product safety (1), product quality (1) |
| Explicit | Openness (2), SC relationship (2), information quality (2), collaboration (1), costs and benefits (1), business strategy (1), regulation (1), SC netw ork (1), problem identification (1), communication media (1), frequency of communication (1), staff involvement (1), information access (1), level of IOIS (1), position in SC (1) | IOIS (23) | N/A | Shelf life (1), demand variability (1), product cost (1), integration focus (1), SC structure (1), information quality (1), information use (1), coordination structure (2), distance to market (1) | Spoilage (1), product availability (1), service level (1), quality compliance (1), communication quality (1), | N/A | Profitability (5), SC efficiency (2), collaboration (2), delivery (2), inventory management (2), customer satisfaction (2), sales (1), transaction cost (1), SC relationship (1), demand uncertainty (1), competitiveness (1), problem resolution (1), price decision (1), environmental cost (1), order fulfilment (1), inventory costs (1), supply costs (1), supply shortages (1) | Product quality (5), product safety (3), product availability (2), product freshness (2), outdate (2), w aste (1), shelf life (1) |
| Implicit | Technology adoption (1) | N/A | N/A | Information quality (10), technology adoption (7), product perishability (2), market pow er (1), information type (1), inventory policy (1), company characteristics (1), SC relationship (1), position in SC (1), information use (1) | N/A | SC visibility and responsive-ness (1) | Service level (1), SC efficiency (1), profitability (1), yield (1), resource allocation (1), sales revenue (1), IOIS efficiency (1), inventory management (1), risk management (1) | Product safety (5), Product quality (4), product availability (3), product freshness (1) |

**Table 3-5: Positioning of IOIS-PPSC constructs and variables *(continued)***

| Explicitly or implicitly mentioned in the literature? | Antecedents (number of articles) | Primary dimensions (number of articles) | Secondary dimensions (number of articles) | Moderating dimensions (number of articles) | Mediating dimensions (number of articles) | Underlying mechanisms of IOIS (number of articles) | Consequences (number of articles) | Perishable product-related performance (number of articles) |
|---|---|---|---|---|---|---|---|---|
| Explicit | Investment in IOIS system (2), technology adoption (1), openness (1) | Technology adoption (5), collaboration (2), demand management (2), SC database (2), SC practices (1), SC relationship (1), logistics solution (1), root causes of food w aste (1), SC resilience (1), governance structure (1), information standard (1), SC integration (1), inventory management (1) | IOIS (20) | Market pow er (1), SC structure (1), business process (1) | N/A | SC visibility (1), SC velocity (1), SC flexibility (1) | Order management (2), demand management (2), inventory management (2), visibility (2), profitability (1), collaboration (1), competitiveness (1), market share (1), forecasting (1), internal efficiency (1), labour hired (1), SC resilience (1), patient safety (1), revenue (1), labour savings (1), logistics efficiency (1), trust (1), size of partner netw ork (1), SC relationship (1), product shortages (1), mismatched units (1) | Product safety (2), product availability (2), w aste (2), product quality (1), unused product (1), blood donations (1), expired stock (1) |
| Implicit | Openness (2), costs and benefits (1), effectiveness of information flow (1), trust (1), entrepreneurial orientation (1) | N/A | N/A | Information quality (13), technology adoption (8), perishable product characteristics (2), information use (2), procurement management (1), quality management (1), logistics functions (1), performance incentives (1), SC relationship (1) | N/A | N/A | Delivery (2), order management (2), administration cost (2), responsiveness (1), customer satisfaction (1), data generation (1), patient safety (1), SC efficiency (1), inventory management (1), transportation management (1) | Product safety (5), product quality (2), product availability (2) |
| Explicit | N/A | Technology adoption (1), pow er balance (1), SC integration (1) | N/A | Company size (1), position in SC (1), perishable product characteristics (1), market characteristics (1), distance to market (1) | N/A | N/A | IOIS (2) | N/A |
| Implicit | N/A | N/A | N/A | Information quality (2) | Trust (1), commitment (1) | N/A | IOIS (1) | N/A |

This thesis further identifies in row 3 that the relationship between IOIS and profitability is indirect and only exists when IOIS influences product quality compliance (e.g. the extent to which suppliers provide products to meet customers' quality requirements) (Peng *et al.*, 2012); in this case, product quality compliance is a mediating variable. This way of mapping the literature helps this thesis to understand how IOIS-PPSC literature interprets the relationship between IOIS and PPSC performance.

#### 3.1.2.1 Positioning of the IOIS construct

Table 3-6 on page 54 summarises the number of articles and respective authors who explicitly or implicitly position IOIS amongst other constructs in the IOIS-PPSC literature. It can be observed that the vast majority of articles address IOIS as either a primary or secondary dimension. As shown in Table 3-5 on page 51, as a primary dimension, IOIS reduces inventory cost, decreases spoilage, and increases availability and service level as consequences (Ketzenberg *et al.*, 2015). The relationship between IOIS as a primary dimension and PPSC performance as the consequence is mediated by the quality of the communication between PPSC actors (Peng *et al.*, 2014). The relationship is also moderated by demand variability, product shelf life, and product cost. The benefits of IOIS are highest when demand variability is high, product shelf lives are short, and the cost of the product is high (Ferguson and Ketzenberg, 2006).

As a primary dimension, IOIS is driven by other constructs including openness and collaboration as its antecedents. Openness between PPSC actors can improve trust and therefore IOIS; increasing the value of the PPSC (Kottila, 2009). Low levels of collaboration hinder the flow of information; affecting product flow, product availability, and competitive advantage (Kottila, 2009). This argument suggests that IOIS can only exist once trust and collaboration are established (Kähkönen and Tenkanen, 2010; Kottila, 2009); which is inconsistent with another stream of research that positions IOIS as an antecedent of collaboration, trust, innovation, and transparency, all of which have been shown to influence PPSC operations and customer satisfaction (Aggarwal and

Srivastava, 2016; Krishnakumar *et al*., 2009; Mylan *et al*., 2015; Paterson *et al*., 2008; Trienekens *et al*., 2012).

**Table 3-6: Respective authors of IOIS-PPSC**

| IOIS-PPSC | Number of articles | Authors |
|---|---|---|
| IOIS as an explicit antecedent | 5 | Aggarwal and Srivastava (2016); Krishnakumar *et al.* (2009); Mylan *et al.* (2015); Paterson *et al.* (2008); Trienekens *et al.* (2012) |
| IOIS as an implicit antecedent | N/A | N/A |
| IOIS as a primary dimension | 23 | Beulens *et al*. (2005); Bevilacqua *et al.* (2009); Eksoz *et al.* (2014); Ferguson and Ketzenberg (2006); Henry and Wernz (2015); Jraisat *et al.* (2013); Kaipia *et al.* (2013); Kassahun *et al.* (2014); Ketzenberg and Ferguson (2008); Ketzenberg *et al*. (2015); Kochan *et al.* (2018); Kottila (2009); Nakandala *et al*. (2017); Peng *et al.* (2012, 2014); Ringsberg (2015); Schwarz and Zhao (2011); Shi *et al*. (2010); Solér *et al*. (2010); Trienekens and Wognum (2013); Yan *et al*. (2016); Zhang and Bhatt (2014); Zhong *et al.* (2015) |
| IOIS as a secondary dimension | 20 | Alftan *et al.* (2015); Anastasiadis and Poole (2015); Chircu *et al*. (2014); Clements *et al*. (2008); Dong *et al.* (2015); Engelseth (2013); Grant (2010); Katsaliaki and Brailsford (2007); Klein *et al.* (2014); Leblanc *et al.* (2015); Liljestrand (2017); Mena *et al.* (2011); Mohtadi and Kinsey (2005); Muangchoo and Kritchanchai (2015); Papert *et al.* (2016); Scholten and Schilder (2015); Smith and Lawrence (2014); Taylor (2006); Taylor and Fearne (2009); Van Veen-Dirks and Verdaasdonk (2009) |
| IOIS as an explicit moderating dimension | N/A | N/A |
| IOIS as an implicit moderating dimension | N/A | N/A |
| IOIS as an explicit mediating dimension | N/A | N/A |
| IOIS as an implicit mediating dimension | N/A | N/A |
| IOIS as an explicit underlying mechanism | N/A | N/A |
| IOIS as an implicit underlying mechanism | N/A | N/A |
| IOIS as an explicit consequence | 2 | Hill and Scudder (2002); Kähkönen and Tenkanen (2010) |
| IOIS as an implicit consequence | 1 | Bhakoo *et al.* (2015) |

As a secondary dimension, IOIS cannot be separated from other primary dimensions such as supply chain relationships, demand management, and technology adoption. Relationships in the PPSC are characterised by intense

IOIS, which facilitates supply chain actors to manage their functions to meet market-specific requirements (Clements *et al.*, 2008). Consistent IOIS and data handling procedures are key to enabling the alignment of demand and supply in the PPSC (Taylor, 2006; Taylor and Fearne, 2009). Adopting IOIS technology such as product movement analysis (PMA) allows the sharing of point of sales (POS) data leading to better forecasts of final demand (Mohtadi and Kinsey, 2005). In addition, the use of standardised information systems, mobile technologies, or radio frequency identification (RFID), all incur high joint investment costs. However, these technologies enable a continuous flow of information and enhanced SC traceability, leading to reduced risk of product safety problems in the PPSC (Chircu *et al.*, 2014; Dong *et al.*, 2015; Engelseth, 2013; Klein *et al.*, 2014).

The review finds no article which posits IOIS as a moderating construct, mediating construct, and/or an underlying mechanism. However, IOIS as a consequence of other constructs does appear. Hill and Scudder (2002) position IOIS as a consequence of technology adoption. They find that although the use of electronic data interchange (EDI) does not significantly impact on the degree of coordination between firms and their customers, EDI users have a higher degree of coordination with their suppliers. They measure coordination in terms of the active role of firms in an efficient consumer response (ECR) programme in which IOIS is a key element (see Corsten and Kumar (2005) for ECR measures). Hill and Scudder (2002) further find that EDI is used as a tool for improving efficiency rather than for facilitating SC integration.

On the other hand, Kähkönen and Tenkanen (2010) examine the relationship between market power and the willingness to share information. They find that supply chain actors with greater market power (close to the end customer) often have control over market intelligence information, and therefore are not willing to share information upstream in the SC. The degree of SC vertical integration also affects the choice of IOIS technologies ranging from barcoding, enterprise resource planning (ERP), and EDI (Bhakoo *et al.*, 2015). To ensure flexibility in sharing information, vertically disintegrated SCs have a broader portfolio of technologies compared to vertically integrated SCs which focus on standardised technologies to monitor and share performance information across the SC (Bhakoo *et al*., 2015).

### 3.1.2.2 The role of perishable product-related dimensions

Although a considerable amount of literature explicitly and implicitly addresses perishable product performance (see Table 3-5 on page 51), only six out of 51 articles explicitly address the importance of the characteristics of perishable products in the PPSC. Additionally, those articles present divergent findings on how perishable product characteristics shape the relationship between IOIS and PPSC performance.

Hill and Scudder (2002), for example, find that product characteristics such as seasonality and perishability do not predict whether a company is more likely to use EDI and hence have enhanced IOIS with its suppliers. In contrast, Clements *et al.* (2008) argue that the vulnerable nature of the products (i.e. being perishable and seasonal) leads to frequent IOIS, supporting tight delivery schedules and PPSC integration, maintaining product quality. Other perishable product characteristics such as sensitivity to temperature also need to be considered when designing an IOIS system to enhance SC visibility and therefore product quality (Papert *et al*., 2016).

Ferguson and Ketzenberg (2006), Ketzenberg and Ferguson (2008), and Ketzenberg *et al.* (2015) are among the few authors that explicitly examine the role of perishable product characteristics in the IOIS-PPSC literature. According to Ferguson and Ketzenberg (2006), the shelf life and demand variability of perishable products moderates the relationship between IOIS and PPSC performance in terms of product freshness. Optimal benefits from sharing information are gained when product shelf lives are short, and demand variability is high (Ferguson and Ketzenberg, 2006; Ketzenberg and Ferguson, 2008).

However, Ketzenberg *et al*. (2015) find that the value of IOIS in the PPSC follows a “diminishing return”. For highly perishable products with very short shelf lives, of a day or less, there is little uncertainty as to when the product will perish; thus sharing time-temperature information confers little value to the supply chain (Ketzenberg *et al*., 2015). The value of information increases with shelf life to an intermediate level of perishability (about a seven-day shelf life); the value then drops as the level of perishability decreases so that sharing time-temperature information becomes irrelevant when the product is not perishable (Ketzenberg *et al*., 2015).

#### 3.1.2.3 Classification of constructs and variables

To characterise the patterns and relationships amongst constructs and variables that explain how IOIS influences PPSC performance, the constructs and variables of IOIS-PPSC identified in Table 3-5 on page 51 were further classified into higher level themes (see Table 3-7 on page 58). In line with Premkumar *et al.* (2005), this thesis classified investments in IOIS systems as relationship/asset-specific investments. All constructs and variables related to supply chain (SC) collaboration and integration were classified as SC interdependence. This is in line with Kim *et al.* (2005) who measure interdependence in terms of the degree of collaborative or integrative work which occurs between SC actors. This classification was also partly based on the dependency factors suggested by Cool and Henderson (1998). Concurring with Yigitbasioglu (2010), Kim *et al.* (2005), and Premkumar *et al.* (2005), relationship/asset-specific investments and SC interdependence were further classified as relationship uncertainty.

This thesis classified constructs and variables such as inventory management, order management, and perishable product characteristics under internal operations, whereas regulation, customer satisfaction, market characteristics, and sales were classified as external conditions. In line with Wong *et al*. (2011), these categories were further classified as environmental uncertainty. Next, all constructs and variables related to technology and information management were classified as IOIS capabilities, concurring with Premkumar *et al.* (2005). Finally, following Beamon (1999) and Yigitbasioglu (2010), this thesis classified SC performance constructs and variables as output, resource, and flexibility measures. Output measures focus on achieving a high level of customer service;

resource measures are designed to achieve high levels of efficiency; whereas flexibility measures are used to assess the ability of SC actors to respond to a changing environment.

**Table 3-7: Classification of IOIS-PPSC constructs and variables**

| Central themes | Categories | Constructs and variables |
|---|---|---|
| Relationship uncertainty | Relationship/asset-specific investments | Investment on IOIS system |
| | SC interdependence | SC collaboration, SC integration, trust, openness, SC visibility/transparency, commitment, power relations, SC relationship, governance structure, coordination structure, SC structure, position in SC, distance to market |
| Environmental uncertainty | External business conditions | Regulation, customer satisfaction, market characteristics, sales |
| | Internal operations | SC practices, demand management, inventory management, order management, procurement management, quality management, transportation management, forecasting, yield, resource allocation, risk management, costs and benefits of IOIS, business strategy, business process, innovation, problem identification, staff involvement, performance incentives, distribution of perishables, entrepreneurial orientation, SC resilience, velocity, flexibility, responsiveness, perishable product characteristics |
| IOIS capabilities | Technology and information management | Technology adoption, information quality, communication quality, communication media, frequency of communication, information access, information types, information standard, information needs, information use, SC database, direction of IOIS, frequency of IOIS |
| PPSC performance | Output performance | Profitability, revenue, sales, delivery, customer satisfaction, service level, yield, stockout, market share, environmental cost, sustainability, product safety, product quality, product availability, shelf life, product freshness, waste, spoilage, blood donations, expired stock, mismatched units, product/supply shortages |
| | Resource performance | SC efficiency, inventory cost, transaction cost, resource allocation, labour hired, administration cost, supply costs |
| | Flexibility performance | Competitiveness, problem resolution, ability to forecast demand, SC resilience, responsiveness |

Following this classification process, Table 3-5 on page 51 was reproduced by replacing the identified constructs and variables with the higher level themes (see Table 3-8 on page 60). To have a clearer depiction of the relationships between the identified themes and subthemes, Figure 3-3 was produced as a conceptual framework summarising the SLR. The conceptual framework was derived from different positioning of IOIS and the other identified themes or subthemes (i.e. as antecedents, primary dimensions, secondary dimensions, moderating dimensions, mediating dimensions, underlying mechanisms, and/or consequences – see Table 3-8 on page 60) and their relationships with PPSC performance.

In Figure 3-3 on page 62, shaded areas represent themes, whereas unshaded areas represent subthemes. Solid arrows in Figure 3-3 on page 62 show the regularity-based relationships between the identified themes or subthemes. The positive and negative symbols at the end of the solid arrows suggest the directions of relationships between themes or subthemes that are inferred quantitatively or qualitatively from the literature. For example, a positive relationship between IOIS and PPSC performance means that IOIS brings positive changes to PPSC performance or the increase in the intensity of IOIS leads to the increase in PPSC performance. The positive relationship between IOIS and PPSC performance also means that the decrease in the intensity of IOIS leads to the decrease in PPSC performance. A negative relationship between IOIS and PPSC performance means that IOIS brings negative changes to PPSC performance or the increase in the intensity of IOIS leads to the decrease in PPSC performance. The negative relationship between IOIS and PPSC performance also means that the decrease in the intensity of IOIS leads to the increase in PPSC performance.

The positive and negative relationships also apply for moderating themes or subthemes. For example, environmental uncertainty can positively or negatively moderate the relationship between IOIS and PPSC performance. Positive moderation can be observed when the higher the environmental uncertainty, the stronger the relationship between IOIS and PPSC performance. In contrast, negative moderation can be observed when the lower the environmental uncertainty, the stronger the relationship between IOIS and PPSC performance.

Finally, the dashed arrows show the relationships between the identified subthemes that are explained using the notion of underlying mechanisms. Notice for example that the dashed arrows flow through rather than point towards SC interdependence and internal operations. This suggests that these two subthemes are the underlying mechanisms that explain the relationship between IOIS and PPSC performance (see sub-subsection 3.1.2.7 on page 67 for details).

**Table 3-8: Positioning of IOIS-PPSC constructs and variables with higher level themes**

| Explicitly or implicitly mentioned in the literature? | Antecedents | Primary dimensions | Secondary dimensions | Moderating dimensions | Mediating dimensions | Underlying mechanisms of IOIS | Consequences/types of PPSC performance |
|---|---|---|---|---|---|---|---|
| Explicit | IOIS | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: Internal operations | N/A | IOIS capabilities: technology and information management | N/A | N/A | Output, resource |
| Implicit | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Explicit | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: external conditions, internal operations<br>IOIS capabilities: technology and information management | IOIS | N/A | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations<br>IOIS capabilities: technology and information management | Environmental uncertainty: internal operations<br>IOIS capabilities: technology and information management | N/A | Output, resource, flexibility |
| Implicit | IOIS capabilities: technology and information management | N/A | N/A | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations<br>IOIS capabilities: technology and information management | N/A | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations | Output, resource |
| Explicit | Relationship uncertainty: Relationship/asset-specific investments, SC interdependence<br>IOIS capabilities: technology and information management | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations<br>IOIS capabilities: technology and information management | IOIS | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations | N/A | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations | Output, resource, flexibility |

**Table 3-8: Positioning of IOIS-PPSC constructs and variables with higher level themes *(continued)***

| Explicitly or implicitly mentioned in the literature? | Antecedents | Primary dimensions | Secondary dimensions | Moderating dimensions | Mediating dimensions | Underlying mechanisms of IOIS | Consequences/types of PPSC performance |
|---|---|---|---|---|---|---|---|
| Implicit | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations<br>IOIS capabilities: technology and information management | N/A | N/A | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: internal operations<br>IOIS capabilities: technology and information management | N/A | N/A | Output, resource, flexibility |
| Explicit | N/A | Relationship uncertainty: SC interdependence<br>IOIS capabilities: technology and information management | N/A | Relationship uncertainty: SC interdependence<br>Environmental uncertainty: external conditions, internal operations | N/A | N/A | IOIS |
| Implicit | N/A | N/A | N/A | IOIS capabilities: technology and information management | Relationship uncertainty: SC interdependence | N/A | IOIS |

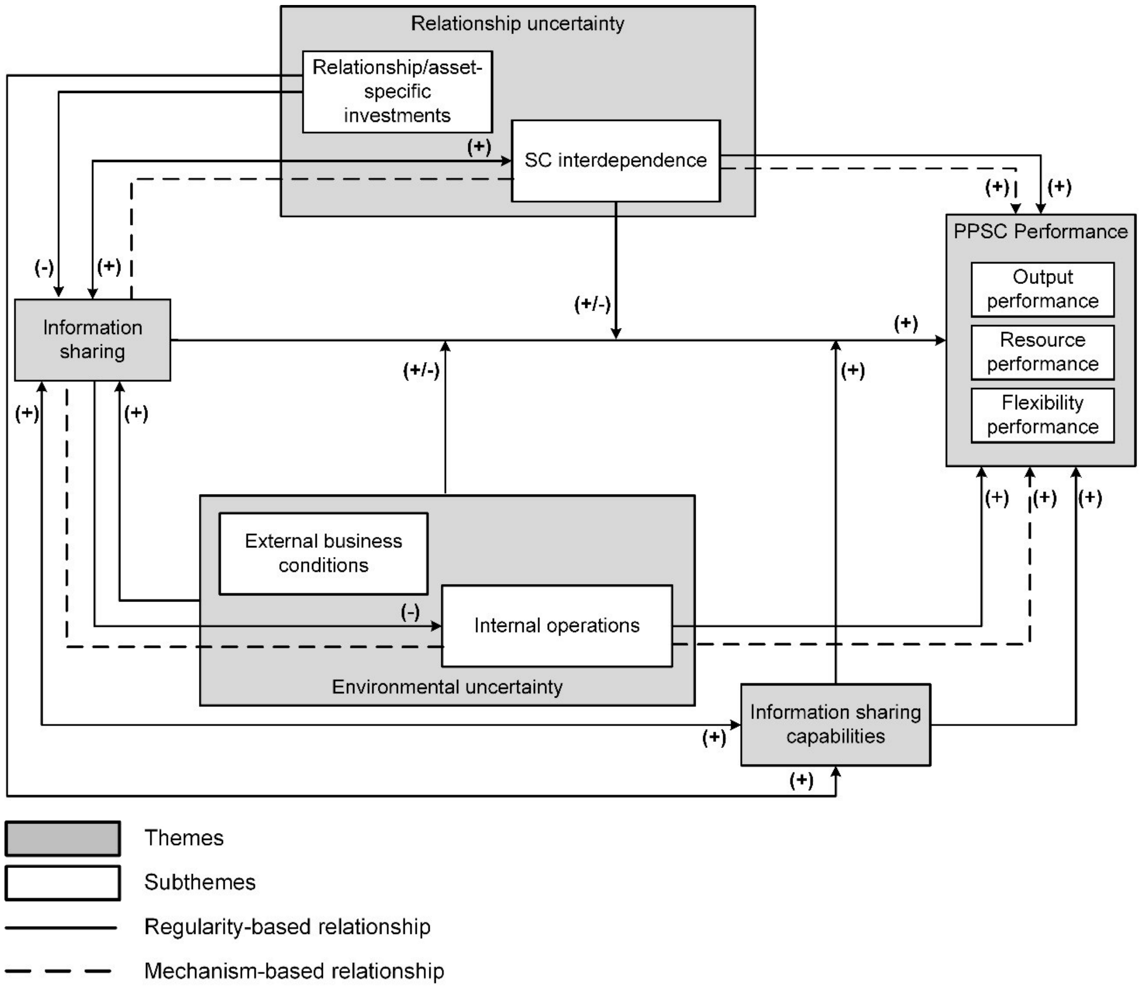


**Figure 3-3: Conceptual framework of IOIS-PPSC from the SLR**

### 3.1.2.4 IOIS, relationship uncertainty, and PPSC performance

The SLR finds the link between IOIS, relationship uncertainty, and PPSC performance. Whilst it is agreed that sharing product-related information is essential in the PPSC and is usually facilitated by traceability systems, in cases where traceability compliance is not mandatory by law, Klein *et al.* (2014) find that high investment cost is a barrier to the adoption of traceability systems. The main cost of such investment is usually borne by the producers, driven by buyers' expectation of safe products and technology infrastructure. This leaves producers in a "locked up" relationship with no real belief in the benefits of the traceability systems they have invested in, hindering IOIS due to the poor use of the systems and therefore affecting product safety in the PPSC (Klein *et al.*, 2014).

In fact, whilst a traceability system is vital for delivering product safety and quality, in practice, SC actors are reluctant to share information using such an expensive system. Instead, manual solutions, although prone to incidents, are preferred to reduce the investment risk (Engelseth, 2013). Whilst more empirical investigation is still required, these arguments imply that high relationship/asset-specific investment does not necessarily lead PPSC actors to share information. Instead, it can negatively affect the willingness to share information when it is perceived to be an expensive solution with minimal benefit for the PPSC actors (see a solid negative arrow flowing from relationship/asset-specific investment to information sharing in Figure 3-3).

Relationship uncertainty also reflects the degree of interdependence amongst SC actors. The SLR finds that the role of SC interdependence in the relationship between IOIS and PPSC performance is inconsistent; and further research is required. For example, some research posits that the degree of interdependence between buyers and suppliers positively affects the intensity of IOIS in the PPSC (e.g. Jraisat *et al.*, 2013; Kottila, 2009 – see a solid positive arrow flowing from SC interdependence to information sharing in Figure 3-3 on page 62). Kottila (2009) also suggests that low levels of collaboration hinder the flow of information; affecting product flow, product availability, and competitive advantage. This puts collaboration as an antecedent of IOIS. In fact, IOIS helps PPSC actors to increase the transparency of their activities, improves trust and strengthens collaboration; thus leading to secure and sustained inter-organisational relationships (e.g., Aggarwal and Srivastava, 2016; Krishnakumar *et al.*, 2009; Paterson *et al.*, 2008) and improved output performance such as product safety, quality, and availability (Clements *et al.,* 2008). This suggests that collaboration is a consequence rather than antecedent of IOIS (see a solid positive arrow flowing from information sharing to SC interdependence in Figure 3-3 on page 62).

The nature of SC interdependence can also moderate the relationship between IOIS and PPSC performance. This moderation effect is particularly relevant when the relationship between SC actors is not mutually beneficial or when there is a power imbalance. For example, retailers with significant market power and a large supplier base are more willing to share sensitive market and inventory information than those with a smaller number of suppliers, and are hence logistically more efficient (Mohtadi and Kinsey, 2005 – see a solid positive arrow flowing from SC interdependence to a positive arrow between information sharing and PPSC performance in Figure 3-3 on page 62). These powerful retailers facilitate open IOIS and are less concerned with the potential for opportunistic behaviour from suppliers. In contrast, Kähkönen and Tenkanen (2010) argue that such retailers can instead use their position and power to control market information and their suppliers and are, therefore, less willing to share information (see a solid negative arrow flowing from SC interdependence to a positive arrow between information sharing and PPSC performance in Figure 3-3 on page 62).

Finally, the moderating impact of SC interdependence is also reflected in Ketzenberg and Ferguson's (2008) study of IOIS in a dyadic SC. In their research, Ketzenberg and Ferguson (2008) compare a decentralised setting – when the retailer and supplier share demand, inventory, and ordering policy but try to maximise their own profit – and a centralised control of information – when incentives and replenishment decisions are coordinated; a practice known as vendor managed inventory (VMI). Even though in the decentralised setting the retailer gains benefit by receiving fresher product from the supplier, Ketzenberg and Ferguson (2008) prove that the centralised control offers a higher increase in the SC profit than that of the decentralised IOIS.

Building on this, Kassahun *et al*. (2014) discuss the technical issue of centralised and decentralised IOIS. In their research, the centralised IOIS is defined as a single shared transparency system that is created to collect and access SC-wide information. The decentralised IOIS, on the other hand, is defined as a distributed information sharing where the SC actors maintain their own transparency systems that are interconnected across the SC. Kassahun *et al*. (2014) argue that to realise the SC-wide transparency that potentially leads to a better guarantee of product safety, quality, and trust amongst the SC actors, the IOIS systems have to accommodate both centralised and decentralised approaches.

#### 3.1.2.5 IOIS, environmental uncertainty, and PPSC performance

The SLR finds an interactive relationship between environmental uncertainty and IOIS. Regulations and product perishability represent uncertainty in the external and internal environments respectively, which motivates SC actors to establish IOIS systems (Kassahun *et al*., 2014 – see a solid positive arrow flowing from environmental uncertainty to information sharing in Figure 3-3 on page 62). The European Union food regulations for example regulate the quality and safety of food products as well as dictate the need for record keeping and the way the food SC actors share information (Kassahun *et al*., 2014). The regulations require transparency through the use of proper labelling systems and sharing information with the SC actors' direct suppliers and customers (Kassahun *et al*., 2014). In return, IOIS enables the tracking and tracing of perishable products, decreasing spoilage, reducing product waste and improving product freshness (Kaipia *et al*., 2013; Ketzenberg and Ferguson, 2008; Ketzenberg *et al*., 2015; Klein *et al*., 2014; Papert *et al.,* 2016); therefore reducing uncertainty in the internal environment (see a solid negative arrow flowing from information sharing to internal operations in Figure 3-3 on page 62).

Despite this interactive relationship, some research demonstrates that environmental uncertainty can also moderate the relationship between IOIS and PPSC performance. Ketzenberg *et al.* (2015) for example suggest that the value of IOIS increases with respect to decreasing demand uncertainty (see a solid negative arrow flowing from environmental uncertainty to a positive arrow between information sharing and PPSC performance in Figure 3-3 on page 62). However, Clements *et al.* (2008) imply that external conditions such as the changing seasons and unpredictable weather increase environmental uncertainty, strengthening the positive relationship between IOIS and PPSC performance. Ferguson and Ketzenberg (2006) also suggest that the benefits of IOIS are highest when demand variability is high, product shelf lives are short, and the product cost is high – in other words, under highly uncertain internal operations. In addition, Ketzenberg and Ferguson (2008) propose that the requirement of the PPSC to deliver fresh products imparts a higher value to IOIS; suggesting that product perishability strengthens the positive relationship between IOIS and PPSC performance (see a solid positive arrow flowing from environmental uncertainty to a positive arrow between information sharing and PPSC performance in Figure 3-3 on page 62).

However, the reviewed IOIS-PPSC literature defines and measures product perishability only considering product shelf life, ignoring the other distinctive set of characteristics, such as vulnerability, susceptibility to contamination by disease and damage by unpredictable weather. All of these characteristics make it difficult to guarantee quality standards and product availability (Clements *et al.*, 2008). Also, special storage conditions, such as a cold chain, are often required to slow the rate of product decay (Van Donselaar *et al.*, 2006). Extensive IOIS is therefore critical for the controlling and monitoring of product safety and quality across the SC (Salin, 1998; Shi *et al.*, 2010). Whilst some of these characteristics are discussed implicitly in the IOIS-PPSC literature, the SLR finds no article which explicitly and specifically addresses the role of perishable product characteristics in shaping the relationship between IOIS and PPSC performance.

#### 3.1.2.6 IOIS, IOIS capabilities, and PPSC performance

This SLR suggests that IOIS capabilities can moderate the relationship between IOIS and PPSC performance. The majority of the reviewed literature implicitly suggests that, to be effective, IOIS needs to be supported by quality information and the relevant adoption of IOIS technology (e.g. Bevilacqua *et al.*, 2009; Kassahun *et al.*, 2014; Shi *et al.*, 2010; Yan *et al.*, 2016; Zhang and Bhatt, 2014); therefore they are implicitly positioned as moderating dimensions in the IOIS-PPSC (see Table 3-5 on page 51). Information quality refers to accuracy, reliability, relevance, adequacy, ease of access and timeliness of the information shared across the PPSC (Bensaou, 1995); whereas IOIS technology can range from RFID to Internet-based traceability systems (e.g. Shi *et al.*, 2010).

This SLR finds that the appropriate use of quality information strengthens the benefits of IOIS, such as reduced waste, increased product availability (e.g. Kaipia *et al.*, 2013), and even improved profitability (e.g. Schwarz and Zhao, 2011). Similarly, visibility of product flow and real-time monitoring of cold chain distribution should be supported by appropriate IOIS technology, such as RFID, sensor, and wireless communication technologies, to ensure product quality during the distribution (e.g. Shi *et al*., 2010) – see a solid positive arrow flowing from information sharing capabilities to a positive arrow between information sharing and PPSC performance in Figure 3-3 on page 62.

Inconsistent with these findings, this SLR also reveals that IOIS capabilities can be a mediating construct and at the same time an antecedent in the IOIS-PPSC, forming an interactive relationship (see a solid interactive positive arrow flowing between information sharing and information sharing capabilities in Figure 3-3 on page 62). For example, Peng *et al.* (2014) suggest that the willingness to share information and IOIS behaviour (i.e. the frequency of sharing information and multifunctional staff involved) positively affect information quality, which in turn positively affects IOIS benefits such as cost reduction, problem resolution, quality control and delivery, and the efficiency of the PPSC. On the other hand, the willingness to share information is dependent on the ease of access of the shared platform such as traceability system or information centre (e.g. Trienekens and Wognum, 2013; Zhong *et al*., 2015), which requires the willingness of PPSC actors to invest in relationship/asset-specific IOIS technologies (e.g. Engelseth, 2013; Klein *et al*., 2014) – see also a solid positive arrow flowing from relationship/asset-specific investments to information sharing capabilities in Figure 3-3 on page 62.

#### 3.1.2.7 The notion of underlying mechanisms in the IOIS-PPSC literature

Whilst the relationship between IOIS and PPSC performance has been diversely and inconsistently addressed in the reviewed literature, the SLR only finds two articles which explicitly and implicitly address *how* the relationship happens using the notion of underlying mechanisms. As none of the reviewed literature explicitly or implicitly states its philosophical perspective, this result implies that there is currently a paucity of research adapting critical realism as a research paradigm to understand the IOIS-PPSC phenomenon (see the philosophical perspective section of Chapter 2 on page 14 in this thesis). This result is important because there is currently a lack of clarity and consistency in the relationship between IOIS and PPSC performance. Understanding the underlying mechanisms of how IOIS influences PPSC performance may therefore help clarify the relationship whilst offering a different way of capturing the IOIS-PPSC phenomenon.

Amongst the two articles, Scholten and Schilder (2015) explicitly unravel the underlying mechanisms of how IOIS influences SC resilience, although IOIS in their research is treated as a secondary dimension of SC collaboration. When sharing information, the PPSC actors need to consider their IOIS behaviour (i.e. content, modality, direction, and frequency of information sharing) and information quality to achieve visibility, velocity, and flexibility of operations, therefore improving SC resilience (Scholten and Schilder, 2015). For example, sharing information on upcoming disruptions via weekly site visits between buyers and suppliers helps generate the visibility of operations across the actors' facilities, enabling early identification of and quick response to possible disruptions (see Figure 3-3 on page 62, a dashed positive arrow flowing from information sharing to PPSC performance through SC interdependence as a subtheme for SC visibility). Sharing accurate and timely information on SC disruptions allows for velocity and flexibility of operations, enabling continuity of production and delivery of products to the end customers (see Figure 3-3 on page 62, a dashed positive arrow flowing from information sharing to PPSC performance through internal operations as a subtheme for SC velocity and flexibility).

Kochan *et al.* (2018) produced another article that implicitly addresses the underlying mechanisms of how IOIS influences PPSC performance. Kochan *et al.* (2018) investigate the use of cloud-based information sharing in the hospital SC and implicitly suggest that IOIS enables the visibility of inventory across the SC, allowing better responsiveness to fluctuations in patient demand, supply lead times, and customer expectation. These mechanisms (i.e. visibility and responsiveness) result in better order fulfilment of medicine in the hospital as well as reductions in supply shortages, supply costs, and inventory costs.

Whilst Scholten and Schilder (2015) and Kochan *et al.* (2018) provide interesting examples of the notion of underlying mechanisms, which are relevant to this thesis, they present some limitations pointing to further research into the IOIS-

PPSC phenomenon. Scholten and Schilder's (2015) research is limited to explaining the relationship between IOIS and visibility, velocity, and flexibility as the important constructs of SC resilience. They call for further exploration on the other important constructs of SC resilience such as redundancy. Kochan *et al.*'s (2018) research is based purely on simulation modelling with certain assumptions made to simplify the interpretation of the results. Empirical research can help validate their results. In addition, the model does not incorporate the perishability of medicines in the hospital SC. Future research should address this characteristic. Finally, Kochan *et al.* (2018) develop and simulate their model only considering normal conditions. They call for future research to study IOIS and its impacts on SC performance in different operational settings, such as in the event of patient emergency and disasters.

### 3.1.3 Conclusions and implications of the SLR

The SLR finds that there is currently a paucity of research into IOIS in the BSC, with no article addressing the phenomenon using an HRO's perspective. This finding therefore confirms the novelty of this thesis.

The SLR provides lessons learnt by reviewing IOIS research in the broader domain of PPSC literature. After selecting and reviewing 51 mainly empirical inter-disciplinary articles on IOIS-PPSC published in the last 16 years, the SLR reveals that research into IOIS-PPSC can be positioned between the intermediate and mature states, calling for further exploration of provisional theories or constructs to refine the existing theories or constructs in the literature. This is evidenced by the prevalence of case study and survey as the dominant methodological approaches to study the IOIS-PPSC phenomenon (see Edmondson and McManus, 2007). In addition, the lack of use of theoretical perspectives to understand the phenomenon alludes back to the fragmented PPSC literature, oriented towards problem solving rather than theory development (Shukla and Jharkharia, 2013).

Whilst all the literature reviewed agrees that IOIS affects PPSC performance, the SLR suggests that the relationship between IOIS and PPSC performance remains unclear and that there is inconsistency in the positioning of IOIS amongst the other constructs and variables identified in the IOIS-PPSC literature. This inconsistency reflects different ways of understanding the phenomenon of IOIS-PPSC and its relationship with PPSC performance. In addition, whilst this thesis has strictly limited the scope of the review to the PPSC context, the role of perishable product characteristics in shaping the relationship between IOIS and PPSC performance has been largely ignored by studies to date. This implies that further investigation into the benefits of IOIS in the PPSC context is required.

Finally, there is currently a paucity of research addressing the relationship between IOIS and PPSC performance using the notion of underlying mechanisms. Although none of the reviewed literature explicitly or implicitly states its philosophical perspective, this result implies that an alternative research paradigm such as critical realism does not currently attract much attention in the reviewed literature. A possible explanation might be linked to the belief that positivism is the predominant philosophical stance in the SCM literature (Aastrup and Halldórsson, 2008; Gammelgaard, 2004, 2017; Mentzer and Kahn, 1995), whereas, critical realism was introduced to it quite recently (see Aastrup and Halldórsson, 2008; Adamides *et al*., 2012; Gammelgaard, 2017). Whilst offering a different way of capturing the IOIS-PPSC phenomenon, adapting the critical realism paradigm with its notion of underlying mechanisms might help clarify the relationship between IOIS and PPSC performance, which has been inconsistently addressed in the reviewed literature.

The findings from the SLR leave some important implications for this thesis. First, the SLR confirms the novelty of this thesis as the reviewed literature reveals no article addressing how IOIS influences blood safety and availability using high reliability theory (HRT). Second, the elaboration of HRT in this thesis reflects the need to explore the provisional theoretical perspectives to understand the IOIS-PPSC phenomenon, which is in line with Kembro *et al.*'s (2014) call for the use of theoretical perspectives to comprehensively understand the phenomenon of IOIS in general SCs. Finally, whilst Scholten and Schilder (2015) and Kochan *et al.* (2018) have attempted to address the underlying mechanisms of *how* IOIS influences PPSC performance, they present some important limitations that lead to the call for further research to understand how IOIS influences PPSC performance across a range of operational conditions. This thesis contributes by building on their arguments and addressing their limitations; at the same time, it explicitly advocates the adaptation of critical realism as a research paradigm underpinning the study to reveal the underlying mechanisms.

### 3.1.4 Research question and key definitions

Informed by the practical and research problems, the critical realism paradigm, HRT, and the results of the SLR, this thesis asks the following research question:

*How does inter-organisational information sharing influence blood safety and availability in the dyadic blood supply chain in normal, high tempo, and emergency conditions?*

Following Lusiantoro *et al*. (2018:258), inter-organisational information sharing (IOIS) is defined as "inter-organisational communication of meaningful data and/or explicit knowledge amongst SC [supply chain] actors". This definition treats information as data (i.e. facts and messages) with relevance and purpose (Choo *et al*., 2000; Davenport, 1997) and as explicit knowledge (e.g. advice, reports, standard operating procedures (SOPs)) that can be easily articulated and transferred across entities (Alavi and Leidner, 2001; Stenmark, 2002). As such, this thesis adapts the notion that information, data, and knowledge are interwoven (Alavi and Leidner, 2001; Kembro and Näslund, 2014; Stenmark, 2002).

This thesis adapts Harland's (1996) definition of "supply chain" as the relationships between two or more organisations, excluding the internal SC and therefore intra-organisational information sharing. The focus on dyadic analysis allows a better understanding of the behavioural aspects of relationships in SCs (Harland, 1996), including IOIS behaviour. The dyadic analysis is also in line with Kembro and Näslund's (2014) recommendation to better represent the "supply chain" by going beyond the perspective of merely a focal organisation in the supply chain.

The dyadic blood supply chain (BSC) refers to the linkage between blood centres and their associated hospitals. Blood centres refer to stock holding units. In practice, stock holding units and hospitals represent the two important actors in the BSC, representing a direct relationship between supply and demand for blood products respectively. In fact, they are usually managed by two separate organisations. It is therefore relevant to focus on IOIS in this dyad as the unit of analysis. From this point forward, the BSC refers to the dyadic linkages between blood centres and their associated hospitals.

In this work, blood refers to blood components, mainly red blood cells (RBCs), platelets (PLTs), and fresh frozen plasma (FFP) that are all critical for human life and are commonly moved across the dyad. In line with WHO (2017a) and Serious Hazards of Transfusion (SHOT) (2016), blood safety covers several issues, such as virus contamination, patient reaction to transfusion, blood quality, and safety-related issues/incidents, both in blood centres and their associated hospitals. Blood availability refers to blood stock levels or sufficiency both in blood centres and their associated hospitals. Some measures such as stockout, overstock, and wastage are also included within the blood availability problem.

Adapting La Porte and Consolini (1998) and to reflect high reliability theory (HRT), three operational conditions are examined in this thesis – normal, high tempo, and emergency. This is relevant due to the fact that the BSC should ensure that blood products are always safe and available whenever required by patients and under any conditions. Accordingly, it is assumed that the BSC operates differently in these different conditions. In this thesis, normal conditions represent business as usual or day-to-day operations where there is no particular event happening that might significantly affect blood safety and availability (BSA). High tempo conditions are those where particular events happen causing sudden changes in BSA. These conditions include internal events (e.g. blood safety incidents, blood shortage, local stockouts, overstocks) and external events (e.g. Christmas, Easter, Bank Holiday, Olympic Games) that might cause “turbulence” (i.e. manageable changes or fluctuations in BSA) within the BSC. Some of the high tempo events might be anticipated or cyclical in nature. Finally, the major unexpected events, such as major haemorrhages, major traffic accidents, fridge failures, floods, terrorist attacks, cyber attacks, national stockouts, and/or any other unexpected events causing high disruption within the BSC, are categorised as emergency conditions.

### 3.1.5 Aim and objectives

The aim of this thesis is to determine and unravel the underlying mechanisms of how inter-organisational information sharing (IOIS) influences blood safety and availability (BSA) in the dyadic blood supply chain (BSC) in normal, high tempo, and emergency conditions. To achieve the aim, five objectives have been set in this thesis:

1. To identify IOIS behaviour (i.e. what, how, with whom, and how often information is shared) associated with ensuring BSA in the dyadic BSC in normal, high tempo, and emergency conditions.
2. To identify co-actions underpinning the IOIS behaviour in the dyadic BSC in normal, high tempo, and emergency conditions.
3. To explain the co-actions underpinning the IOIS behaviour using high reliability theory, particularly its central concept of collective mindfulness in the dyadic BSC in normal, high tempo, and emergency conditions.
4. To identify and explain if there are other emerging underlying mechanisms that explain the co-actions underpinning the IOIS behaviour in the dyadic BSC in normal, high tempo, and emergency conditions.
5. To propose and explain a theoretical framework characterising the underlying mechanisms of how IOIS influences BSA in the dyadic BSC in normal, high tempo, and emergency conditions.

The following chapter (Chapter 4) presents the research methodology that is informed by the findings of the SLR.

# 4 RESEARCH METHODOLOGY

In this chapter, the research methodology adopted in this thesis is presented in detail. It covers fundamentals and rationales for adapting the research design as well as data collection and data analysis methods to answer the research question.

## 4.1 Research design

The embedded multiple case study designed for theory elaboration is adapted to answer the research question (Ketokivi, 2006; Ketoviki and Choi, 2014; Yin, 2014). Figure 4-1 on page 76 shows the research design used in this thesis. The one-way arrows represent the flow of the research processes, whereas the two-way arrows suggest that the two processes are interactive. In this section, the fundamentals and rationales for adapting this research design are presented.

Yin (2014:16) defines case study as "an empirical enquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context especially when the boundaries between phenomenon and context may not be clearly evident". Case study enables the extensive and in-depth description of a social phenomenon and is suitable for answering "how" research questions in order to understand relevant behavioural events that cannot be manipulated (Yin, 2014). Case study should meet *the duality criterion* in that it is *situationally grounded* on the unique context of research and seeks *a sense of theoretical generality* to broaden theoretical understanding through abstraction, therefore enabling theory elaboration (Ketokivi and Choi, 2014).

Edmondson and McManus (2007) suggest that case study is fit for research that falls into the intermediate state in which relationships among constructs are commonly unclear and inconsistent. Above all, case study supports the critical realism paradigm that offers a deeper understanding of relationships among events/constructs through the notion of underlying mechanisms (Aastrup and Halldórsson, 2008; Easton, 2010).

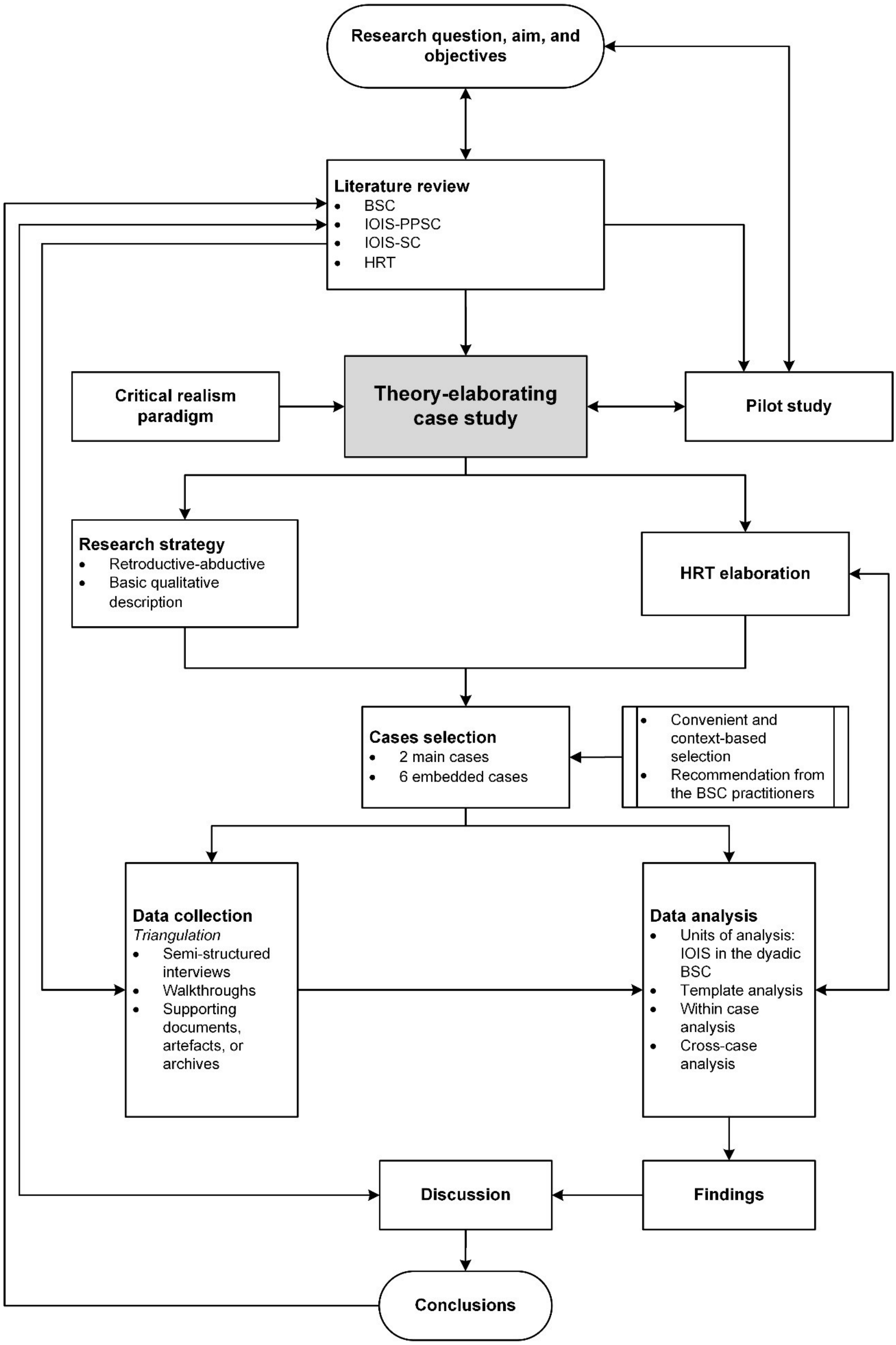


**Figure 4-1: Research design of the thesis**

**Table 4-1: Fundamentals and rationales for adapting the case study design**

| Fundamentals of case study design | Is the fundamental met in this thesis? | Rationales for adapting case study design in this thesis that are in line with the fundamentals |
|---|---|---|
| Case study is "an empirical enquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2014:16). | Yes | A contemporary phenomenon of IOIS behaviour in the unique context of the BSC is investigated. |
| Case study is suitable for answering "how" research questions in order to understand relevant behavioural events that cannot be manipulated (Yin, 2014). | Yes | This thesis seeks to answer the question *how does inter-organisational information sharing influence blood safety and availability in the dyadic blood supply chain in normal, high tempo, and emergency conditions?* |
| Case study should meet *the duality criterion* in that it is *situationally grounded* on the unique context of research and seeks *a sense of theoretical generality* to broaden theoretical understanding through abstraction, therefore enabling theory elaboration (Ketokivi and Choi, 2014). | Yes | Whilst contextually grounded on the BSC, this thesis seeks to elaborate HRT, particularly its central concept of collective mindfulness, to explain the underlying mechanisms of the relationship between IOIS and BSA. |
| Case study is fit for research that falls into the intermediate state in which relationships among constructs are commonly unclear and inconsistent (Edmondson and McManus, 2007). | Yes | The systematic literature review suggests that there is inconsistency and lack of clarity in the positioning of IOIS amongst other constructs that affect the PPSC performance. Disagreements on the positive impacts of IOIS on the supply chain (SC) performance are also found from the general SC literature. |
| Case study supports the critical realism paradigm that offers a deeper understanding of relationships among events/constructs through the notion of underlying mechanisms (Aastrup and Halldórsson, 2008; Easton, 2010) | Yes | See Chapter 2 on the philosophical perspective of critical realism underpinning this thesis. |
| Case study enables extensive and in-depth description of a social phenomenon (Yin, 2014) | Yes | The use of case study is recommended by Kembro and Näslund (2014), following problems of data collection and analysis when using a survey to comprehensively understand IOIS from the perspective of more than one actor in a supply chain. |

In line with these fundamentals, in this thesis, a contemporary phenomenon of inter-organisational information sharing (IOIS) behaviour in the unique context of the blood supply chain (BSC) is investigated to answer the question *how does inter-organisational information sharing influence blood safety and availability in the dyadic blood supply chain in normal, high tempo, and emergency conditions?* This contextually grounded research seeks to elaborate high reliability theory (HRT), particularly its central concept of collective mindfulness, to explain the underlying mechanisms of the relationship between IOIS and blood safety and availability (BSA).

The systematic literature review (SLR) presented in this thesis suggests that there is inconsistency and lack of clarity in the positioning of IOIS amongst other constructs that affect the perishable product supply chain (PPSC) performance. Disagreements on the positive impacts of IOIS on SC performance are also found from the general SC literature, indicating that the extant IOIS research has entered the intermediate state that fits the use of case study (Edmondson and McManus, 2007). In addition, the use of case study is also recommended by Kembro and Näslund (2014), following problems of data collection and analysis when using a survey to understand IOIS from the perspective of more than one actor in a supply chain. Table 4-1 on page 77 presents the fundamentals and rationales for adapting the case study design, whereas Table 4-2 shows the characteristics of case study as compared to the other research methods.

**Table 4-2: Methodological fit of case study compared to the other methods**

| Methods | Maturity of research | Research questions | Requires control of behavioural event? | Focusses on contemporary events? |
|---|---|---|---|---|
| Case study | Nascent or intermediate | How and/or why? | No | Yes |
| Survey | Mature | Who, what, where, how many, and/or how much? | No | Yes |
| Archival analysis | Nascent or intermediate | Who, what, where, how many, and/or how much? | No | Yes/no |
| History analysis | Nascent | How and/or why? | No | No |
| Physical experiment | Nascent, intermediate, or mature | How and/or why? | Yes | Yes |
| Computer experiment | Nascent, intermediate, or mature | How and/or why? | Yes | Yes |

**Source: adapted and modified from Yin (2014), Edmondson and McManus (2007), Robinson (2004), and Twomey and Cadman (2002)**

This thesis uses embedded multiple case study to allow for both within-case and cross-case analyses to unravel similarities (literal replication) and differences between cases (theoretical replication) (Yin, 2014). Whilst enabling theory elaboration (Benbasat *et al*., 1987), multiple cases are likely to result in a more generalisable, parsimonious, and robust theory than a single case (Eisenhardt and Graebner, 2007). In addition, multiple cases increase external validity and reduce the possibility of having researcher bias (Voss *et al.*, 2002). The selection of multiple cases and its rationales are presented later in this chapter.

Theory elaboration is defined as "the process of conceptualizing and executing empirical research using preexisting conceptual ideas or a preliminary model as a basis for developing new theoretical insights by contrasting, specifying, or structuring theoretical constructs and relations to account for and explain empirical observations" (Fisher and Aguinis, 2017:438). Theory elaboration is an important methodological approach to case study research (Ketokivi and Choi, 2014). The logic for theory elaboration using case study is built on Ketokivi and Choi (2014):

> "Theory elaboration focuses on the contextualized logic of a general theory. In this regard, its underlying logic is similar to theory testing. The primary difference is that the researcher does not seek to test this logic, but rather, to *elaborate* it. While the researcher may be able to apply an existing general theory, it may be the case that the context is not known well enough to obtain sufficiently detailed premises that could be used in conjunction with the general theory to deduce testable hypotheses. Also, the researcher may wish to explore the empirical context with more latitude and serendipity, therefore, empirical data are used not only to test a theory but also to challenge it. Theory-elaborating case research also differs from theory-generating case research in that the researcher has identified a general theory that can be used to approach the empirical context." (Ketokivi and Choi, 2014:236)

To indicate the fit for adapting theory-elaborating case study, this thesis follows the assessment process proposed by Ketokivi and Choi (2014) and Fisher and Aguinis (2017) (see Figure 4-2 on page 81). The assessment process is explained as the following. In this thesis, HRT is elaborated. As shown in the theoretical perspective section in Chapter 2 on page 19, HRT offers an interesting and compelling insight of collective mindfulness that can be used to explain the phenomenon of IOIS in the BSC context. This theory has in fact provided a complementary basis for formulating the research question addressed in this thesis. The potential of using HRT to understand the IOIS phenomenon in the

BSC fulfils the first condition for using a theory-elaborating case study design (see Figure 4-2 on page 81).

Despite the potential for using HRT, the information sharing phenomenon is only lightly and inadequately discussed in the context of the theory. In fact, the IOIS phenomenon is currently underexplored in this theory. In addition, HRT has focussed its attention on organisational rather than an SC context, so that inter-organisational coordination is hardly discussed in this theory. As a consequence, it is currently not possible to derive explicit and proper *a priori* theoretical hypotheses on the relationship between IOIS and the BSA based on HRT. This lack of adequacy in explaining the phenomenon fulfils the second condition for using theory-elaborating case study design (see Figure 4-2 on page 81).

Finally, whilst HRT does not support the formulation of theoretical hypotheses on the IOIS phenomenon, this theory can be adapted and contextualised as *a priori* theory to explain the underlying mechanisms of how IOIS influences BSA in the BSC. Empirical data gathered and analysed in this thesis can be integrated with HRT, enriching the explanatory power of this theory whilst extending its application to the other context and unit of analysis. This fulfils the third and last condition for using theory-elaborating case study design (see Figure 4-2 on page 81)

## 4.2 Research strategy

In line with the use of the theory-elaborating case study design, a combined retroductive-abductive research strategy is used in this thesis. Retroductive means that the research focusses on investigating the underlying mechanisms of a phenomenon (Blaikie, 2007), whereas abductive means that the research process requires the researcher to go back and forth between the elaborated theory and the empirical data (Ketokivi and Choi, 2014) to come up with plausible explanations of a phenomenon (see Harman, 1965; Ketokivi, 2006; Merton, 1957). This strategy ensures that the process of unravelling the underlying mechanisms of the IOIS phenomenon in the BSC is guided by HRT as a theoretical perspective in this thesis.

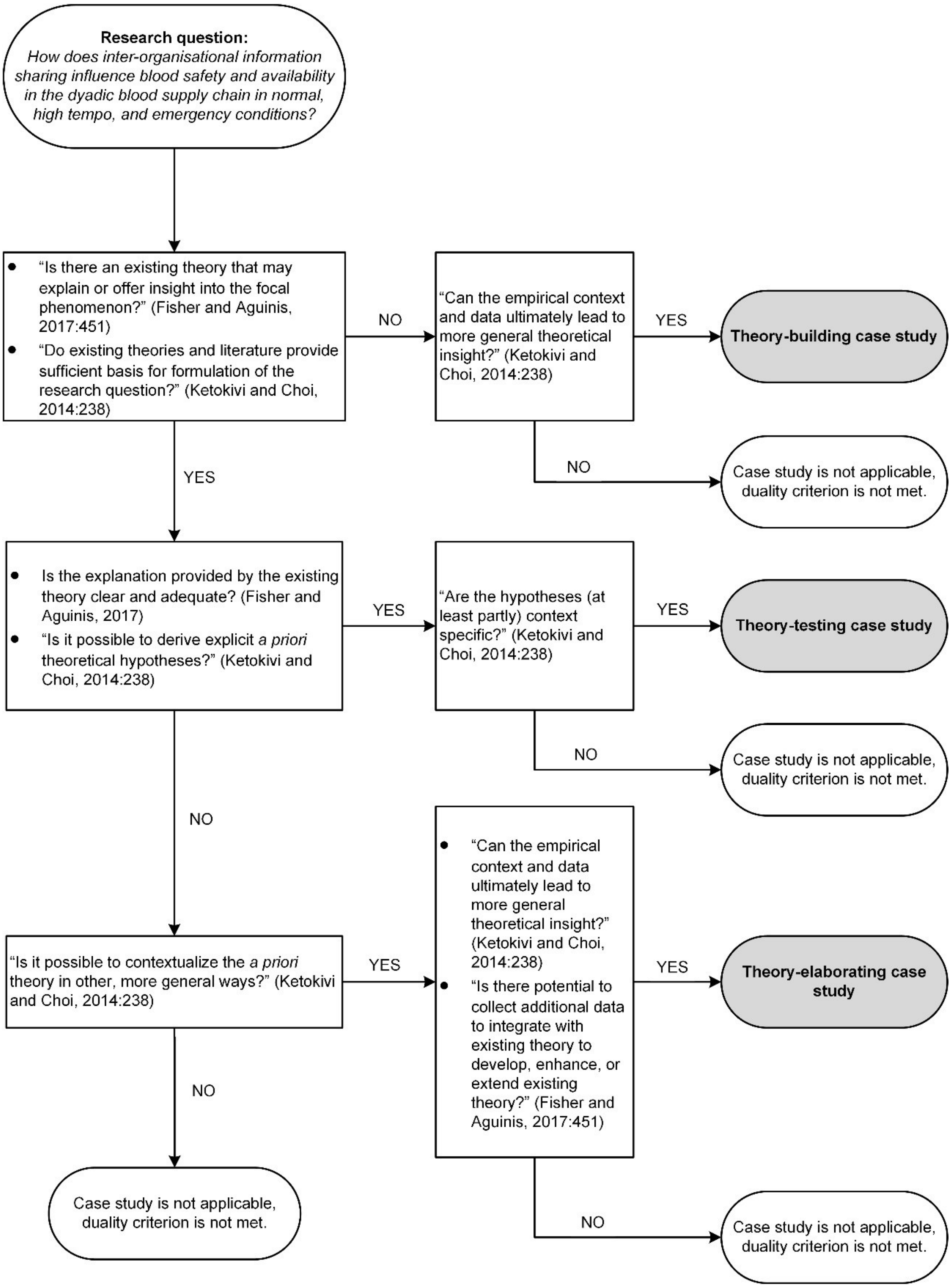


**Figure 4-2: Assessment of the fit of theory-elaborating case study design**
**Source: adapted from Ketokivi and Choi (2014) and Fisher and Aguinis (2017)**

To support this strategy and to reduce researcher interpretation bias, the basic qualitative descriptive approach is employed (Sandelowski, 2000, see also Baxter and Jack (2008) and Gammelgaard (2017) who support the argument for using qualitative case study). Whilst this approach supports theoretical interpretation from the data, it keeps the interpretation closer to the facts identified from the data. This distinguishes the basic qualitative description from the other qualitative approaches, such as grounded theory, phenomenology, ethnography, or narrative studies, which emphasise more on understanding meaning as a basis for interpretation (Sandelowski, 2000). This approach also differs from quantitative description in quantitative methods, where researchers set a range of expectations and draw conclusions from the results of assumption-based statistical tests, therefore leaving limited room for unexpected results and elaborated interpretation (Sandelowski, 2000).

Practically, qualitative description allows the identification, description, and interpretation of behavioural events (i.e. IOIS behaviour) and enables the descriptive representation of data in the form of *context, intervention, mechanism,* and *outcome* (CIMO) (see Chapter 2 for details of this logic) revealed by the data sources (see Sandelowski, 1998, 2000; Wolcott, 1994). This approach is therefore essential to meet the research objectives in this thesis (see Chapter 1). In addition, the use of the basic qualitative description is highly advocated in healthcare research (Sandelowski, 2000); therefore it is also contextually relevant to the BSC research in this thesis. Detailed data collection and analysis based on this approach are explained in the later sections of this chapter.

## 4.3 Main cases selection and description

Whilst data access is a key consideration for selecting cases in this thesis (see Gammelgaard, 2017), two main cases were selected on the basis of the different contexts in which the BSC operates. The first case represents a centralised and tightly regulated BSC (the UK BSC), whereas the second case represents a decentralised and loosely regulated BSC (the Indonesian BSC). The selection of these two cases follows theoretical replication logic to identify polar or extreme types – “cases with sharply contrasting characteristics that will highlight differences being studied" (Voss *et al*., 2002:203). Meredith (1998) argues that the selection of extreme cases is appropriate to study a phenomenon where further elaboration is still required. In fact, Flyvbjerg (2006:229) suggests that "atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied". This logic is in line with information-oriented selection, i.e. maximising the utility of information from a small sample by selecting cases based on the expectation of the content of the information (Flyvbjerg, 2006). As such, it is expected that the two contrasting cases can provide an interesting, rich, and comprehensive understanding on the underlying mechanisms of how IOIS influences BSA, hence increasing the theoretical generalisability of the research.

Practically, these two contrasting contexts were chosen because they are able to represent the general BSC modes of operation. On the one hand, WHO (2017a) recommends that nationally integrated and regulated blood supply networks are required to ensure blood safety and availability. As WHO (2017a) suggests:

> "WHO recommends that all activities related to blood collection, testing, processing, storage and distribution be coordinated at the national level through effective organization and integrated blood supply networks. The national blood system should be governed by national blood policy and legislative framework to promote uniform implementation of standards and consistency in the quality and safety of blood and blood products. [...] that [mode of operations] can provide sufficient and timely supplies of safe blood and blood products to meet the transfusion needs of all patients." WHO (2017a)

On the other hand, WHO (2017a) states that only 68% of countries reporting to the WHO Global Database on Blood Safety 2013 have a national blood policy, whereas only 58% of reporting countries have specific regulations regarding the safety and quality of the blood transfusion practice. This 58% of reporting countries consists of 79% of high-income, 64% of middle-income, and 41% of low-income countries. This figure indicates that a significant part of the world's BSC is currently operating under supposedly disintegrated and loosely regulated BSA practices.

In line with the WHO's recommendation, the BSC in the UK particularly England is centrally controlled and monitored by a single national organisation called the

National Health Service Blood and Transplant (NHSBT). This organisation covers the management of blood supply processes including blood collection, testing, manufacturing, stock holding, and distribution of blood across the UK. Every year, the NHSBT collects around 1,456,000 units of blood via a network of fixed blood donation centres and mobile blood collection teams (NHSBT, 2018c). There are currently three manufacturing centres and 15 stock holding units managed by the organisation, serving over 250 hospitals across the UK (NHSBT, 2018). The number of manufactured blood units in each manufacturing centre and stock levels in each stock holding unit are continuously monitored and coordinated at the national level. Whilst certain decisions related to BSA issues are coordinated across the BSC, each blood centre (i.e. stock holding unit) is capable of providing services and handling BSA issues related to its associated hospitals.

Moreover, the BSA in this country is managed with the tight national regulations under the Medicines and Healthcare products Regulatory Agency (MHRA). The regulations cover many issues including the minimum national stock levels, traceability of blood products, and mandatory reporting of blood safety incidents. A national blood transfusion committee has also been established to promote good transfusion practices and help the BSC comply with the regulations. The focus of the main case is England because it represents the largest area served by the NHSBT. England also has the biggest number of population and therefore the highest need for blood compared to other areas in the UK. It is therefore expected that the case can give a comprehensive view of the BSC operations in the UK.

In contrast, although certain activities such as training and blood donation campaigns are coordinated nationally, the BSC in Indonesia is decentralised and mainly managed by the Indonesian Red Cross (PMI). Unlike the UK BSC, the Indonesian BSC is not entirely and continuously controlled and monitored by a single national organisation. In 2015, the Indonesian BSC manufactured around 4,072,436 units of blood via fixed blood donation centres and mobile blood collection teams across the country (Ministry of Health Republic of Indonesia, 2017). There are in total of 414 blood centres serving around 2,869 hospitals in

Indonesia (Ministry of Health Republic of Indonesia, 2017, 2018). Whilst each blood centre itself is capable of collecting, manufacturing, holding stock, and distributing blood and blood products to its associated hospitals within its operational area, the number of manufactured blood units and stock levels in the blood centre are not continuously monitored and coordinated at the national level. This leads to ineffective distribution of blood products across the country. In other words, each blood centre in Indonesia has its own blood stock policy with full control over its stock levels.

Although national regulation on the standards of the blood transfusion service (e.g. blood quality management, blood donation, cold chain process) in Indonesia does exist, some governance aspects, such as the national guidelines on the appropriate clinical use of blood and the national haemovigilance system, are currently lacking (WHO, 2017c). In fact, the national blood transfusion committee is not effectively run to help the BSC comply with the regulation. Consequently, not all BSC actors across the country follow the prescribed standard (Director of National Blood Donation and Hospital of the Indonesian Red Cross, interview data).

In summary, two main cases (the UK and Indonesian BSCs) were selected in this thesis to reflect two contrasting modes of BSC operations and to provide an interesting, rich, and comprehensive understanding on the phenomenon of IOIS in the BSC. These main cases are labelled throughout this thesis as the centralised and tightly regulated BSC (the UK BSC) versus the decentralised and loosely regulated BSC (the Indonesian BSC). The following section presents the selection and description of embedded cases representing these two contrasting contexts.

## 4.4 Embedded cases selection and description

To ensure richness and accuracy of the research (see Martin and Eisenhardt, 2010; Yin, 2003), six embedded cases were selected from the two contrasting BSC contexts. These embedded cases consist of three cases from the centralised and tightly regulated BSC and three from the decentralised and loosely regulated BSC, each consisting of one blood centre and four associated hospitals, giving a total of 30 participating entities across the two different contexts. Figures 4-3 and 4-4 on page 87 present the schematic illustration of the selected cases, whereas Tables 4-3 and 4-4 on pages 88 and 89 respectively present the details of the selected cases from both BSC contexts. MC, EC, and BC refer to main case, embedded case, and blood centre respectively. To maintain the confidentiality of the participating entities, the original names of the blood centres and the hospitals were changed to codes.

The embedded cases were selected using a convenience approach (see Aggarwal and Srivastava, 2016; Pagell and Krause, 1999). The primary consideration for using this approach is the time constraint (see Eisenhardt, 1989a; Perry, 1998) and difficulties in data access, particularly in Indonesia. During the selection process, BSC practitioners were involved to provide recommendations on the selected entities and to help with the data access.

The selection of the embedded cases considered different sizes, locations, and blood inventory management practices of the entities. This variety ensures the validity and rigour of the cases and reduces biased data (see Stanger, 2013). In this respect, the number of blood centres and hospitals selected in each main case concurs with Flyvbjerg (2006) in selecting three to four cases with variation in certain dimensions. Whilst this variation such as hospital sizes might have an impact on operational efficiency (see Eakin, 1991; Hsing and Bond, 1995; Polyzos, 2002; Watcharasriroj and Tang, 2004), it is not the intention of this thesis to focus on analysing the impact of this variation on the relationship between IOIS and BSA (see Scholten and Schilder, 2015; Stanger, 2013). Instead, this variation is important to capture as many IOIS behaviour and mechanisms as possible to comprehensively understand how IOIS influences BSA (see Sandelowski, 1995, 2000).

The three blood centres and their associated hospitals in the UK were selected based on the recommendation from the NHSBT Blood Stocks Management Scheme (BSMS) Manager. Similarly, the three blood centres in Indonesia were selected after discussion with the Director of National Blood Donation and Hospital of the Indonesian Red Cross (PMI). Given the decentralised structure of the Indonesian BSC, the selection of the four hospitals associated with each blood centre was based on the recommendation from the blood centre's manager.

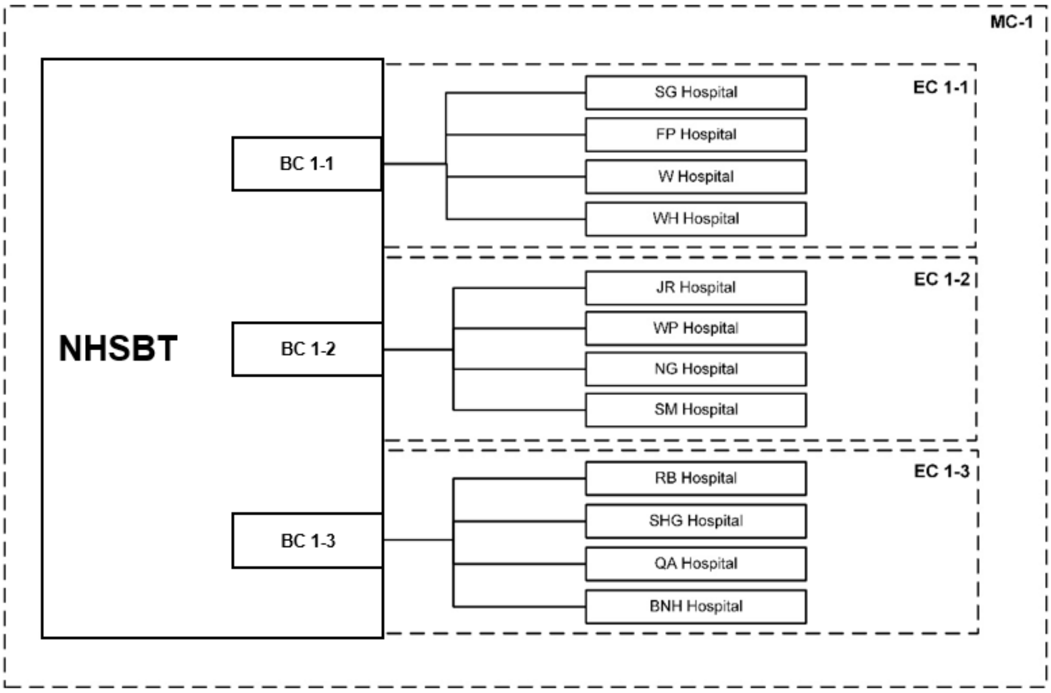


**Figure 4-3: Schematic illustration of the selected cases from MC-1**

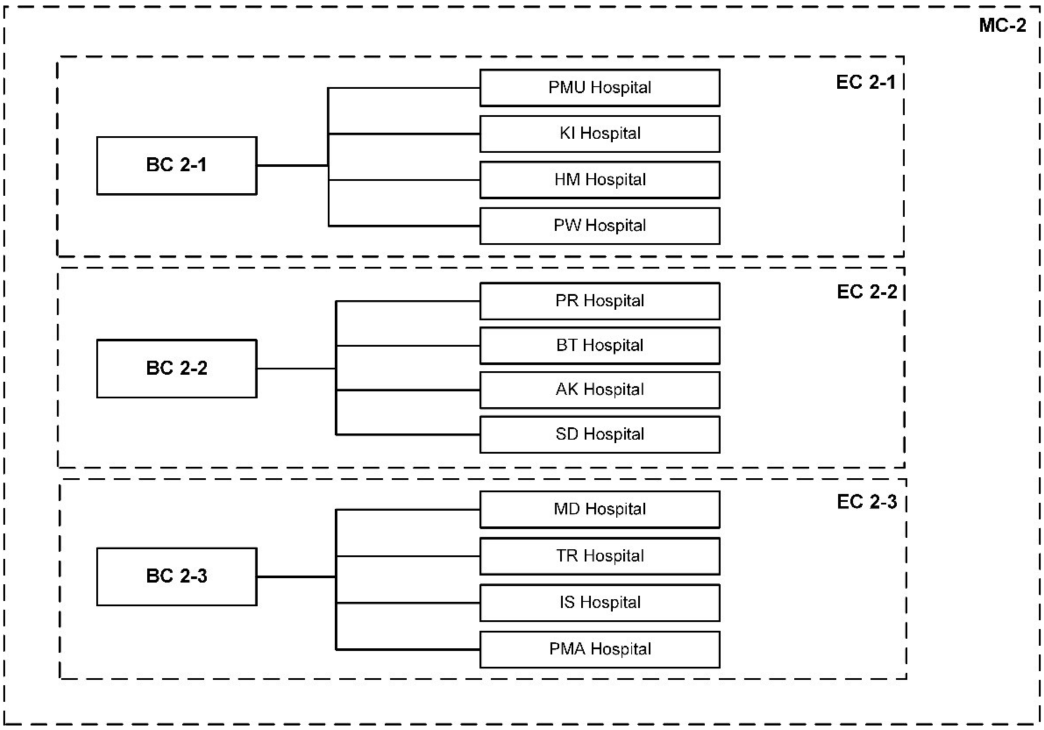


**Figure 4-4: Schematic illustration of the selected cases from MC-2**

**Table 4-3: Profile and data description of the selected cases from MC-1**

| Main case | Embedded cases | Entities | Total hospitals served by the BCs | Annual red blood cells (RBCs) issued from blood centres (units) | Additional attributes | Informants (number of people) | Walk-throughs | Supporting documents, artefacts, or archives |
|---|---|---|---|---|---|---|---|---|
| Centralised & tightly regulated BSC (MC-1) | Strategic view s | Central NHSBT | Over 250 | - | - | Head of Hospital Customer Service (1) | - | - |
| | | | | | | National Lead Patient Blood Management Practitioner Team (1) | - | - |
| | | | | | | National Product Manager (1) | - | √ |
| | | | | | | Assistant Director Governance and Resilience (1) | - | √ |
| | EC 1-1 | BC 1-1 | 49 | 273,286 | - | Hospital Services Team Manager (1) | √ | √ |
| | | SG Hospital | - | >9,700 (very high) | University Teaching Hospital | Lead Transfusion Practitioner (1), Transfusion Practitioner (1) | √ | √ |
| | | FP Hospital | - | >6,250 <=9,700 (high) | General Hospital | Lead Transfusion Practitioner (1), Transfusion practitioner (1) Biomedical Scientist (1) | √ | √ |
| | | W Hospital | - | >4,000 <=6,250 (moderate) | General or District General Hospital | Chief Biomedical Scientist the Transfusion Manager (1) | √ | √ |
| | | WH Hospital | - | >1,000 <=4,000 (low ) | District General Hospital | Blood Transfusion Coordinator and Quality Lead (1), Associate Practitioner (1), Biomedical Scientist (1) | √ | √ |
| | EC 1-2 | BC 1-2 | 13 | 72,186 | Partly VMI | Hospital Services Manager (1) | √ | √ |
| | | JR Hospital | - | >9,700 (very high) | University Teaching Hospital; Fully VMI | Laboratory Manager (1), Transfusion Practitioner (1), Project Development Manager (1) | √ | √ |
| | | WP Hospital | - | >4,000 <=6,250 (moderate) | General or District General Hospital | Transfusion Practitioner (1), Senior Biomedical Scientist (1) | √ | √ |
| | | NG Hospital | - | >4,000 <=6,250 (moderate) | General or District General Hospital | Operational Manager Transfusion and Haematology (1) | √ | √ |
| | | SM Hospital | - | >4,000 <=6,250 (moderate) | General or District General Hospital | Lead Biomedical Scientist (1) | √ | √ |
| | EC 1-3 | BC 1-3 | 15 | 66,507 | Partly VMI | Hospital Services Manager (1) | - | √ |
| | | RB Hospital | - | >4,000 <=6,250 (moderate) | General or District General Hospital; Fully VMI | Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager (1) | √ | √ |
| | | SHG Hospital | - | >9,700 (very high) | University Teaching Hospital | Blood Transfusion Section Manager (1) | √ | √ |
| | | QA Hospital | - | >6,250 <=9,700 (high) | General Hospital | Blood Transfusion Operations Manager (1), BMS Section Leader (1) | √ | √ |
| | | BNH Hospital | - | >1,000 <=4,000 (low ) | District General Hospital | Transfusion Operations Manager (1), Senior Biomedical Scientist (1) | √ | √ |
| Notes | | - | - | The low – very high scales are based on the BSMS hospital size classification. The BC issues are based on 2016-2017 data. | The hospital type classification is based on data provided by BSMS. VMI: vendor managed inventory | - | - | - |

## Table 4-4: Profile and data description of the selected cases from MC-2

| Main case | Embedded cases | Entities | Total hospitals served by the BCs | Annual red blood cells (RBCs) issued from blood centres (units) | Additional attributes | Informants (number of people) | Walk-throughs | Supporting documents, artefacts, or archives |
|---|---|---|---|---|---|---|---|---|
| Decentralised & loosely regulated BSC (MC-2) | Strategic view | Central PMI | 2,869 | - | - | Director of National Blood Donation and Hospital (1) | - | - |
| | EC 2-1 | BC 2-1 | 75 | 100,348 | - | Blood Donation and Marketing Manager (1), Blood Storage and Distribution Manager (1), Project Development Manager (1), Staff of Blood Testing Department (1), Quality Control Manager (1) | √ | √ |
| | | PMU Hospital | - | >6,250 <=9,700 (high) | General Hospital | Laboratory Manager (1), Transfusion Practitioner (1) | √ | √ |
| | | KI Hospital | - | >1,000 <=4,000 (low ) | General Hospital | Laboratory Manager (1), Blood Bank Manager (1) | √ | √ |
| | | HM Hospital | - | <=1,000 (very low ) | General Hospital; NBB | Medical Consultant (1), Laboratory Manager (1) | √ | √ |
| | | PW Hospital | - | >1,000 <=4,000 (low ) | General Hospital | Laboratory Manager (1) | √ | √ |
| | EC 2-2 | BC 2-2 | 150 | 41,000 | - | Head of City Red Cross (1), Blood Donation Manager (1), Blood Management General Affairs (1) | √ | √ |
| | | PR Hospital | - | >6,250 <=9,700 (high) | General Hospital | Deputy Laboratory Manager (1) | √ | √ |
| | | BT Hospital | - | >4,000 <=6,250 (moderate) | General Hospital | Blood Bank Staff (1) | √ | √ |
| | | AK Hospital | - | >1,000 <=4,000 (low ) | General Hospital | Blood Bank Manager (1), Blood Bank Staff (1) | √ | √ |
| | | SD Hospital | - | <=1,000 (very low ) | Mother and Children Hospital; NBB | Midw ife (1) | √ | - |
| | EC 2-3 | BC 2-3 | 7 | 4,258 | - | Transfusion Practitioner (1) | √ | √ |
| | | MD Hospital | - | <=1,000 (very low ) | General Hospital; NBB | Senior Nurse (1), Nurse (1) | √ | - |
| | | TR Hospital | - | <=1,000 (very low ) | General Hospital; NBB | Hospital General Affairs (1), Blood Administration Manager (1) | √ | - |
| | | IS Hospital | - | <=1,000 (very low ) | General Hospital; NBB | Nurses (2) | √ | - |
| | | PMA Hospital | - | <=1,000 (very low ) | General Hospital; NBB | Nurse (1) | √ | - |
| Notes | | - | - | The very low – high scales are based on the BSMS hospital size classification. The BC issues are based on average annual data estimated by the BC managers. | NBB: no blood bank. | - | - | - |

The hospitals' sizes were classified using BSMS scales ranging from very low to very high usage of red blood cells (RBCs) (i.e. the most commonly used blood component). Accordingly, the sizes of the blood centres and their associated hospitals in both contexts vary in terms of the number of RBCs issued annually from the blood centres. Overall, the selected blood centres and hospitals in the UK issued more RBCs annually and therefore their overall size is bigger compared to the selected blood centres and hospitals in Indonesia.

The types of the hospitals also vary. Typically, the University Teaching Hospitals in the UK use very high RBCs annually, followed by University Teaching or General Hospitals (high), General or District General Hospitals (moderate), District General or Private Hospitals (low), and Private Hospitals (very low). Such categorisation, however, is not applicable for the hospitals in Indonesia, which are instead categorised based on their services offered to the public. Accordingly, most of the selected hospitals in Indonesia are categorised as General Hospitals (i.e. hospitals that treat any general patients' conditions), whereas one hospital is categorised as Mother and Children Hospital, which only treats illness related to mother and children.

To reflect on the variation of the blood inventory management practices, the selection of entities in the UK includes two blood centres and two hospitals which have adopted vendor-managed inventory (VMI) – a practice where the blood centres have complete information and control over stock levels in their associated hospitals. Whilst all selected hospitals in the UK have a blood bank, six out of 12 selected hospitals in Indonesia are operating with no blood bank (see Tables 4-3 and 4-4 on pages 88 and 89 respectively for details). The unavailability of blood banks has left some implications for the Indonesian BSC. Hospitals with no blood bank typically do not have proper blood storage facilities to maintain the blood quality. Whilst hospitals with a blood bank can control their own stock levels, hospitals with no blood bank do not have complete control over their stock levels and depend largely on the stock available in their associated blood centres. Consequently, the overall IOIS practices between the blood centres and hospitals in Indonesia are expected to be different compared to those in the UK.

Despite the justifications for the embedded cases selection, it is worthwhile to note that there is no exact guideline from the literature on the ideal number of cases to be selected. Martin and Eisenhardt (2010) for example use six cases to study how executives create high and low performing cross-business-unit collaborations in multi-business organisations. Seuring (2008) reports that most case study research in the supply chain management (SCM) discipline commonly uses a single case with a few researches having more than two cases. Voss *et al.* (2002) suggest a rule of thumb that multiple case studies can have three to 30 cases, whereas Eisenhardt (1989a) suggests that a number between four to ten cases usually works well. The number of embedded cases selected in this research is therefore in line with these general guidelines. In fact, upon the data analysis, theoretical saturation has been reached with six embedded cases. In this thesis, theoretical saturation means that replication of the findings have been found across the embedded cases in each study context. Therefore, adding more cases might not provide significant incremental learning and insight to further understand the studied phenomenon (Eisenhardt, 1989a). In other words, the aim of this research can already be achieved with these selected cases.

## 4.5 Data collection

For each embedded case, primary data were collected through semi-structured interviews, supported by walkthroughs, supporting documents, artefacts, and archives (see Tables 4-3 and 4-4 on pages 88 and 89 respectively). This triangulation of data sources can increase the accuracy of the data as well as the credibility and robustness of the research (Jick, 1979; Martin and Eisenhardt, 2010; Rothbauer, 2008). In fact, it is suggested, for qualitative descriptive research, that researchers "collect as much data as they can that will allow them to capture all of the elements of an event that come together to make it the event that it is. As long as they are "in the field," they are obliged to consider as data whatever they observe in the field" (Sandelowski, 2000:336). Practically, in this thesis, a range of data sources are useful to capture as many inter-organisational information sharing (IOIS) behaviour and mechanisms as possible that explain how IOIS influences blood safety and availability (BSA) in normal, high tempo, and emergency conditions. Appendix A on page 223 presents the data collection protocol.

The use of semi-structured interviews in this thesis is in line with theory-elaborating case study, in that the researcher attempts to use *a priori* theory (i.e. high reliability theory (HRT)) and knowledge from extant literature (i.e. IOIS in supply chains (SCs)) to develop pre-determined but flexibly structured questions. In fact, the semi-structured interview supports the importance of serendipity in theory-elaborating case study, which “entails remaining open to unanticipated findings and the possibility that the general theory requires considerable reformulation” (Ketokivi and Choi, 2014:236, citing Merton, 1957). Unlike the unstructured interview, the semi-structured interview allows the researcher to have more control over the interview topics, but requires no fixed responses to each question, as is usually required in a structured interview or a survey questionnaire (Ayres, 2008).

The interviews were conducted face to face with key informants responsible for ensuring BSA in the blood centres and the associated hospitals. Follow up questions were asked when necessary through emails. Whenever applicable, more than one informant was interviewed in each entity through snowballing (Morgan, 2008), ranging from informants at strategic levels (e.g. Hospital Services Managers, Transfusion Operations Managers, Blood Bank Managers) to informants at operational/technical levels (e.g. Transfusion Practitioners, Biomedical Scientists, and Nurses), who are directly involved in managing BSA in their entities. To have comprehensive results, semi-structured interviews were also conducted with strategic informants at the national level (e.g. National Product Manager, Director of National Blood Donation and Hospital). Interviewing informants with multiple roles and multiple hierarchical levels reduces informant bias (Martin and Eisenhardt, 2010). In total 58 informants were interviewed for this research (29 UK and 29 Indonesian). With the informants’ consents, the interviews were tape-recorded, the length of which varies from 30 minutes to 2.5 hours.

To reduce the informants' bias, the interviews focussed on facts and events to understand processes or actions rather than on the informants' interpretation. The interview questions were pilot tested with seven blood supply chain (BSC) practitioners representing blood centres and hospitals from the two main cases. This was to ensure that the informants would understand the questions and to prevent misinterpretation that could lead to biased data.

To ensure the validity of the information provided by the informants, the interviews were started with general questions on the role of informants and the extent to which they were involved in managing BSA in the blood centres or hospitals. Subsequently, the informants were asked to describe how they (representing the blood centres or hospitals) ensured BSA in normal, high tempo, and emergency conditions. This is relevant to reflect HRT (La Porte and Consolini, 1998) that the BSC should ensure that blood products are always safe and available whenever required by patients in any conditions. Accordingly, it is assumed that the BSC operates differently in these different conditions.

The informants were then asked to identify IOIS behaviour associated with their practices to ensure BSA in normal, high tempo, and emergency conditions. For example, to reflect on the important element of HRT (i.e. managing unexpected events – see Weick and Sutcliffe, 2007), some interview questions asked about the BSC actors' IOIS behaviour and how they ensured BSA when they encountered unexpected conditions such as blood stockouts, blood safety problems, fridge failures, terrorist attacks, or floods in their facilities.

As suggested by the current SC literature (e.g. Kembro and Näslund, 2014; see also Mohr and Nevin, 1990), during the interview, the informants were also probed to provide details of the elements of IOIS behaviour, i.e. what (content), how (modality), with whom (direction), and how often (frequency) the information is shared. Finally, additional questions were asked to further understand the importance, benefits, and obstacles of IOIS practices in blood centres and their associated hospitals.

To gain factual information on what the informants experienced or observed and to increase the accuracy of the information, the interviews were supported by a courtroom questioning technique (i.e. asking questions to reveal facts rather than opinions – see Bourgeois and Eisenhardt, 1988; Huber and Power, 1985; Lipton, 1977; Martin and Eisenhardt, 2010). This technique was also useful to gain details when informants provided limited information or when certain themes emerged that required further elaboration. For example, the informants were asked to provide examples of specific disruptive events, blood safety incidents, or blood transfusion policies mentioned during the interviews. They were also asked to elaborate on details of their actions and IOIS practices following certain incidents, such as "who participated in emergency meetings?", "what agenda was discussed during the committee meetings?"

Following the interviews (INTs), whenever applicable, walkthroughs (WTs) in the form of blood centre and laboratory tours were conducted to understand the real operations to ensure BSA. The walkthroughs lasted for 30 minutes to one hour and were also tape-recorded. Supporting documents (DCMTs), artefacts (ARTFs) and/or archives (ARs) were also collected when applicable. DCMT includes SOPs, annual reports, monthly reports, post incident debrief reports, key performance indicator (KPI) reports, project briefing presentations, and service level agreements. ARTF includes monthly magazines and published journal articles particularly mentioned during the interviews. Finally, AR includes web-based monthly BSA updates, evidence of written communication including emails, and confirmed minutes of regular meetings.

## 4.6 Data analysis

This thesis focusses on IOIS in the dyadic BSC as the unit of analysis. Prior to data analysis, to capture as rich information as possible from the informants, the recorded interviews and walkthroughs were transcribed verbatim into Microsoft Word documents. To allow a more effective data processing, DCMTs, ARTFs, and ARs were also converted into transcripts in the form of Microsoft Word documents. To ensure accuracy, some interviews were transcribed using a paid online transcription software (i.e. https://go-transcribe.com/) and the results were double-checked using manual transcription. During the transcription process, to ensure the clarity of the speech, the speed of the recorded interviews were slowed by 50% (maximum). The transcripts were then sent back to the key informants for validation and to ensure accurate interpretation of any specific terminology mentioned during the interviews. Their feedbacks were incorporated into the final transcripts, ready for the next process.

Combining all the data sources, in total around 689,909 words or 1,408 pages of Arial 12 font size, single line spaced transcripts were prepared for the coding process. The coding process was supported by NVivo 11 Plus software, which is suitable for handling large quantities of qualitative data and serves as an integrated and transparent case study database. All these data sets were then coded and analysed using template analysis.

### 4.6.1 Template analysis

King (2012) defines template analysis as a style of thematic analysis of textual data that allows a flexibility of coding structure, defining tentative *a priori* themes, and an iterative process of applying, modifying, and re-applying the initial template. These characteristics distinguish template analysis from other approaches, such as grounded theory and interpretative phenomenological analysis, which offer a more inductive and rigid coding structure that is less flexible and more time-consuming when used with larger data sets (King, 2012). Moreover, template analysis has been used to analyse the interview data and fits with the critical realist paradigm (King, 2012) and the qualitative descriptive approach (Sandelowski, 2000). This is because template analysis can be flexibly used to unravel the underlying mechanisms of a relationship between constructs (see Lusiantoro *et al.*, 2018) and allows the elaboration of *a priori* theory in the coding process. As King (2012) suggests:

> "[…] it [template analysis] can be employed in the kind of realist qualitative work that accepts much of the conventional positivistic position of mainstream quantitative social science […]. [Template analysis is suitable for] research that is concerned with "discovering" the underlying causes [mechanisms] of human action and which seeks to achieve researcher objectivity and to demonstrate coding reliability." (King, 2012:427)

The process of template analysis was started with defining the *a priori* themes and subthemes. To better understand the IOIS phenomenon in SCs, Kembro and Näslund (2014) suggest that it is important to analyse IOIS behaviour amongst the SC actors. Following up this recommendation, this thesis adopts Mohr and Nevin's (1990) study as *a priori* themes to identify IOIS behaviour amongst the BSC actors in terms of content, modality, direction, and frequency of IOIS in normal, high tempo, and emergency conditions. Mohr and Nevin (1990) were followed because they propose a comprehensive set of IOIS behaviours in an SC. Another set of *a priori* themes, which are very important in this thesis, are the five collective mindfulness principles of HRT – preoccupation with failure (PF), reluctance to simplify (RS), sensitivity to operations (SO), commitment to resilience (CR), and deference to expertise (DE). The elements of collective mindfulness principles presented in Table 2-1 on page 23 of Chapter 2 are used as *a priori* themes and subthemes for the template analysis. These elements were adopted from various sources, including books (i.e. Weick and Sutcliffe, 2007, 2015), a seminal article (i.e. Weick *et al*., 1999), and a report containing a comprehensive literature review on HRT (i.e. Lekka, 2011), therefore they represent a comprehensive view of collective mindfulness principles to date.

Given the *a priori* themes and subthemes, *context, intervention, mechanism, and outcome* (CIMO) logic (Denyer *et al*., 2008) was applied in the coding process (see Chapter 2 for details of this logic). CIMO is a useful logic to present the trail of interpretation and evidence on the how IOIS influences BSA across a range of operational conditions. To enable this logic in the coding process, excerpts specifically related to the IOIS behaviour were first identified from the transcripts. Brinkmann and Kvale (2015) call these excerpts the natural "meaning units". Coding – "the process of attaching a label (code) to a section of text to index it as relating to a theme" (King, 2012:431) – was then performed on the meaning units. For the first order coding, an *in vivo* technique was adopted, when applicable, by assigning labels to the excerpts using words or short phrases taken from the excerpts themselves (King, 2008). In line with the qualitative description approach, this technique ensures information accuracy and reduces potential coding bias by allowing "concepts [to] stay as close as possible to research participants' own words or use their own terms because they capture a key element of what is being described" (King, 2008:473).

The next process involves identifying the operational conditions in which the excerpts were found (i.e. in normal, high tempo, or emergency conditions) and identifying the IOIS behaviour that is activated in those conditions (i.e. what, how, with whom, and how often information is shared). The former represents the notion of operational *contexts (C)*, whereas the latter represents the *interventions (I)* that are used by the BSC actors to influence BSA. Figure 4-5 shows examples of IOIS behaviour identified from the data.

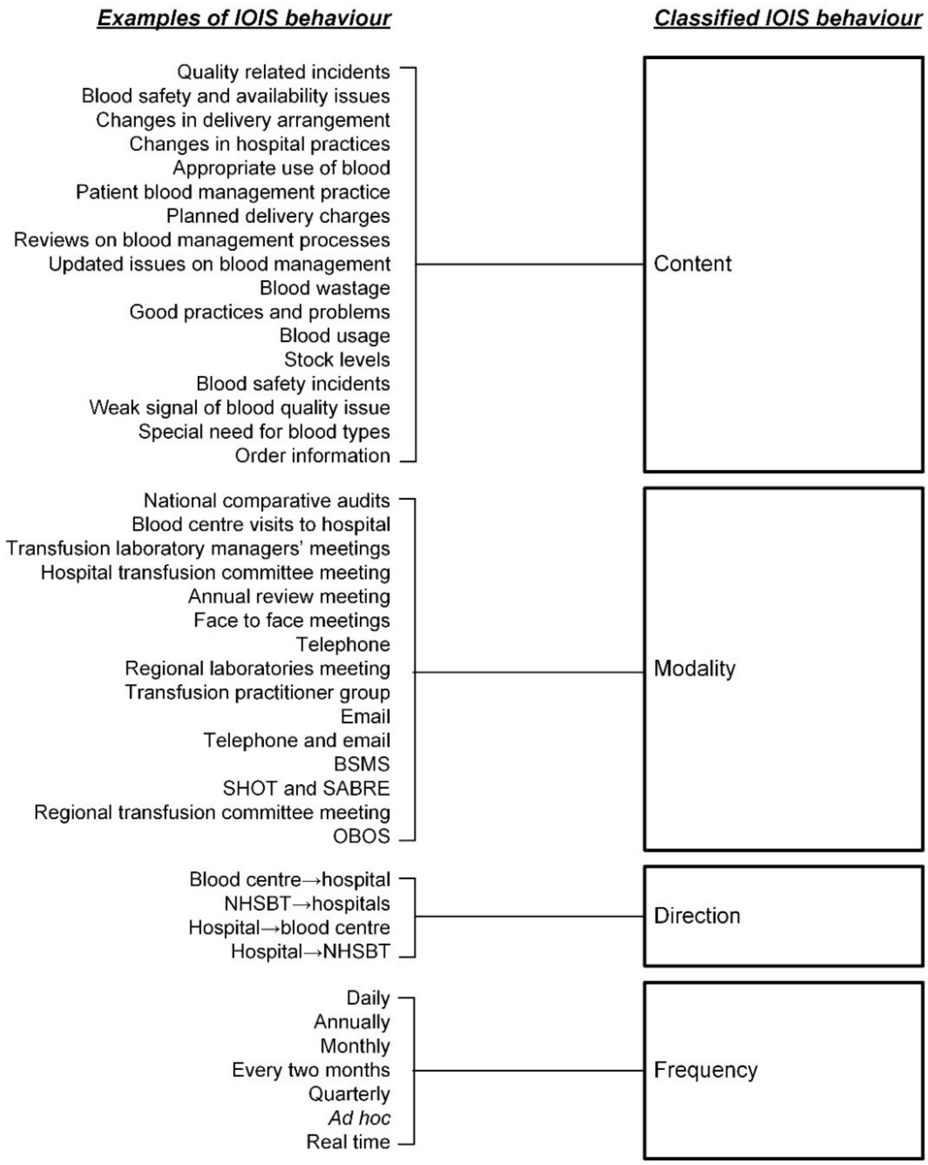


**Figure 4-5: Examples of IOIS behaviour identified from the data**

Using the same excerpts, the first order coding subsequently identified the co-actions underpinning the IOIS behaviour (i.e. actions that happen together with IOIS behaviour). When sharing information, the BSC actors do not only convey certain facts, messages, or knowledge, using certain media, with certain direction and frequency, but they are actually trying to do something (referred to in thesis as the co-action) that leads to changes in BSA. The co-actions can be positive or negative, which subsequently produce positive or negative changes in BSA.

The co-actions are very important in this thesis because they can represent the underlying *mechanisms (M)* that explain how IOIS influences BSA in normal, high tempo, and emergency conditions. More importantly, the identification of the co-actions represents the way this thesis unravels the IOIS behaviour that constitutes the acts of collective mindfulness (see Vogus and Sutcliffe, 2012). In the critical realism terminology (see section 2.1 in Chapter 2 on page 15), the underlying mechanism operates in the real domain of reality that can be revealed through a process of interpretation (see Easton, 2010; Sayer, 2000). The identification of the co-action in this thesis therefore involves an element of interpretation.

A case study research on SC visibility by Barratt and Oke (2007) can be used to illustrate what is meant by the co-action in this thesis. They suggest that IOIS influences SC performance through the notion of SC visibility, i.e. the extent to which SC actors share or have access to quality information and to which the SC actors perceive the shared information as useful and meaningful. Barratt and Oke (2007) argue that it is the SC visibility, not information sharing *per se*, that leads to improved operational performance. What can be inferred from this study is that "sharing information only" is not enough, so that information sharing should create a visibility to positively influence SC performance. Therefore, when the SC actors share information, there are two actions that are required to work together – "sharing information" and "creating visibility" across the SC. As such, "creating visibility" is the co-action representing a mechanism that explains how information sharing influences SC performance.

Having coded the co-actions of IOIS behaviour from the excerpts, the second order coding was started by assigning the positive and negative co-action codes into *a priori* subthemes and themes derived from the HRT. This assignment was conducted by matching the co-action codes with the *a priori* subthemes of collective mindfulness principles in Table 2-1 on page 23. Parallel coding was also performed, when applicable, to allow assigning two or more relevant codes to the same subthemes and themes (Julien, 2008; King, 2012). This coding process is in line with what Yin (2014) calls *explanation building*, i.e. a specific type of pattern matching that involves an iterative process of going back and forth between data and theory to provide a compelling theory-based explanation of a phenomenon. Yin (2014) argues that this process can result in a more precise understanding of the studied phenomenon, especially to answer causal questions of "how" or "why" something happened. In the SC literature, Ketokivi (2006) and Scholten and Schilder (2015) have used a similar technique to this alongside the theory-elaborating case study.

Taking the above example, "creating visibility", as a co-action of IOIS matches with the positive effort of high reliability organisations to have "transparency" to understand the big picture of their operations, which is a subtheme of the sensitivity to operations (SO) principle. Therefore, "creating visibility" is assigned to "transparency" as a subtheme and SO as a theme. Whilst Table 2-1 on page 23 only provides positive subthemes and themes of collective mindfulness (PF+, RS+, SO+, CR+, DE+), negative subthemes and themes can be inferred otherwise when they are not enacted. For example, "not questioning seemingly inappropriate orders from hospitals" is a negative co-action of IOIS, which means that there is "no scepticism", therefore "no reluctance to simplify" (RS-). The results of this second order coding were therefore categorised as codes that reflect the positive subthemes and themes as well as negative subthemes and themes of collective mindfulness. Respectively, Figures 4-6 and 4-7 on pages 100 and 101 respectively illustrate examples of positive and negative co-actions, subthemes, and themes of collective mindfulness identified from the data. Detailed explanations of these mechanisms are presented in the findings of Chapter 5 in this thesis.

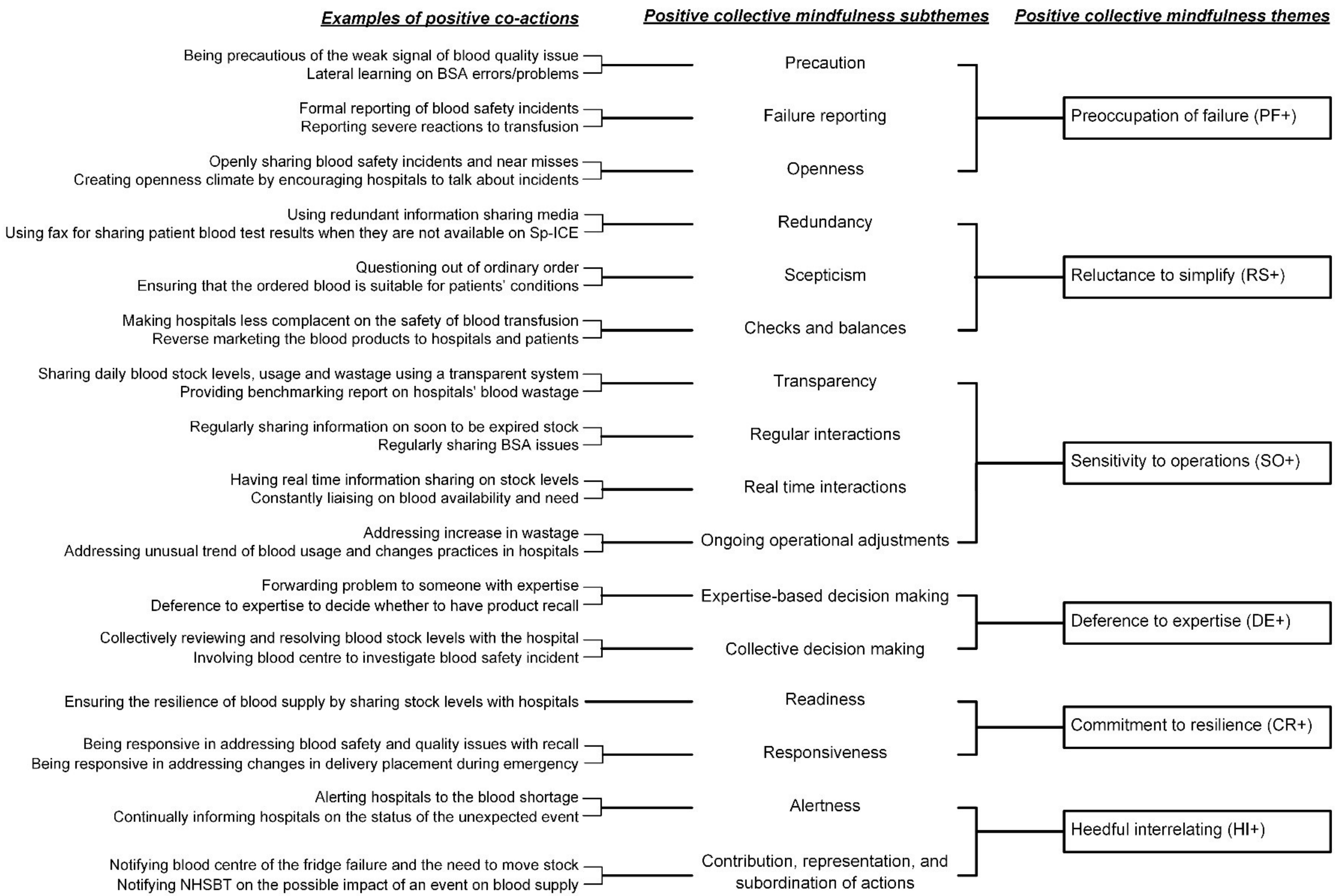


**Figure 4-6: Examples of positive co-actions, subthemes, and themes of collective mindfulness identified from the data**

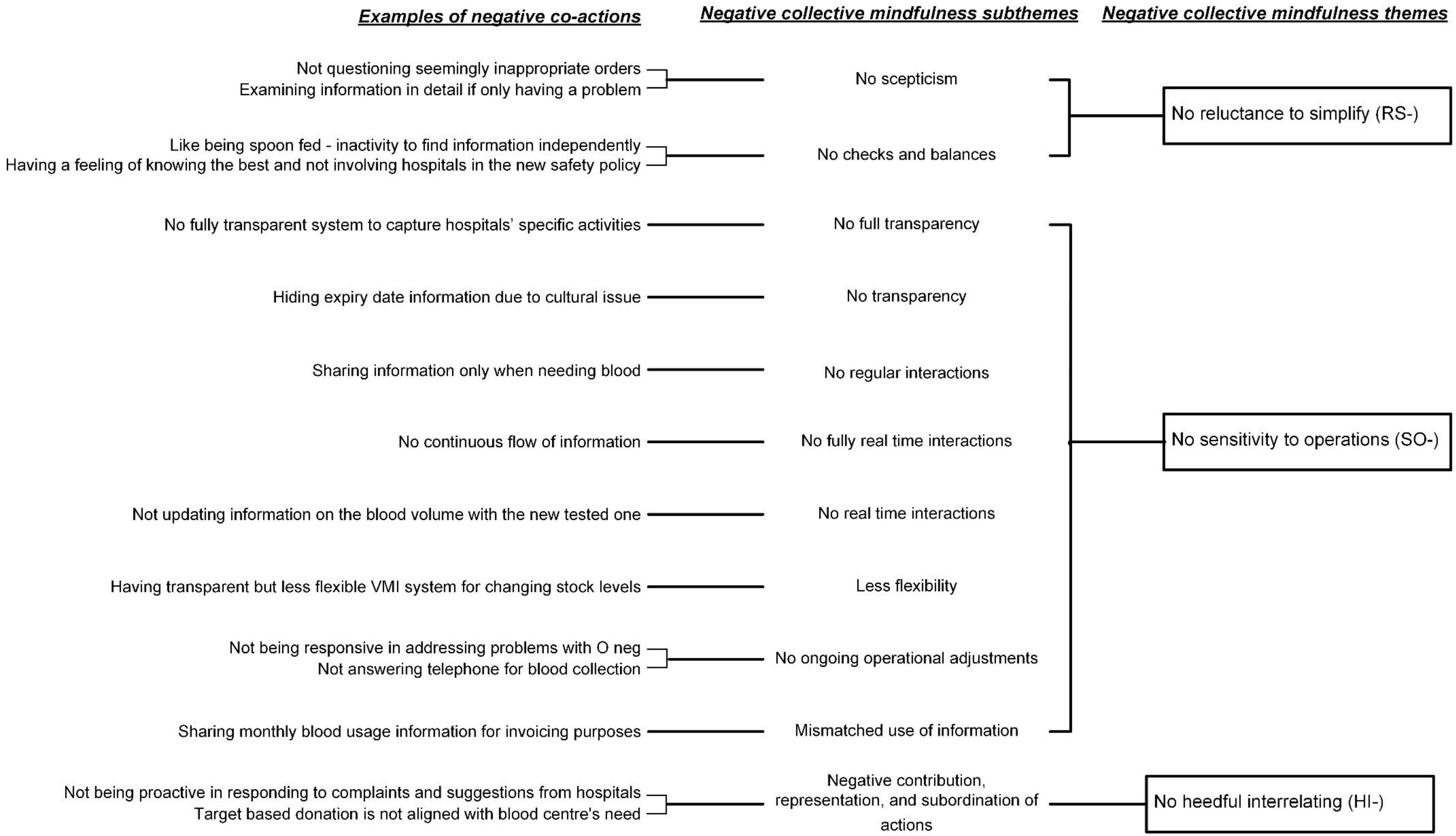


**Figure 4-7: Examples of negative co-actions, subthemes, and themes of collective mindfulness identified from the data**

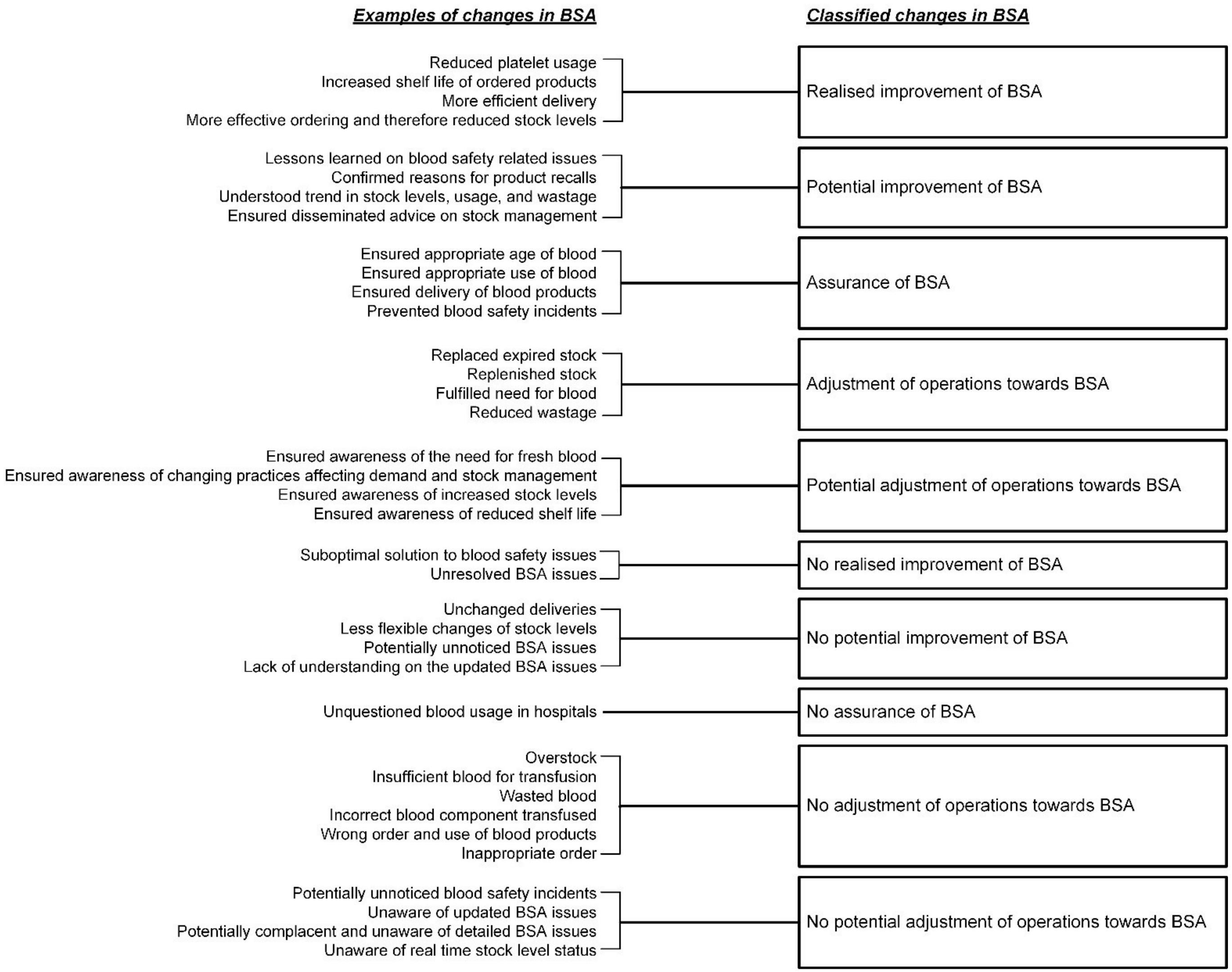


**Figure 4-8: Examples of changes in BSA identified from the data**

In this second order coding process, this thesis also applied some degree of "serendipity", i.e. remaining open to unanticipated findings from the data (Ketokivi and Choi, 2014). Whilst this thesis focusses on the five core principles of collective mindfulness (PF, RS, SO, CR, DE) as *a priori* themes, template analysis allows the coding process to identify themes beyond these five core principles. Practically, during the coding process, any codes that do not match with the five core principles were analysed separately. These unmatched subthemes were then categorised into a theme that is more suitable to describe the unanticipated findings. This process has resulted in an emerging theme of *heedful interrelating* (HI) that was named following Weick and Roberts (1993). This theme captures some IOIS behaviour that reflects the BSC actors' awareness of their interrelated roles in the BSC that contribute to changes in BSA performance. Details of this emerging theme is presented in Chapter 5.

Following the identification of the collective mindfulness mechanisms, the *outcomes (O)* produced by the mechanisms were finally identified from the excerpts. To do this, the excerpts were carefully examined for any indications of changes related to BSA. The notion of changes in BSA performance was adapted from Denyer *et al.*'s (2008) definition of *outcomes* as various changes resulted from interventions and mechanisms enacted in certain contexts. Whilst this thesis cannot claim the exact changes in the BSA, the changes were interpreted qualitatively from explicit and/or implicit statements in the excerpts. When an excerpt did not provide enough information to indicate changes related to BSA, supporting information from other excerpts within the same interview transcript was used to cross-reference.

In this thesis, the outcomes are represented by positive or negative changes or "no changes" in the BSA as a result of the IOIS behaviour and the co-actions enacted in normal, high tempo, and emergency conditions. Whilst no *a priori* themes are available from the BSC literature to categorise changes in BSA performance, this thesis categorised the changes as they emerged from the data (see Figure 4-8 on page 102 for examples). To capture the subtlety of the changes, the following categorisation was developed:

- *Realised improvement of BSA.* This category represents actual changes in BSA after IOIS that reflect improvement of BSA compared to that of before IOIS. For example, real time information sharing on blood stock levels between a blood centre and its associated hospital under the vendor-managed inventory (VMI) programme has resulted in a more effective replenishment of the hospital's blood stock, and therefore better blood availability across the BSC, compared to that of before the VMI. This realised improvement was stated explicitly in an excerpt. If the excerpt explicitly suggests otherwise (i.e. VMI does not improve BSA), then it is coded under *no realised improvement of BSA*.

- *Potential improvement of BSA*. This category represents potential changes in BSA after IOIS that potentially lead to improvement of BSA. For example, sharing blood safety incident reports across the BSC provides lessons learnt for blood centres and their associated hospitals. Whilst this statement was explicitly identified from an excerpt, the improvement of BSA as a result of having the lessons learnt was not explicitly identified from the excerpt. However, it can be implied using other supporting information from the transcript that the lessons learnt can lead hospitals to be more aware and potentially change practices to prevent similar incidents happening in the future. Therefore, there is a potential improvement on blood safety. If the excerpt explicitly or implicitly suggests otherwise (i.e. sharing incident reports does not provide lessons learnt), then it is coded under *no potential improvement of BSA*.

- *Assurance of BSA.* This category represents the prevention of unwanted changes that can potentially lead to worse BSA. For example, an excerpt explicitly reveals that a blood centre might share information by questioning its associated hospital when the order figure is out of the ordinary. Other supporting information from the transcript suggests that the blood centre does that to make sure that the hospital places the appropriate order and therefore use the ordered blood appropriately and safely. If the excerpt explicitly or implicitly suggests otherwise (i.e. no questioning of orders), then it is coded under *no assurance of BSA.*

- *Adjustment of operations towards BSA.* This category represents adjusted changes (which can be temporal in nature) to maintain BSA after IOIS. For example, hospitals will be notified and warned when there is an unusual increase in the use of blood that leads to shortage of a critical blood group such as O negative. Adjustment of operations (e.g. treating patients with alternative blood groups) will subsequently be made to reduce the blood usage and to maintain the availability of the blood group across the BSC. These statements were explicitly identified from an excerpt. If the excerpt explicitly suggests otherwise (i.e. adjustment of operations is not made), then it is coded under *no adjustment of operations towards BSA.*
- *Potential adjustment of operations towards BSA.* This category represents potential adjusted changes to maintain BSA after IOIS. For example, a hospital might inform its associated blood centre that there will be some changes in its medical practices, which will subsequently increase the demand for a particular blood group. Whilst this statement was explicitly identified from an excerpt, the adjustment of operations in the blood centre as a result of the changing practices was not explicitly identified from the excerpt. However, it can be implied using other supporting information from the transcript that the awareness of the blood centre of the changing practices can potentially lead to the adjustment of their services to meet the demand and maintain blood availability in the hospital. If the excerpt explicitly or implicitly suggests otherwise (i.e. the blood centre is not aware of the changes in medical practices), then it is coded under *no potential adjustment of operations towards BSA.*

The process of coding all elements of the CIMO logic were first completed for one embedded case, which becomes an initial template to be used for coding the next embedded cases. The end product of this process is the “final” template (see King, 2012) representing all the data sets in this thesis. Figure 4-9 on page 108 illustrates the coding structure as a template used in this thesis.

To illustrate the overall template analysis and CIMO logic, Table 4-5 on page 109 provides three examples from one embedded case (EC 1-1) of the centralised and tightly regulated BSC (MC-1). As shown in Table 4-5 on page 109, in a normal condition *(context – C)*, a Blood Transfusion Coordinator and Quality Lead of the WH Hospital found a weak signal of the blood quality problem (e.g. a strange look or colour of the blood) and decided to use the telephone to share the information with its associated blood centre *(intervention – I)*, which might eventually decide to recall the blood product. This information sharing activity represents the hospital's precautions regarding the potential blood quality problem that is potentially harmful for patients *(mechanism – M)*. This mechanism is in line with a positive enactment of collective mindfulness principle of preoccupation with failure (PF+) that treats any weak signal of failure as a potential danger for the system. As a result, it can be inferred from the excerpt that IOIS has helped the hospital assure blood safety by preventing the use of blood with the potential quality problem *(outcome – O)*. The excerpt was taken from the interview (INT) data. Similar data were also found during walkthrough (WT) in this hospital.

In a high tempo condition *(context – C)*, when there is a blood shortage in the blood centre, a Transfusion Practitioner of the SG Hospital will be informed and advised by the blood centre to use product substitutions. The blood centre uses fax and email to share this information *(intervention – I)*, creating a redundancy *(mechanism – M)* to ensure that the hospital is aware of the information so it can potentially adjust its operations to reflect on the condition *(outcome – O)*. Redundancy represents a positive enactment of collective mindfulness principle of reluctance to simplify (RS+), which emphasises the need for system backups to avoid any failure. The excerpt was taken from the interview (INT) data. Similar data were also found during interviews with the blood centre and the other hospitals.

Finally, in an emergency condition *(context – C)* when a major haemorrhage happens to a patient, a lot of blood is required, triggering stockout in the FP hospital. This condition leads the hospital to share the authorised blue light (emergency) order information via the online blood ordering system (OBOS) and telephone *(intervention – I)*. There is more than one co-action underpinning this IOIS behaviour *(mechanisms – M)*. First, by sharing the order information, the hospital is being responsive in addressing the immediate need for blood during the emergency. Second, the shared information is authorised by the named medical consultant to ensure that the emergency blood is actually required, reflecting an act of scepticism. Finally, the telephone is used to follow up the OBOS order, creating redundancy to ensure the blood centre's awareness of the urgent order. The data from other sources (not presented in Table 4-5 on page 109) suggest that this redundancy is very important, particularly during the night shift where the number of staff tends to be smaller so they might be busy with something else and not pay particular attention to the OBOS.

The first co-action (responsiveness) reflects a positive enactment of collective mindfulness principle of commitment to resilience (CR+), whereas the last two co-actions (scepticism and redundancy) represent a positive enactment of collective mindfulness principle of reluctance to simplify (RS+). The enactment of these mechanisms leads to the potential adjustment of operations (fulfilled urgent order) and assurance of blood availability during the emergency conditions *(outcomes – O)*. This example further suggests that under a certain context, more than one mechanism can be enacted at the same time to produce the desired outcomes. The excerpt was taken from the interview (INT) data. Similar data were also found in the blood centre and other hospitals through walkthroughs (WTs) and supporting documents (DCMTs).

***1. The blood centre or associated hospitals***
- ***1.1. Normal, high tempo, or emergency conditions***
  - ***1.1.1. IOIS content***
    - *1.1.1.1. see Figure 4-5*
    - *1.1.1.2. ...*
  - ***1.1.2. IOIS modality***
    - *1.1.2.1. see Figure 4-5*
    - *1.1.2.2. ...*
  - ***1.1.3. IOIS direction***
    - *1.1.3.1. see Figure 4-5*
    - *1.1.3.2. ...*
  - ***1.1.4. IOIS frequency***
    - *1.1.4.1. see Figure 4-5*
    - *1.1.4.2. ...*
  - ***1.1.5. Co-actions and collective mindfulness principles***
    - *1.1.5.1. Co-actions of IOIS representing PF+*
      - *1.1.5.1.1. see Figure 4-6*
      - *1.1.5.1.2. ...*
    - *1.1.5.2. Co-actions of IOIS representing RS+*
      - *1.1.5.2.1. see Figure 4-6*
      - *1.1.5.2.2. …*
    - *1.1.5.3. Co-actions of IOIS representing SO+*
      - *1.1.5.3.1. see Figure 4-6*
      - *1.1.5.3.2. …*
    - *1.1.5.4. Co-actions of IOIS representing CR+*
      - *1.1.5.4.1. see Figure 4-6*
      - *1.1.5.4.2. …*
    - *1.1.5.5. Co-actions of IOIS representing DE+*
      - *1.1.5.5.1. see Figure 4-6*
      - *1.1.5.5.2. …*
    - *1.1.5.6. Co-actions of IOIS representing HI+*
      - *1.1.5.6.1. see Figure 4-6*
      - *1.1.5.6.2. …*
    - *1.1.5.7. Co-actions of IOIS representing RS-*
      - *1.1.5.7.1. see Figure 4-7*
      - *1.1.5.7.2. …*
    - *1.1.5.8. Co-actions of IOIS representing SO-*
      - *1.1.5.8.1. see Figure 4-7*
      - *1.1.5.8.2. …*
    - *1.1.5.9. Co-actions of IOIS representing HI-*
      - *1.1.5.9.1. see Figure 4-7*
      - *1.1.5.9.2. …*
  - ***1.1.6. Changes in blood safety and availability***
    - *1.1.6.1. Realised improvement of BSA*
      - *1.1.6.1.1. see Figure 4-8*
      - *1.1.6.1.2. …*
    - *1.1.6.2. Potential improvement of BSA*
      - *1.1.6.2.1. see Figure 4-8*
      - *1.1.6.2.2. …*
    - *1.1.6.3. Assurance of BSA*
      - *1.1.6.3.1. see Figure 4-8*
      - *1.1.6.3.2. …*
    - *1.1.6.4. Adjustment of operations towards BSA*
      - *1.1.6.4.1. see Figure 4-8*
      - *1.1.6.4.2. …*
    - *1.1.6.5. Potential adjustment of operations towards BSA*
      - *1.1.6.5.1. see Figure 4-8*
      - *1.1.6.5.2. …*
    - *1.1.6.6. No realised improvement of BSA*
      - *1.1.6.6.1. see Figure 4-8*
      - *1.1.6.6.2. …*
    - *1.1.6.7. No potential improvement of BSA*
      - *1.1.6.7.1. see Figure 4-8*
      - *1.1.6.7.2. …*
    - *1.1.6.8. No adjustment of operations towards BSA*
      - *1.1.6.8.1. see Figure 4-8*
      - *1.1.6.8.2. …*
    - *1.1.6.9. No potential adjustment of operations towards BSA*
      - *1.1.6.9.1. see Figure 4-8*
      - *1.1.6.9.2. …*

**Figure 4-9: Example of the coding structure**

## Table 4-5: Examples of template analysis and CIMO logic

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | Weak signal of blood quality problem; telephone; hospital→blood centre; *ad hoc* | Being precautious of the weak signal of blood quality problem | Precaution | PF+ | Prevented usage of blood with the potential quality problem (H) | Assurance of BSA | "Sometimes people just don't like the look of something. And you know if you don't like the look of a product, people phone up and say you know I don't like the look of the product. But it's not often that we get a quality problem." *INT – Blood Transfusion Coordinator and Quality Lead WH Hospital* | WH Hospital (INT 1, WT 1) |
| High tempo | Blood shortage and product substitution; fax and email; blood centre→hospital; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured awareness of blood shortage and substitution (H) | Potential adjustment of operations towards BSA | "So generally we will get a fax and an email to say that there is a shortage of the blood component and we are advised to use substitutions." *INT – Transfusion Practitioner SG Hospital* | BC 1-1 (INT 4), W Hospital (INT 3), SG Hospital (INT 3), FP Hospital (INT 2) |
| Emergency | Order information; OBOS and telephone; hospital→blood centre; *ad hoc* | Being responsive in addressing the immediate need for blood during emergency; authorising the shared information; using redundant information sharing media | Responsive-ness; scepticism; redundancy | CR+; RS+ | Ensured awareness of incoming order during emergency (BC); confirmed order during emergency (H) | Potential adjustment of operations towards BSA; assurance of BSA | "So if the patient is O neg and they are bleeding very heavily, then we probably would need to get some blood down very quickly for them. If they are O pos, we've probably get plenty of stock to support them until [they get what they need] and then we may need to get some more afterwards. If someone's [condition is] very complicated or they are going to [use up] our stock like nobody's business, then we would order blue light from NHSBT. And you have to have consultant, named consultant to authorise a blue light delivery. And it's very clear on the OBOS, you can click blue light, you have to put all those details in and then you click send and then you follow it up with phone call, just to let them know that it's coming through." *INT – Transfusion Practitioner FP Hospital* | BC 1-1 (WT 1; DCMT 1), SG Hospital (WT 2), FP Hospital (INT 1), W Hospital (INT 1) |

### 4.6.2 Within-case and cross-case analyses

Upon completion of the template analysis (i.e. the "final" template), within-case and cross-case analyses were conducted. Within-case analysis was conducted to analyse the patterns of data within each case to understand a studied phenomenon from the perspective of a stand-alone entity (Voss *et al.*, 2002). Whereas cross-case analysis was performed to seek for replication of the findings (the patterns identified from each case) across cases (Bourgeois and Eisenhardt, 1988; Eisenhardt, 1989a, 1989b; Martin and Eisenhardt, 2010; Voss *et al.*, 2002; Yin, 2014). The ultimate aim of these analyses is "to build a general explanation that fits each individual case, even though the cases will vary in their details" (Yin, 2014:148). The process for conducting within-case and cross-case analyses in this thesis was particularly adapted from Bourgeois and Eisenhardt (1988) and Martin and Eisenhardt (2010), who have provided a clear practical guidance on the notion of replication logic in their multiple-case research. Figure 4-10 on page 113 shows the procedure for conducting within-case and cross-case analyses in this thesis.

Within-case in this thesis refers to within each case study context, i.e. *within* the centralised and tightly regulated blood supply chain (BSC) (MC-1) and *within* the decentralised and loosely regulated BSC (MC-2). Each of these main cases (MC-1 and MC-2) consists of three embedded cases, each covering four dyadic relationships (i.e. the relationships between a blood centre and its four associated hospitals) (see the case study structures in Figures 4-3 and 4-4 on page 87). For MC-1 for example, within-case analysis was done by examining the collective mindfulness (CM) principles enacted in the dyadic relationships for three embedded cases (EC 1-1, EC 1-2, and EC 1-3). This thesis first examined what CM principles were enacted in the EC 1-1. It then examined whether the CM principles found in the EC 1-1 were replicated in the EC 1-2 and EC 1-3. The common CM principles enacted across the EC 1-1, EC 1-2, and EC 1-3 represent the result of within-case analysis of the MC-1. Technically, the within-case analysis was conducted in two steps as follows.

First, in each embedded case, the positive and negative enactments of CM principles (the principles for short), previously identified through template analysis, were examined in each operational condition (i.e. in normal, high tempo, or emergency). Because this thesis focusses on *inter-organisational information sharing (IOIS) in the dyadic BSC* as the unit of analysis, it only focusses on the principles that had been identified in both the blood centre and its associated hospitals *(the dyad)*. The principles were included in the analysis *only if* they had been identified in the blood centre and *more than one* of its associated hospitals. In other words, the principles that had been identified *only* in the blood centre *or only* in the hospitals *or* in both the blood centre and *only one* of its associated hospitals were dropped from the analysis. It is important to note that, due to the centralised nature of the BSC in MC-1, when the principles could not be identified in the blood centres in the EC 1-1, EC 1-2, and EC 1-3, the principles identified in the Central NHSBT were used to represent the blood centres.

For example (see Figure 4-3 on page 87), in the EC 1-1, the principles were included in the analysis *only if* they had been identified in the blood centre (BC 1-1) or in the Central NHSBT *and at least two* of its associated hospitals, e.g. (the SG and FP Hospitals) or (the SG, FP, and W Hospitals), or (the SG, FP, W, and WH Hospitals). The principles that had been identified *only* in the BC 1-1 (or in the Central NHSBT) *or only* in the SG Hospital *or* in both the BC 1-1 (or in the Central NHSBT) *and only* the SG Hospital were dropped from the analysis. Whilst minimising the biased perspective of the individual entity within each embedded case, this process increases the accuracy and robustness of the research. It also ensures that the CM principles were in fact collectively enacted (i.e. there is a sufficient level of agreement and interaction amongst entities involved in the dyadic relationships) – see Bourgeois and Eisenhardt (1988); Martin and Eisenhardt (2010); Vogus and Sutcliffe (2012). This process was repeated for the EC 1-2 and EC 1-3.

The second step of the within-case analysis was to identify the common principles across the embedded cases. Given the results of step 1, in a similar fashion, the principles were included for the analysis *only if* they had been identified in *more* *than one* embedded case in each case study context. In other words, the principles that had been identified *only in one* embedded case were dropped from the analysis. Using the same example from Figure 4-3 on page 87, the principles were included in the analysis *only if* they had been identified in the EC 1-1 and EC 1-2 *or* in the EC 1-1, EC 1-2, and EC 1-3. The principles that had been identified *only* in the EC 1-1 *or only* in the EC 1-2 *or only* in the EC 1-3 were dropped from the analysis. As such, the series of embedded cases (i.e. EC 1-1, EC 1-2, EC 1-3) were treated as a series of experiments, so that each embedded case serves to confirm or disconfirm the interpretations drawn from the previous ones, ensuring the robustness and rigour of the research (see Bourgeois and Eisenhardt, 1988; Martin and Eisenhardt, 2010). This process was repeated for the MC-2 (i.e. the decentralised and loosely regulated BSC).

The results of the within-case analysis in each case study context (main case) were the confirmed CM principles that represent the underlying mechanisms of how IOIS influences blood safety and availability (BSA) in the dyadic BSC in normal, high tempo, and emergency conditions. The cross-case analysis was then conducted to compare and contrast the underlying mechanisms between the centralised and tightly regulated BSC and the decentralised and loosely regulated BSC. The results of this analysis are presented in the Findings of Chapter 5 in this thesis.

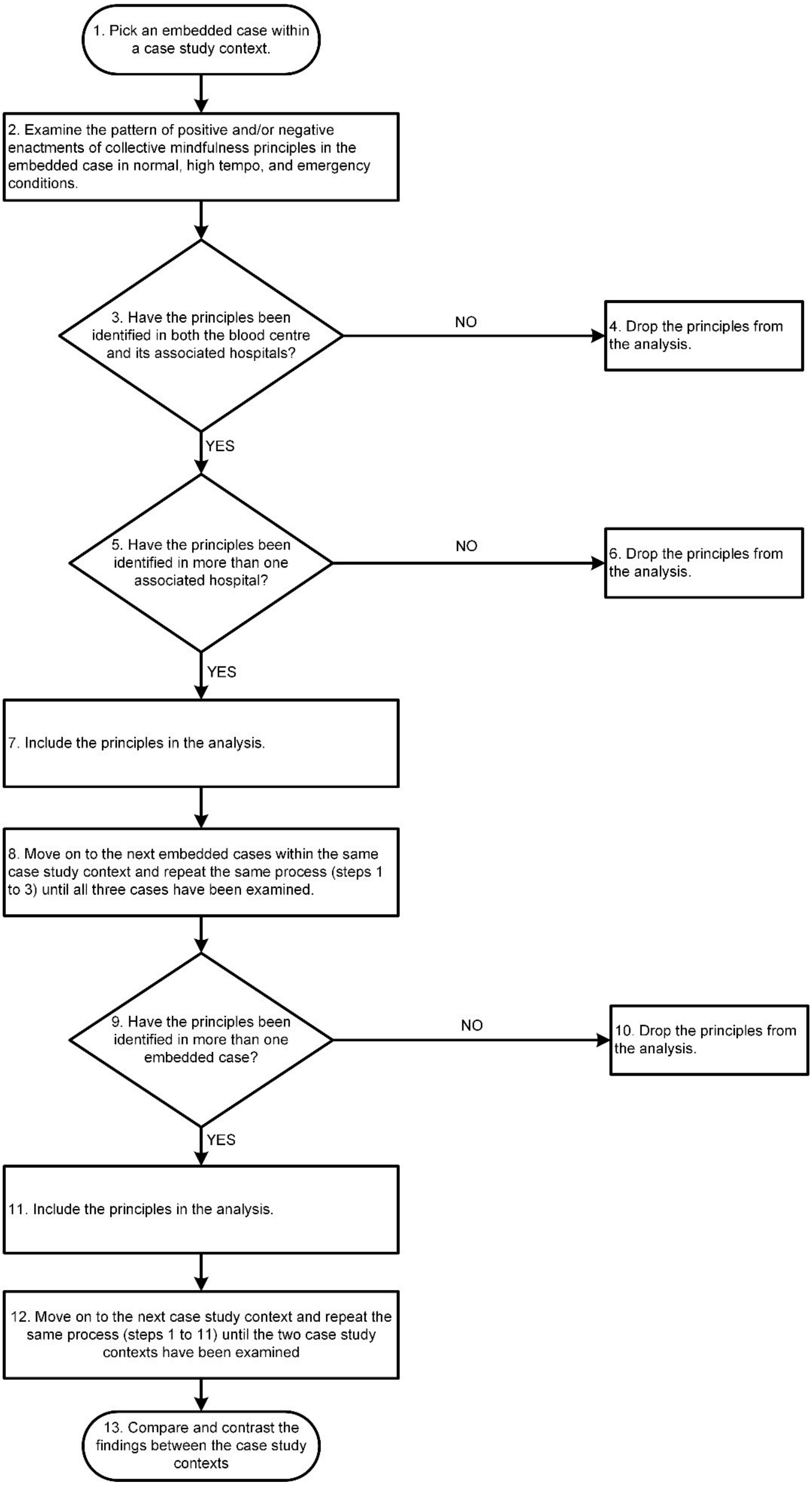


**Figure 4-10: Procedure for conducting within-case and cross-case analyses**

## 4.7 Validity and reliability of the case study

To ensure methodological rigour, this thesis attempts to address the validity and reliability of the case study in various ways. As such, it follows some of the recommendations proposed by Yin (2014) and Gibbert *et al.* (2008) to maintain the internal validity, construct validity, external validity, and reliability of the case study. Although the notion of validity and reliability are commonly used to assess methodological rigour in the positivist tradition, the flexibility of critical realism to use of a wide range of research methods means that this notion can also be adapted under the critical realism paradigm (see Aastrup and Halldórsson, 2008; Halldórsson and Aastrup, 2003; Sayer, 2000).

Internal validity or logical validity assesses "whether the researcher provides a plausible causal argument, logical reasoning that is powerful and compelling enough to defend the research conclusions" (Gibbert *et al.*, 2008:1466). In line with Gibbert *et al.* (2008) and Yin (2014), in this thesis, internal validity was enhanced using a specific type of pattern matching called *explanation building* (Yin, 2014), that involves an iterative process of going back and forth between data and theory to provide a compelling theory-based explanation of a phenomenon. The template analysis subsection (see subsection 4.6.1 on page 95) provides a detailed description of the coding process to illustrate this attempt.

Construct validity refers to the quality of the conceptualisation of the relevant concept, by assessing "the extent to which a study investigates what it claims to investigate, that is, […] the extent to which a procedure leads to an accurate observation of reality" (Gibbert *et al.*, 2008:1466 citing Denzin and Lincoln, 1994). As recommended by Gibbert *et al.* (2008) and Yin (2014), construct validity in this thesis was enhanced in several ways. First, this thesis attempted to establish a clear chain of evidence, i.e. the alignment of the research question, research design, and evidence proposed in this thesis. Second, it seeks to triangulate the data sources and therefore evidence by collecting data using semi-structured interviews, walkthroughs, supporting documents, artefacts, and archives.

In addition, to enhance construct validity, a pilot study was conducted to confirm the feasibility of conducting the full research, the fit of the methodology, and the validity of the research question (see Schreiber, 2008). In this pilot, semi-structured interviews were conducted with seven informants (four from the UK BSC and three from the Indonesian BSC), representing BSC practitioners from blood centres and their associated hospitals in strategic and operational positions. Supporting data from walkthroughs and related documents were also collected and analysed.

The results of the pilot study confirmed the feasibility of conducting a full research, the fit of the methodology, and the validity of the research question. The pilot study improved the researcher's understanding on the effectiveness of the research methods. It also helped the researcher understand the difficulties and challenges in obtaining data access from the field. Relevant data from the pilot study were incorporated into the full research (see Hill and Scudder, 2002) and was presented on two separate occasions. It was presented orally at the European Logistics Association (ELA) Doctoral Workshop 2016 and received constructive feedback from reviewers and other doctoral researchers. It was also presented as a poster at the BBTS Annual Conference 2017 organised by the British Blood Transfusion Society. Practical feedback including data presentation was received from some medical consultants in this blood transfusion practitioner conference.

Next, external validity assesses the ability to analytically (not statistically) generalise the case study findings to other case study contexts according to the relevance of similar principles or theoretical concepts (Yin, 2014). In other words, case study does not seek to generalise the results to the sampled population (Yin, 2014). In line with Gibbert *et al.* (2008) and Yin (2014), the embedded multiple-case study design adopted in this thesis enhances the external validity. Cross-case analysis was applied, allowing replication logic to understand commonalities and differences of findings across different case study contexts.

Finally, reliability refers to transparency and replication of the case study, allowing subsequent researchers to follow the research processes to arrive at the same insights (Gibbert *et al.*, 2008). As recommended by Gibbert *et al.* (2008) and Yin (2014), in this thesis, a case study protocol was produced in the form of data collection protocol and transparent processes for conducting the research. A case study database, including raw data sets, coded data sets, and the completed coding structure, was documented in NVivo 11 Plus.

## 4.8 Summary of the research methodology

This thesis adapts embedded multiple case study methodology designed for theory elaboration. Whilst the design of this research is informed both by the systematic literature review (SLR) and a pilot study, the methodology developed in this thesis is fundamentally grounded in the critical realism paradigm and the perspective of high reliability theory (HRT). To reflect on these fundamentals, a combined retroductive-abductive approach and basic qualitative description are used as the research strategy. Two main cases with three embedded cases for each main case are selected using convenient and context-based approaches, representing the contexts of centralised and tightly regulated as well as decentralised and loosely regulated BSCs. The data are collected using the triangulation of semi-structured interviews, walkthroughs, and other supporting documents including artefacts and archives. Template analysis, coupled with within-case and cross-case analyses, are then adapted to analyse the data. The following chapter (Chapter 5) presents the findings as a result of these processes.

# 5 FINDINGS

In this chapter, findings from the case studies are presented. The reporting of the findings follows a common reporting style for multiple-case study suggested by Yin (2014). As such, instead of presenting the embedded cases as separate chapters, which is considered to be impractical (see Scholten and Schilder, 2015; Stanger, 2013), this chapter briefly highlights the results of within-case analysis for each embedded case. The majority of this chapter then presents the results of the cross-case analysis (across the two main cases) and uses the information from the embedded cases as the evidentiary basis of the thesis. Ultimately, this reporting style helps this chapter focus on addressing the aim of this thesis – to determine and unravel the underlying mechanisms of how inter-organisational information sharing (IOIS) influences the blood safety and availability (BSA) in the dyadic blood supply chain (BSC) in normal, high tempo, and emergency conditions – rather than presenting particular details of each of the embedded cases.

In this chapter, the general findings of within-case analysis are first highlighted. Patterns of IOIS behaviour (i.e. what, how, with whom, and how often information is shared) across a range of operational conditions are then presented to generally understand the IOIS profile of the investigated cases. The enactments of collective mindfulness principles in each operational condition are then described alongside a theoretical framework derived from the data analysis. Examples of representative excerpts are used to illustrate the enactments. In line with Åhlström (2007), Fawcett *et al.* (2014), Gammelgaard (2017), Martin and Eisenhardt (2010), and Scholten and Schilder (2015), the representative excerpts are used to support the story telling whilst maintaining a close link between data and theory in the case study. The findings are then summarised at the end of the chapter.

## 5.1 General findings of within-case analysis

Within-case analysis was conducted on two main cases that represent two contrasting case study contexts – a centralised and tightly regulated BSC (MC-

1) and a decentralised and loosely regulated BSC (MC-2). Three embedded cases from each main case were examined during the analysis process. These cases were coded as EC 1-1, EC 1-2, and EC 1-3 for the MC-1 and EC 2-1, EC 2-2, and EC 2-3 for the MC-2. Highlights of the findings from each of these embedded cases are presented in this section.

EC 1-1 consists of five BSC actors – one blood centre (i.e. BC 1-1) and four associated hospitals (i.e. SG, FP, W, and WH). In general, a wide range of information is shared two-way between the blood centre and the hospitals. With a centralised structure of the BSC in the MC-1, a wide range of information is also shared two-way between the Central NHSBT as a single national organisation managing all blood centres in England and the hospitals. However, as the tempo of the operations becomes higher (i.e. towards high tempo and emergency conditions), the amount of information shared between the blood centre and the hospitals decreases; the number of media used to share the information also decreases; and the frequency of sharing the information is less regular (more *ad hoc*) – see Tables B-1 and B-4 in Appendix B on pages 226 and 236 respectively. This IOIS behaviour reflects different co-actions to manage blood safety and availability, which match with the positive and negative enactments of collective mindfulness (CM) principles in normal, high tempo, and emergency conditions – see Tables C-1 and C-4 in Appendix C on pages 245 and 258 respectively.

Not all the BSC actors in the EC 1-1, however, enact the same CM principles when sharing information across a range of operational conditions. As a result, some enactments of the CM principles are not verifiable in the EC 1-1 (see the results of the verification process in Table D-1 in Appendix D on page 270; details of the verification process have been presented in subsection 4.6.2 in Chapter 4 on page 110). The positive and negative enactments of the verified CM principles represent the underlying mechanisms that explain the changes in BSA in the EC 1-1 in normal, high tempo, and emergency conditions (see Tables E-1 and E-4 in Appendix E on pages 276 and 286 respectively). Overall, the process of how IOIS influences BSA across a range of operational conditions in the EC 1-1 is exemplified using the logic of *context, intervention, mechanism,* and *outcome*

(CIMO logic – see section 2.1 in Chapter 2 on page 15 and subsection 4.6.1 in Chapter 4 on page 95) in Tables F-1 and F-4 in Appendix F on pages 295 and 325 respectively.

EC 1-2 involves one blood centre (i.e. BC 1-2) and four associated hospitals (i.e. JR, WP, NG, and SM). As in the EC 1-1, the same patterns of IOIS behaviour are observed between the blood centre and the hospitals. Two-way information sharing is observed between the blood centre and the hospitals as well as between the Central NHSBT and the hospitals. Whilst a wide range of information is shared in normal conditions, the amount of information shared and the number of media used to share the information between the blood centre and the hospitals decrease in high tempo and emergency conditions. The frequency of sharing the information is also less regular during the conditions – see Tables B-2 and B-4 in Appendix B on pages 230 and 236 respectively. The positive and negative co-actions and enactments of CM principles that reflect this IOIS behaviour in normal, high tempo, and emergency conditions are presented in detail in Tables C-2 and C-4 in Appendix C on pages 250 and 258 respectively. The positive and negative enactments of the verified CM principles (see Table D-2 in Appendix D on page 271) explain the changes in BSA in the EC 1-2 in normal, high tempo, and emergency conditions (see Tables E-2 and E-4 in Appendix E on pages 280 and 286 respectively). The CIMO logic exemplifying the overall process of how IOIS influences BSA across a range of operational conditions in the EC 1-2 is presented in Tables F-2 and F-4 in Appendix F on pages 306 and 325 respectively.

EC 1-3 covers the dyadic relationships between the BC 1-3 blood centre and the RB, SHG, QA, and BNH hospitals. In this embedded case, this thesis also finds the same patterns of IOIS behaviour as in the EC 1-1 and EC 1-2. Whilst the blood centres (or the Central NHSBT) and the hospitals share two-way information on a wide range of content, this thesis finds that the higher the tempo of the operations, the fewer the amounts of information shared between the blood centre and the hospitals. Higher tempo of operations also means more *ad hoc* information sharing and fewer media used to share the information – see Tables

B-3 and B-4 in Appendix B on pages 233 and 236 respectively. This IOIS behaviour is reflected in the positive and negative co-actions and enactments of CM principles across a range of operational conditions (see Tables C-3 and C-4 in Appendix C on pages 254 and 258 respectively). Within the verification process (see Table D-3 in Appendix D on page 272), this thesis finds the positive and negative enactments of CM principles that explain the changes in BSA in the EC 1-3 in normal, high tempo, and emergency conditions (see Tables E-3 and E-4 in Appendix E on pages 283 and 286 respectively). Tables F-3 and F-4 in Appendix F on pages 316 and 325 respectively present the CIMO logic exemplifying the overall process of how IOIS influences BSA across a range of operational conditions in the EC 1-3.

EC 2-1 consists of five BSC actors – one blood centre (i.e. BC 2-1) and four associated hospitals (i.e. PMU, KI, HM, and PW). In general, two-way information sharing is observed between the blood centre and the hospitals. However, the decentralised structure of the BSC in the MC-2 means that there is no information shared between the central Indonesian Red Cross (PMI) and the hospitals. Whilst a wide range of information is shared between the blood centre and the hospitals in normal conditions, the frequency of sharing the information is less regular in high tempo and emergency conditions. As the tempo of the operations becomes higher, the amount of information shared and the number of media used to share the information between the blood centre and the hospitals decreases (see Table B-5 in Appendix B on page 240). The positive and negative co-actions and enactments of CM principles that reflect this IOIS behaviour in normal, high tempo, and emergency conditions are presented in Table C-5 in Appendix C on page 265. The verified CM principles are presented in Table D-4 in Appendix D on page 273, whereas the changes in BSA in the EC 2-1 in normal, high tempo, and emergency conditions are presented in Table E-5 in Appendix E on page 290. The overall process of how IOIS influences BSA across a range of operational conditions in the EC 2-1 is exemplified using the CIMO logic in Table F-5 in Appendix F on page 344.

EC 2-2 involves one blood centre (i.e. BC 2-2) and four associated hospitals (i.e. PR, BT, AK, and SD). As in the EC 2-1, the same patterns of IOIS behaviour are observed between the blood centre and the hospitals in EC 2-2. Whilst a wide range of information is shared two-way between the blood centre and the hospitals, this thesis finds fewer amounts of information shared in high tempo and emergency conditions. With more *ad hoc* information sharing, fewer numbers of media are used to share the information in these conditions. Table B-6 in Appendix B on page 242 presents the details of IOIS behaviour in the EC 2-2. The positive and negative co-actions and enactments of CM principles that reflect this IOIS behaviour in normal, high tempo, and emergency conditions are presented in detail in Table C-6 in Appendix C on page 267. The results of the verification process for the enactments of CM principles are presented in Table D-5 in Appendix D on page 274, whereas the changes in BSA in the EC 2-2 in normal, high tempo, and emergency conditions are detailed in Table E-6 in Appendix E on page 292. Finally, the CIMO logic exemplifying the overall process of how IOIS influences BSA across a range of operational conditions in the EC 2-2 is presented in Table F-6 in Appendix F on page 349.

EC 2-3 covers the dyadic relationships between the BC 2-3 blood centre and the MD, TR, IS, and PMA hospitals. In this embedded case, this thesis also finds the same patterns of IOIS behaviour as in the EC 2-1 and EC 2-2. The blood centre and hospitals share a wide range of information as a two-way process. Towards high tempo and emergency conditions, fewer numbers of information shared and fewer numbers of media used to share the information are observed between the blood centre and the hospitals. In addition, all information is shared on an *ad hoc* basis regardless of the operational conditions (see Table B-7 in Appendix B on page 244). The positive and negative co-actions and enactments of CM principles that reflect the IOIS behaviour across a range of operational conditions can be seen in Table C-7 in Appendix C on page 269. The verified enactments of CM principles are presented in Table D-6 in Appendix D on page 275, whilst the changes in BSA in the EC 2-3 in normal, high tempo, and emergency conditions are documented in Table E-7 in Appendix E on page 294. The overall process of how IOIS influences BSA across a range of operational conditions in the EC 2-3 is presented using the CIMO logic in Table F-7 in Appendix F on page 352.

## 5.2 General patterns of IOIS behaviour across cases

In this section, the inter-organisational information sharing (IOIS) behaviour identified through within-case analysis is compared and contrasted. This thesis finds differences and similarities in IOIS behaviour across the two main cases in normal, high tempo, and emergency conditions. In all operational conditions, the blood supply chain (BSC) actors in the centralised and tightly regulated context (MC-1) share a wider range of information covering a wider number of aspects in the BSC (e.g. inventory management, supply, delivery, changes in operations, blood safety incidents) compared to that in the decentralised and loosely regulated context (MC-2). This indicates that the MC-1 is more open to sharing information than MC-2.

A similar pattern is also identified for the modality of sharing information, in which, compared to MC-2, the MC-1 uses a wider variety of information sharing media ranging from conventional (e.g. telephone, email, face-to-face meeting) to more advanced information sharing systems (e.g. online blood ordering system (OBOS), web-based stock levels, usages, wastage, and safety incidents reporting systems). This indicates a richer and more flexible nature of information sharing in the MC-1, compared to the MC-2.

Due to the centralised control of the BSC in the MC-1, the direction of information sharing in this case is rather different from that of the MC-2. The three blood centres in the MC-1 are centrally managed by the NHSBT, a single national organisation that manages the whole blood supply in England. As a consequence, information is not only shared between the blood centres and their associated hospitals, but also between the Central NHSBT and all hospitals served by this organisation.

For example, the blood centres in the MC-1 often provide advice on blood stock management, quality, and/or incident-related issues to their associated hospitals, whereas the Central NHSBT frequently share information, via a website, on the general BSA issues that are accessible and actionable for all hospitals across the country. Similarly, the hospitals not only share order and complaint information with their associated blood centres, but also share information such as blood stock levels, usages, wastage, and safety incidents to the Central NHSBT via national reporting systems such as the Blood Stocks Management Scheme (BSMS). The information shared with the Central NHSBT is then processed and shared back with the reporting hospitals to help them understand the general trends of their BSA. Whilst this thesis separates the direction of information sharing from and to the blood centres and from and to the Central NHSBT, many informants refer to the "NHSBT" when they mean blood centres. During the data analysis process, the different direction of information sharing was therefore identified by understanding and confirming the specific context in which information sharing was mentioned by the informants. Figure 5-1 illustrates the direction of information sharing in the MC-1.

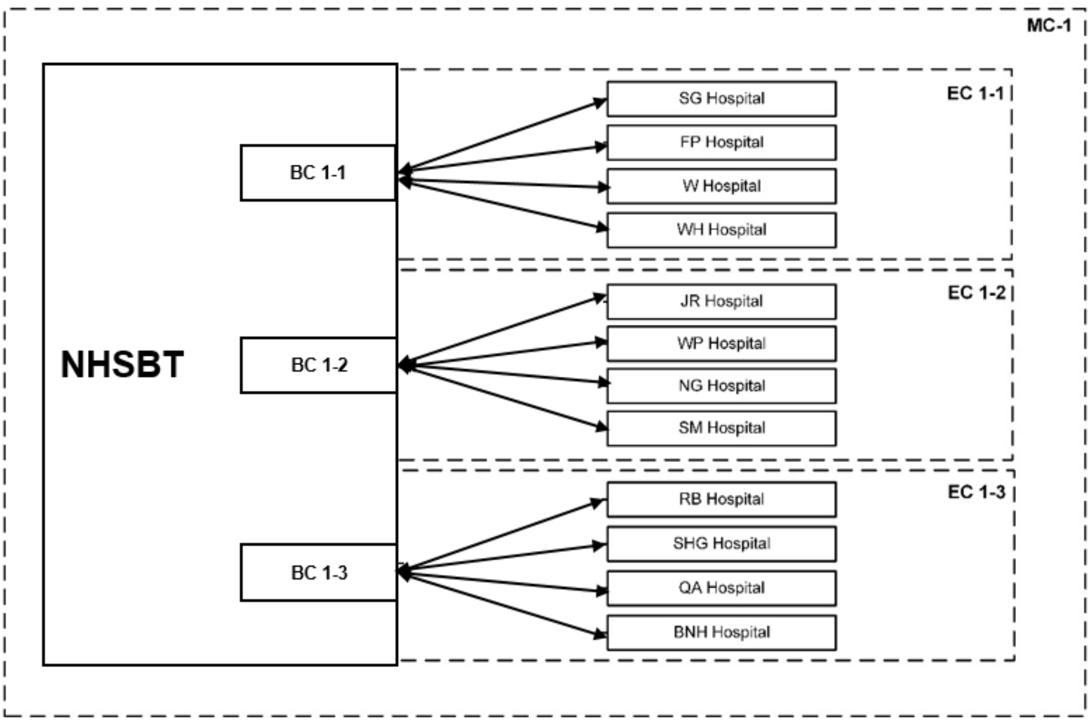


**Figure 5-1: The direction of information sharing in the MC-1**

In the MC-2, information is only shared in isolation between each blood centre and each of its associated hospitals. Whilst a national website that is publicly accessible does exist, the content of information on the website is very general and not focussed on the BSA issues. In fact, two of the three blood centres investigated in this thesis (i.e. EC 2-1 and EC 2-2) have their own websites which are used as a one-way information sharing medium from the blood centres to their associated hospitals. Figure 5-2 illustrates the direction of information sharing in the MC-2.

Finally, this thesis finds that, as the tempo of the operations becomes higher (i.e. towards high tempo and emergency conditions), a similar pattern of IOIS behaviour is identified for both MC-1 and MC-2. The higher the tempo of the operations, the less content of information is shared using fewer and leaner media such as telephone, email, and/or fax. The information is also shared on a more *ad hoc* rather than planned basis. This pattern represents the nature of the unexpected conditions requiring immediate responses to address critical BSA issues. Examples of information shared in these conditions include blood shortage or stockout, product recall, blood safety incidents, severe reaction to transfusion, patients' major haemorrhages, road traffic accidents, and/or major incident alerts such as flood or terrorist attacks.

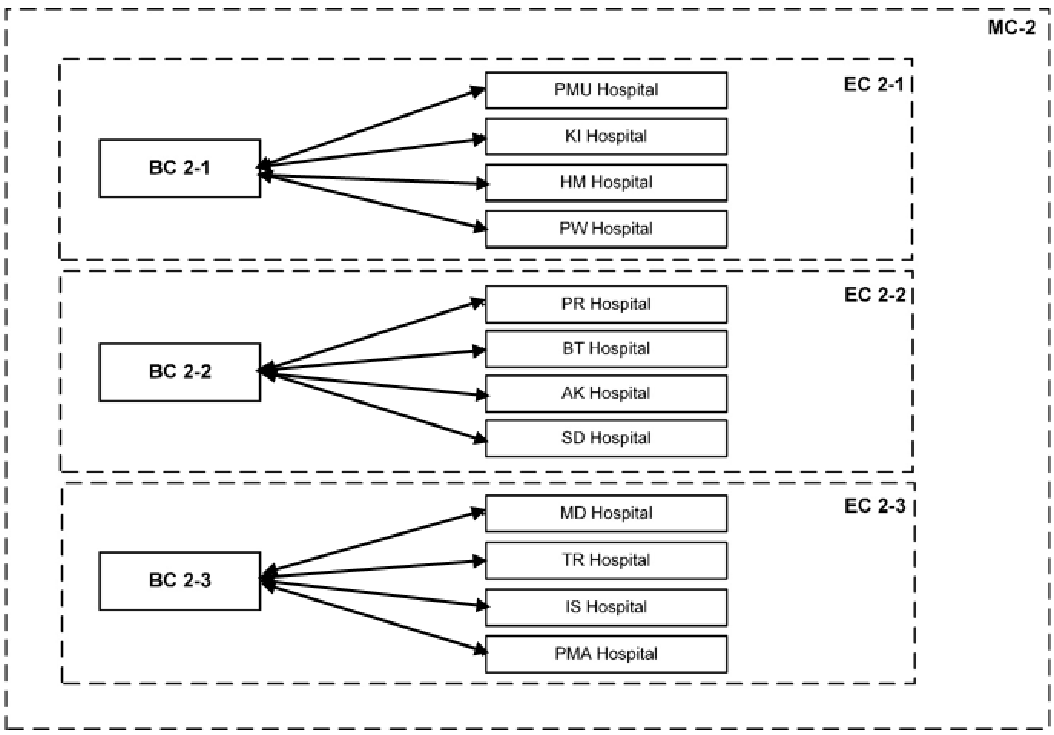


**Figure 5-2: The direction of information sharing in the MC-2**

## 5.3 IOIS behaviour and collective mindfulness across cases

In this section, the findings are first presented at a high level of abstraction followed by a detailed description with relevant examples from the data.

This thesis asks *how does inter-organisational information sharing influence blood safety and availability in the dyadic blood supply chain in normal, high tempo, and emergency conditions?* This thesis finds that IOIS influences BSA through the dynamic enactments of collective mindfulness (CM) principles. Figure 5-3 on page 126 presents a theoretical framework derived from the data analysis that illustrates the dynamic in normal, high tempo, and emergency conditions.

In this framework, CIMO logic is applied, treating the MC-1, MC-2, and the operational conditions as the contexts *(C)*; IOIS behaviour as the interventions *(I)*; the CM principles as the mechanisms *(M)*; and changes in the BSA performance as the outcomes *(O)*. Detailed descriptions of this logic are presented in the following subsections, whereas detailed examples of supporting evidence with this logic for each embedded case in the MC-1 and MC-2 are presented in Appendix F on page 295.

The framework posits that when sharing or receiving information, the BSC actors not only convey or receive certain facts, messages, or explicit knowledge, using certain media, with a certain direction and frequency, but they also enact co-actions (e.g. being precautious with blood safety issues, avoiding making assumptions, being transparent, being responsive, being aware of their role in the BSC), that match with the CM principles postulated in high reliability organisations (HROs). These CM principles represent the underlying mechanisms that are responsible for producing changes in the BSA in the MC-1 and MC-2 in normal, high tempo, and emergency conditions.

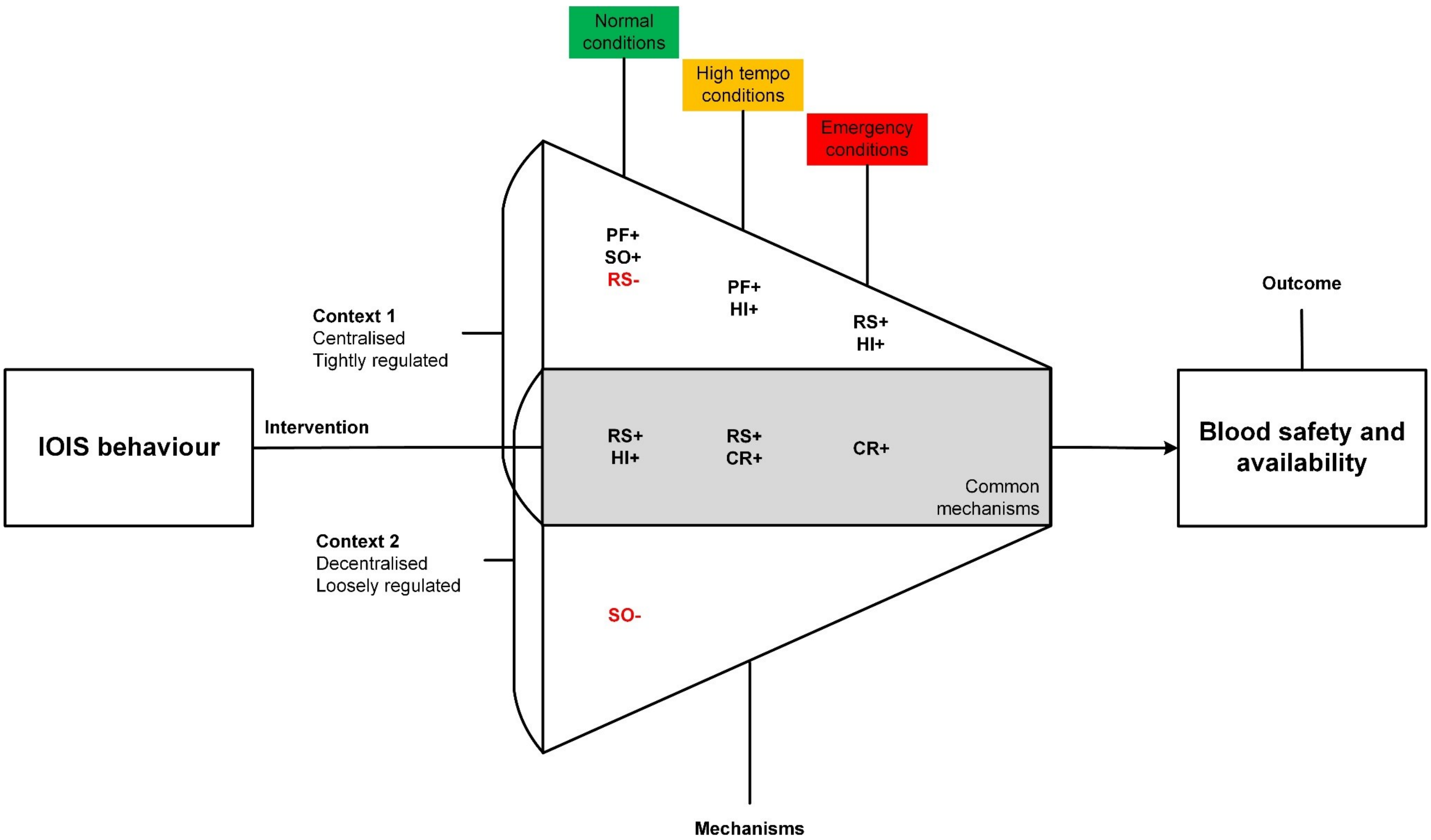


**Figure 5-3: A collective mindfulness framework of how IOIS influences BSA across a range of operational conditions**

As suggested in the framework, this thesis finds that IOIS influences BSA through common mechanisms (i.e. mechanisms that are identified in both MC-1 and MC-2) and context-specific mechanisms (i.e. mechanisms that are identified only in MC-1 or MC-2). Whilst the framework shows that not all of the *a priori* CM principles can serve as the underlying mechanisms that explain how IOIS behaviour influences BSA across the operational conditions, the CM principles that are used in the framework have passed a rigorous verification process to ensure that they are commonly found across the embedded cases in the MC-1 and MC-2. This means that the CM principles are only included in the framework when they are enacted in more than one embedded case in each case study context (see Table 5-1 on page 128). Details of the verification process have been presented in subsection 4.6.2 in Chapter 4 on page 110.

For example, in normal conditions, the positive principle of reluctance to simplify (RS+) is found in both main cases (the MC-1 and MC-2) which is confirmed by their respective embedded cases of EC 1-1, EC 1-2, EC 1-3 and EC 2-1, EC 2-2, EC 2-3. RS+ is therefore verified and included as an underlying mechanism in the framework. On the other hand, the positive principle of deference to expertise (DE+) is only found in MC-1 which is only confirmed by one respective embedded case of EC 1-2. DE+ is therefore not verified and not included as an underlying mechanism in the framework.

The framework also suggests that more CM principles are positively enacted in the MC-1 compared to those in the MC-2. This indicates that the BSC actors in the centralised and tightly regulated BSC are collectively more mindful when sharing or receiving information than those in the decentralised and loosely regulated BSC. The framework further suggests that in normal conditions, IOIS can negatively influence BSA through the negative enactments of some CM principles (i.e. reluctance to simplify (RS-) and sensitivity to operations (SO-)).

**Table 5-1: The prevalence of CM principles across the investigated cases**

| Operational conditions | CM principles | Supporting cases | Verified? |
|---|---|---|---|
| Normal | PF+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-1) | - |
| | RS+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-1, EC 2-2, EC 2-3) | √ |
| | SO+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-1) | - |
| | CR+ | - | - |
| | DE+ | MC-1 (EC 1-2) | - |
| | HI+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-1, EC 2-2, EC 2-3) | √ |
| | PF- | - | - |
| | RS- | MC-1 (EC 1-1, EC 1-2) | √ |
| | SO- | MC-1 (EC 1-2) | - |
| | | MC-2 (EC 2-2, EC 2-3) | √ |
| | CR- | - | - |
| | DE- | - | - |
| | HI- | MC-1 (EC 1-1) | - |
| | | MC-2 (EC 2-2) | - |
| High tempo | PF+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-1) | - |
| | RS+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-1, EC 2-2, EC 2-3) | √ |
| | SO+ | MC-1 (EC 1-3) | - |
| | CR+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-2, EC 2-3) | √ |
| | DE+ | MC-1 (EC 1-2) | - |
| | HI+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | PF- | - | - |
| | RS- | - | - |
| | SO- | - | - |
| | CR- | - | - |
| | DE- | - | - |
| | HI- | - | - |
| Emergency | PF+ | - | - |
| | RS+ | MC-1 (EC 1-1, EC 1-3) | √ |
| | SO+ | - | - |
| | CR+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | | MC-2 (EC 2-1, EC 2-3) | √ |
| | DE+ | - | - |
| | HI+ | MC-1 (EC 1-1, EC 1-2, EC 1-3) | √ |
| | PF- | - | - |
| | RS- | - | - |
| | SO- | - | - |
| | CR- | - | - |
| | DE- | - | - |
| | HI- | - | - |

Unexpectedly, this thesis reveals the positive enactments of some of the CM principles that are not currently explained in the extant HRO's literature. For example, Weick and Sutcliffe (2015, 2007), Weick *et al*. (1999), and Lekka (2011) all categorise the positive principles of *preoccupation with failure* (PF+), *reluctance to simplify* (RS+), and *sensitivity to operations* (SO+) into the principles of anticipation and therefore they should be enacted in normal conditions. On the other hand, the principles of *commitment to resilience* (CR+) and *deference to expertise* (DE+) are categorised into the principles of containment, which should be enacted when unexpected events break out. Whilst confirming this categorisation, this thesis interestingly reveals the enactments of PF+ and RS+ during the unexpected events (i.e. PF+ is enacted in high tempo conditions and RS+ is enacted in both high tempo and emergency conditions). This thesis therefore argues that the enactments of the CM principles across a range of operational conditions are more dynamic than the high reliability theory (HRT) has suggested. This dynamic is described in detail with relevant examples in the following subsections.

Despite the enactments of the five core principles of collective mindfulness, this thesis also reveals an emerging mechanism of *heedful interrelating* (HI), which is found across a range of operational conditions particularly in the MC-1. Although HI+ has been linked to collective mindfulness in HROs (Weick and Roberts, 1993), HI+ is not currently incorporated into the five core principles of collective mindfulness that are used as *a priori* themes in this thesis (see Weick and Sutcliffe, 2015, 2007; Weick *et al*., 1999; Lekka, 2011). HI+ emphasises the sense of *alertness* to the important events in the organisations' environment which might affect the performance of those organisations (Weick and Roberts, 1993). To constitute heedful interrelating, "actors in the system construct their actions (contributions), understanding that the system consists of connected actions by themselves and others (representation), and interrelate their actions within the system (subordination)" (Weick and Roberts, 1993:357).

These acts of alertness, contribution, representation, and subordination build on the CM principle of sensitivity to operations (SO+) which places emphasis on having a big picture of operations and knowledge of interrelations within the system (i.e. having transparency of the system). However, HI+ is slightly different from SO+. HI+ is about understanding how a system is configured and seeing one's work as a contribution to the system, not as a silo activity. It is also about seeing how one's work fits with the work of others to achieve the system goals. Practically, HI+ is about the awareness of the BSC actors that their actions not only affect their BSA, but also the BSA across the BSC. HI+ is prevalent across cases and operational conditions particularly in the MC-1 and is therefore treated as an emerging principle separated from SO+.

Finally, this thesis finds that the enactments of CM principles in each case study context are responsible for producing changes in the BSA across a range of operational conditions. Tables 5-2 and 5-3 on pages 132 and 133 respectively present these qualitative associations in the MC-1 and MC-2 respectively. It can be observed from the tables that each verified CM principle can be broken down into sub-principles that are dynamically enacted in normal (N), high tempo (HT), and emergency conditions (E). Compared to the MC-2, the enactments of the CM sub-principles in the MC-1 are associated with the higher number of changes in BSA (ticked areas). These changes in BSA not only mean that IOIS behaviour is applied to assure and adjust the BSA as a response to the dynamic changes in their environment, but also to improve the BSA performance across the BSC. This pattern is not widely observed in the MC-2, which focusses more on assurance and adjustment of operations towards BSA. This indicates that the BSC actors in the MC-2 tend to apply certain IOIS behaviours to fulfil immediate needs for BSA with a fire fighting mode of operations. The following subsections elaborate these findings in more detail.

### 5.3.1 IOIS behaviour and CM principles in normal conditions

Normal conditions represent business as usual or day-to-day operations where there is no particular event happening that might significantly affect BSA. In these conditions, reluctance to simplify (RS+) and heedful interrelating (HI+) are the positive mechanisms that are commonly found across the embedded and main cases. This suggests that regardless of the case study contexts (the MC-1 or MC-

2), IOIS behaviour leads to positive changes in the BSA when RS+ and HI+ principles are enacted in normal conditions.

Beside these two positive mechanisms, context-specific mechanisms are also found in the MC-1 and MC-2. The IOIS behaviour in the MC-1 enacts the positive CM principles of preoccupation with failure (PF+), sensitivity to operations (SO+), and the negative principle of reluctance to simplify (RS-). On the other hand, the IOIS behaviour in the MC-2 reflects the negative enactment of sensitivity to operations (SO-). The more positive enactments of the CM principles in the MC-1 indicate that the BSC actors in the MC-1 are collectively more mindful when sharing or receiving information in normal conditions than those in the MC-2. This finding also indicates that the underlying mechanisms explaining *how* IOIS influences the BSA in normal conditions are different across the case study contexts. The following sub-subsections describe each of the enacted CM principles in detail.

#### 5.3.1.1 Positive enactment of reluctance to simplify (RS+)

When sharing information, the BSC actors across the embedded cases in both the MC-1 and MC-2 enact the principle of reluctance to simplify (RS+). Their IOIS behaviour reflects the acts of *redundancy, scepticism,* and *checks and balances* (see Table 2-1 in Chapter 2 on page 23 for details of these elements in HROs) to improve and assure the BSA as well as to adjust their operations towards the BSA (see Tables 5-2 and 5-3 on pages 132 and 133 respectively; see also section 4.6.1 in Chapter 4 on page 95 for the different categorisation of changes in BSA). Redundancy, scepticism, and checks and balances are very important considering the unique characteristics of BSC. Unlike many other perishable products, blood cannot be reproduced and requires stringent operations to ensure blood safety for patients. In addition, the supply of blood products depends on the availability of donors that is not easy to predict. Redundancy, scepticism, and checks and balances therefore ensures a robust system to avoid wasting blood as a precious resource and to prevent any errors that can lead to fatal consequences for patients.

## Table 5-2: CM principles and the classified changes in BSA in MC-1

| CM principles | | Realised improvement of BSA | | | Potential improvement of BSA | | | Assurance of BSA | | | Adjustment of operations towards BSA | | | Potential adjustment of operations towards BSA | | | No realised improvement of BSA | | | No potential improvement of BSA | | | No adjustment of operations towards BSA | | | No potential adjustment of operations towards BSA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E |
| PF+ | Precaution | √ | - | - | √ | √ | - | √ | √ | - | - | - | - | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Failure reporting | - | - | - | √ | √ | - | - | √ | - | - | √ | - | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Openness | - | - | - | - | - | - | - | √ | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| RS+ | Redundancy | - | - | - | √ | √ | √ | √ | √ | √ | - | - | √ | √ | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - |
| | Scepticism | √ | - | - | - | √ | - | √ | √ | √ | - | - | √ | √ | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - |
| | Checks and balances | √ | - | - | √ | - | - | √ | √ | - | √ | - | - | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SO+ | Transparency | √ | - | - | √ | - | - | √ | - | - | √ | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Regular interactions | √ | - | - | √ | - | - | √ | - | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Real time interactions | √ | - | - | - | - | - | √ | - | - | √ | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Ongoing operational adjustments | √ | - | - | √ | - | - | √ | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| CR+ | Responsiveness | - | √ | - | - | √ | - | - | √ | √ | - | √ | √ | - | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - |
| HI+ | Alertness | - | - | - | √ | √ | √ | √ | √ | √ | √ | - | √ | √ | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - |
| | Contribution, representation, and subordination of actions | √ | - | - | √ | √ | - | √ | √ | √ | √ | √ | - | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - | - |
| RS- | No scepticism | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | - | √ | - | - | √ | - | - | √ | - | - |
| | No checks and balances | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | - | √ | - | - | - | - | - |

## Table 5-3: CM principles and the classified changes in BSA in MC-2

| CM principles | | Realised improvement of BSA | | | Potential improvement of BSA | | | Assurance of BSA | | | Adjustment of operations towards BSA | | | Potential adjustment of operations towards BSA | | | No potential improvement of BSA | | | No assurance of BSA | | | No adjustment of operations towards BSA | | | No potential adjustment of operations towards BSA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E | N | HT | E |
| PF+ | Precaution | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Failure reporting | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Openness | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| RS+ | Redundancy | - | - | - | - | - | - | √ | √ | - | √ | - | - | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Scepticism | - | - | - | - | - | - | √ | √ | - | √ | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Checks and balances | - | - | - | √ | - | - | √ | - | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SO+ | Transparency | - | - | - | √ | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Regular interactions | - | - | - | √ | - | - | √ | - | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Real time interactions | - | - | - | - | - | - | √ | - | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Ongoing operational adjustments | - | - | - | - | - | - | √ | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| CR+ | Responsiveness | - | - | - | - | - | - | - | √ | - | - | - | √ | - | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - |
| HI+ | Alertness | - | - | - | - | - | - | √ | - | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Contribution, representation, and subordination of actions | - | - | - | √ | - | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SO- | No transparency | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | - |
| | No regular interactions | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - |
| | No real time interactions | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | - | - | - | - | - | - | - | - | - | - |
| | No ongoing operational adjustments | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | - | - | - | - |
| | Mismatched use of information | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | - | √ | - | - | - | - | - | - | - | - |

The act of redundancy represents the BSC actors' reluctance to rely only on one aspect of the IOIS behaviour which can be fallible. For example, in the MC-1, redundancy is identified when the NHSBT shares the blood management updates on the hepatitis C virus (HCV) negative blood to the hospitals using more than one information sharing media. To ensure that the hospitals are aware of the information and to potentially improve blood safety, the updates are shared verbally in the regional transfusion committee meeting and electronically via email.

The use of back-up information sharing media also represents redundancy in the MC-1. For example, when the patient blood test results are not available on the Sp-ICE (i.e. Specialist Services electronic reporting using Sunquest's Integrated Clinical Environment – a web-based system to share patient diagnostic reports), fax is used to securely share the information with the hospitals. As a Blood Transfusion Operations Manager at the QA Hospital suggests:

> "So when we haven't got NHS.net account, you can't be transferring information, patients' information, via email because it can be intercepted. So we use fax for very rarely really because for [blood test] result [from] NHSBT there is Sp-ICE which is electronic. And we only want them to fax us interim results if they are not available on Sp-ICE." *INT – Blood Transfusion Operations Manager QA Hospital EC 1-3*

Similarly, the use of redundant information sharing media is also identified in the MC-2. For example, when sharing order information, the hospitals use both order form or request letter and telephone as a way to confirm the blood order and therefore assuring blood availability for the hospitals. A Laboratory Manager at the PMU Hospital suggests:

> "We use an order form to request blood, because we have an agreement with the blood centre, so we specify how many blood [packs] we would like to order. We then phone the blood centre, "from this hospital, we would like to order this many blood packs". Our staff will then go to the blood centre with a box and thermometer, take the order from there." *INT – Laboratory Manager PMU Hospital EC 2-1*

RS+ is also manifested in the act of scepticism when sharing information. This act reflects the BSC actors who do not easily trust each other. They avoid making assumptions, therefore creating a system with positive doubts that the precautions are sufficient. For example, in the MC-1, scepticism is indicated by the blood centres ignoring any unspecified requests for fresh blood from the hospitals. This is to ensure that the requested blood is really used for justifiable clinical purposes, therefore avoiding unnecessary use of fresh blood that could lead to overstocking short-dated blood, which is likely to be wasted. Scepticism is also identified when the blood centres share information to ensure that they provide blood that is suitable and safe for patients.

The act of scepticism might not be applicable in other supply chain contexts, where the consequences of having errors in the supply chain operations are not as critical as in the BSC. For example, having an error in the ordering process (e.g. over-order) might not be a critical issue for a pharmaceutical supply chain. Whilst the over-order can increase the inventory cost due to overstock, it might not affect the health of customers of pharmaceutical products. In the BSC, however, over-order can be a critical issue particularly when the supply of blood is limited due to the lack of donors' availability. In this case, over-order of blood products in one hospital could create shortage or even stockout of blood products in other hospitals, resulting in patients not having sufficient blood when needed. This error should therefore be avoided using the act of scepticism. The Hospital Services Manager at the BC 1-2 Blood Centre suggests:

> "So we wouldn't say to the hospital that you need this instead of this. But we might advise. If we notice that something is out of the ordinary that they have ordered, we might question and say "did you want to speak with the clinician?", and we might question it and if they order really out of ordinary." *INT – Hospital Services Manager BC 1-2 EC 1-2*

In the MC-2, whilst maintaining blood availability in the blood centres is a big challenge, scepticism is manifested for example when the hospitals share information to confirm the availability of blood before ordering from the blood centres. Scepticism is also reflected in the blood centres' order management. As a common practice amongst the hospitals that do not have a blood bank in the MC-2, ordering blood means reserving and using the blood centre's facility to store the blood products. To ensure that the ordered blood is not left in the blood centres for a long time and ends up being wasted, once the order has been confirmed, the blood centres subsequently share information to question the use of the ordered blood within the hospitals. The unused blood with shelf life remaining is then reallocated to other hospitals in need. A Midwife at the SD Hospital and a Blood Administration Manager at the TR Hospital suggest:

> "When the patient has gone home, there is then a decision that the blood is not used. It can be that the blood centre phones us or we phone the blood centre to cancel the [ordered and reserved] blood, [because] it's not going to be used." *INT – Midwife SD Hospital EC 2-2.*

> "But usually the blood centre also calls us, calls the nurse here, "this patient with this name, we still have the blood, do you still want to use it?" If it is not used, it may be used automatically allocated to other patients so there is no blood wasted." *INT – Blood Administration Manager TR Hospital EC 2-3.*

Finally, RS+ involves the act of checks and balances. When sharing information, the BSC actors attempt to ensure that their counterparts are checked to improve the BSA and avoid any abuse of operations that makes the BSA worse. In the MC-1, the act of checks and balances is reflected, for example, when the NHSBT and the hospitals discuss and evaluate the NHSBT services to the hospitals. This action is conducted at the transfusion practitioner regional meeting on a quarterly basis, in which important information on the key performance indicators (KPIs) is shared to see the potential improvement for the BSA.

Another way to ensure checks and balances in the MC-1 is a two-way information sharing on blood wastage between the hospitals and the Central NHSBT via the Blood Stocks Management Scheme (BSMS). This practice provides accountability that motivates the hospitals to prevent unnecessary waste in their facilities. As the following excerpt suggests:

> "Well BSMS is like an accountability isn't it? So it means you are recording, because at the end of the day blood and platelets are [donated]. Somebody sees [the records] there, their [reporting] time you know. So, you don't want to be wasting it. You want to utilise it as best as you can. So, that BSMS helps a lot in giving us accountability. So when you have those transparency figures and you can see how much you are wasting and when we have summary reports like [the NHSBT administrator sends] us. It's those things that make you share the information, keep you in check I think." *INT – Blood Transfusion Operations Manager QA Hospital EC 1-3*

The act of checks and balances in the MC-1 is also manifested when the NHSBT shares lessons learnt on blood safety incidents to reduce complacency on the safety of blood transfusion, which can lead to potential improvement of blood safety in the hospitals. As the following excerpt suggests:

> "So, when something goes wrong, everyone suddenly goes, "oh my god that could have been me", you know. When everything, the thing about transfusion it is actually really safe, as much as I go on about it, it is very safe compared to a lot of other things that happen to patients. So, people will become quite complacent because you can give transfusions for 20 years and never see a reaction and never have a problem and you become like "ya another transfusion, whatever" so you become really complacent about the checks that you should do. And you think "ah the blood's safe, there is no point in doing this observation, it's fine". But, if you suddenly have an incident in a trust, somebody dies, it really wakes everybody up. And it's those stories and those lessons that you've learned, that are the best way of sharing that back, really." *INT – National Lead Patient Blood Management Practitioner Team NHSBT*

In the MC-2, the act of checks and balances is identified when the blood centres share information to increase the hospitals' compliance with the blood safety practices. For example, the blood centre in the EC 2-2 recommends its associated hospitals to use voluntary or regular rather than replacement or family donors who are likely to have blood quality issues. From the blood centre's experience, replacement or family donors usually have poor self-assessment of their health. Some family donors even lie about their health conditions just to donate their blood for their relatives.

Checks and balances in the MC-2 are also reflected when the blood centres and the hospitals share information through an audit process that is regularly conducted by the blood centres to ensure the BSA in the hospitals. As the Blood Donation and Marketing Manager at the BC 2-1 Blood Centre suggests:

> "We go there [to the hospitals], regular visits. […] We visit them every three months; usually it's me and [my colleague]. We then have trainings for the hospitals' blood banks, if there are any problems. Sometimes we have meetings with the hospitals' blood banks. […] What we do is everything, we socialise about [current blood management policy], and then about making a report, transfusion, we check everything, the cross-match there, stock planning, labelling, everything, blood group [compatibility]. […] there is a report for the blood safety

[in the hospitals that is shared with us]." *INT – Blood Donation and Marketing Manager BC 2-1 EC 2-1*

#### 5.3.1.2 Positive enactments of heedful interrelating (HI+)

HI+ represents another common mechanism in normal conditions that emerges from the data and is verified across the embedded cases in both the MC-1 and MC-2. In the MC-1, HI+ is manifested in the acts of alertness, contribution, representation, and subordination. Alertness is reflected for example when the blood centres notify the hospitals about the delivery of short-dated blood which affects the stock profile of the hospitals. Alertness is also identified when the blood centres remind the hospitals using the vendor managed inventory (VMI) system that some of their stocks are soon to expire and recommend the hospitals to use them first. Another example of alertness is when NHSBT warns hospitals and patients on the harmful risk of transfusion which could lead to death if it is not appropriately administered. The awareness of the risk of transfusion can lead to potential improvement of blood safety in the hospitals, as the following excerpt suggests:

"We have put that and we've just changed the wording in the patients' information leaflets [shared with the hospitals] and it's the first time whether actually there was written the word "death" in the patients' information leaflets. Because you have to know in terms of the rules and the law around consent, patient consent, you have to actually, have to say if there is a risk of death, you have to say there is and there is a risk of death. So we, but it must be really hard for patients to try to you know understand, you know, the risks etc. […] because it's risky, you know it's liquid transplant effectively, it's how we would describe it. You wouldn't have a kidney transplant if you didn't need one, so don't have a blood transfusion if you don't need one." *INT – National Lead Patient Blood Management Practitioner Team NHSBT*

In the MC-2, the hospitals alert the blood centres for example by putting notes when they require fresher blood for haemodialysis patients. Similarly, the blood centres alert the hospitals by calling them when the ordered blood is ready for collection or by sending them a formal letter when there is a potential reaction to transfusion from the ordered blood. These mechanisms can lead to the potential adjustments of the hospitals' operations towards maintaining the BSA. The Laboratory Manager at HM Hospital suggests:

> “From the blood centre usually if there is a reaction [to transfusion], there will be a reaction, there will be a notification from the blood centre. For example, this blood that is going to be transfused to the patient, there will be a reaction or incompatible. […] [They] use a formal letter.” *INT – Laboratory Manager HM Hospital*

The act of contribution, representation, and subordination on the other hand is reflected when the blood centres and the hospitals share information because they are aware that their changes in operations are likely to influence each other. In the MC-1 for example, the hospitals were made aware that the NHSBT were planning to increase their stock levels in response to the 2012 Olympics. The increase in stock levels means that overstock was likely to happen after the event, leaving the hospitals with short-dated blood to use.

Similarly, any changes in the hospitals’ practices that influence the demand for blood are shared with the blood centres so they can adjust their operations to maintain blood availability in the BSC. As the following excerpt suggests:

> “Because a hospital practice influences NHSBT, so again every year as part of the process, I say to anticipate any changing practice. So for example if we suddenly took on liver transplant, we would order lots more FFP. So, therefore we would flag it and then they would work out, you know, based on what they supply to [the other hospital]. If we said we are now gonna be doing a patient week as well, they will then sort of re-evaluate how they produce their stock, meeting this new demand. So again there is so much interaction.” *INT – Transfusion Practitioner SG Hospital EC 1-1*

In the MC-2, the act of contribution, representation, and subordination is identified for instance when the blood centre shares information with the hospitals to resolve the issue of replacement donors, which affects the BSA across the BSC. For example, the BC 2-2 blood centre and its associated hospitals often have conflicting recommendations on the use of replacement donors. On the one hand, the hospitals allow their patients to use family or replacement donors. On the other hand, the blood centre recommends the hospitals to use voluntary or regular donors to ensure the quality and safety of the blood. Whilst ensuring the blood safety for patients, the use of voluntary or regular donors also ensures that the hospitals make use of the stocks in the blood centre, avoiding overstock which could lead to wastage. As the following excerpt suggests:

"We have an obstacle. The hospitals say "please use family donor, use replacement donor, use fresh blood", that's what the hospitals say. We have warned the hospitals about that. If [they] want fresh blood, we have it. What happens then is we have overstock because [the hospitals use] replacement donors. […] I even gathered [them], 90 hospitals were gathered together for that [problem to be resolved]. What I want is how the blood quality can be achieved according to standard operating procedures." *INT – Blood Donation Manager BC 2-2 EC 2-2*

#### 5.3.1.3 Positive enactment of preoccupation with failure (PF+)

Whilst RS+ and HI+ represent the common mechanisms explaining how IOIS influences BSA in the MC-1 and MC-2, PF+ represents a context-specific mechanism that is verified in the MC-1. PF+ is manifested in the IOIS behaviour that embraces the acts of *precaution, failure reporting,* and *openness* towards "the health" of the BSC (see Table 2-1 in Chapter 2 on page 23 for details of these elements in HROs). Precaution is identified, for example, when hospitals share information on the weak signals of failure (e.g. a strange look of the blood) with the blood centres to prevent any unwanted consequences such as blood safety incidents in patients. Precaution is also reflected when the hospitals share information in the form of failure reporting via a national incidents reporting system to provide lessons learnt annually that help the BSC actors identify errors and potentially improve their BSA. The reported failure include but are not limited to delays in transfusion, wrong blood in tubes, wrong labels, wrong transfusion, and wrong cross-match. A Transfusion Practitioner at the WP Hospital suggests:

"They [blood safety incidents] are also all reported to SHOT [the serious hazards of transfusion] and obviously any delays or failure to supply blood in a timely manner, we will look all of those […]. Things like the benchmarking is available [on the annual SHOT report], you just log on, you pull off your data for your area. And then again we share it and we discuss those things [blood safety incidents] at regional meetings. And it allows us to benchmark ourselves and get a feel for where our errors are occurring and whether we have got a particular problem. It focuses on what area you need to tackle." *INT – Transfusion Practitioner WP Hospital EC 1-2*

A Biomedical Scientist at WH Hospital echoes:

"It's [the annual SHOT report] basically a big book and all of the reports get compiled into that book for the whole entire year for the whole of the country. And it outlines, it would do like statistics about how many transfusion, wrong patient wrong blood, wrong patient right blood, right blood wrong patient. And you know incidents of trolley, incompatible transfusion, and it's all compiled and it has case studies. […] because by myself reading this report and learning from other people's mistakes, I am less likely to make the mistake that someone else has already made by educating myself." *WT – Biomedical Scientist WH Hospital EC 1-1*

PF+ is also manifested in the openness when sharing information. For example, to improve the BSA, the BSC actors do not hide anything from each other when sharing blood safety incidents or near misses. This is to allow them to gain detailed insights on the incidents and the good practices needed to handle them – should they happen in their facilities. As the following excerpt suggests:

"We are really really keen to share lessons learnt. And that's why we don't hide anything. You know we are perfectly happy to hang our dirty laundry up in public. You know yes we've got cases of ours in the [annual] SHOT report, you know we can find them because it's important that as a community as a national transfusion community we learn and we improve. That's actually one of our trust values, that we learn and we improve. So we have a very open culture for that. *INT – Operational Manager Transfusion and Haematology NG Hospital EC 1-2*

Whilst PF+ is not verified across the embedded cases in the MC-2, one of the three embedded cases investigated (i.e. EC 2-1) enacts PF+ when sharing information (see Table 5-1 on page 128). For example, any failure in the hospitals, such as wrong blood groups or reactions to transfusion are reported monthly to the blood centre using email or in the form of written documents. Precaution on the other hand is identified when the hospitals share the blood donation plan with the blood centre to prevent stockout during high tempo conditions, such as Ramadhan (a fasting month for Muslims). During the Ramadhan period, it is difficult to maintain the blood availability across the BSC. Because most Indonesians are Muslim and during this period (about 30 days) they do not eat and drink for the whole day from sunrise to sunset, so a lot of people become reluctant to donate blood mainly because of some faith or health considerations. Having blood stocks during this period is therefore essential and has to be organised in advance. As a Laboratory Manager at the PMU Hospital suggests:

> “[We organise] a big blood donation session in which our staff are the participants. We make a proposal for the blood centre to organise the big donation session in this hospital to fulfil stockout during Ramadhan.” *INT – Laboratory Manager PMU Hospital EC 2-1*

### 5.3.1.4 Positive enactment of sensitivity to operations (SO+)

The enactment of SO+ is verified across the embedded cases in the MC-1. SO+ is about having *transparency, regularity of interactions, real time interactions,* and *ongoing operational adjustments* to prevent errors from cumulating (see Table 2-1 in Chapter 2 on page 23 for details of these elements in HROs). When sharing information, these elements of SO+ are reflected in the IOIS behaviour of the BSC actors in the MC-1. For example, the hospitals in MC-1 share daily blood stock levels, usage, and wastage with the blood centres via a transparent system called VANESA. The information is then processed and shared back with the hospitals in the form of monthly trend reports. Whilst providing accountability of the hospitals’ operations, this transparency allows them to evaluate and potentially improve their BSA. Moreover, transparency also enables the hospitals to compare their BSA with other hospitals and the NHSBT to monitor their operations at the local, regional, and national levels. As the following excerpt suggests:

> “Built into that [VANESA] are reports from the NHSBT which indicate on a regular basis our wastage levels and our O level, O negative stock level, and where we are, again comparing us with the recommended level so that we can compare ourselves with other Trusts in the south central region particularly, and also nationally. […] We get a monthly report from the NHSBT administrator for south central. […] That’s sent through email.” *INT – Transfusion Operations Manager BNH Hospital EC 1-3*

SO+ is also identified when the IOIS behaviour reflects the regularity of interactions between the BSC actors. For example, any blood management updates or issues as well as the current BSA performance or issues are shared and discussed in the hospital, regional, and national transfusion committee meetings on a quarterly basis. Some hospitals that adopt VMI receive an email every day on the stocks in hand and their expiry dates. Whilst this can also be interpreted as the act of alertness that belongs to the principle HI+, the regularity of the interactions reflect the BSC actors’ attempt to build a big picture and shared understanding of operations to potentially improve the BSA, which are embraced by the principle of SO+. As described by the Chief Biomedical Scientist the Transfusion Manager at the W Hospital:

> "NHSBT patient blood management is invited to our hospital transfusion committee meetings which are every quarter. […] So they are part of our hospital transfusion committee meeting so they can feed in from NHSBT and take any of our issues back as part of that meeting. […] We talk about wastage, we talk about usage, we talk about changes to the system, any quality issues, any recall events, any shortages et cetera. So we have a, you know, an agenda meeting. Any new documents that are being produced and that were required for use, any difficulties we have." *INT – Chief Biomedical Scientist the Transfusion Manager W Hospital EC 1-1*

Real time interactions also characterise IOIS behaviour that embraces SO+. This act is facilitated, for example, by the use of the VMI information system that enables the VMI-adopting blood centres to obtain real time access to the hospitals' stock levels information which is updated every 30 minutes. The blood centres can therefore see the current stock conditions and accordingly make an effective replenishment to maintain the ideal blood availability in the hospitals. Furthermore, real time interactions are reflected when the blood centres and hospitals continuously communicate and work together to fulfil the hospitals' need. As a Transfusion Practitioner at the SG Hospital suggests:

> "So it's constantly NHSBT liaise with us about what they've got available, we liaise with them about what we need." *WT – Transfusion Practitioner SG Hospital EC 1-1*

Finally, SO+ is manifested when information sharing reflects the act of ongoing operational adjustments to prevent errors from cumulating. For example, when the hospitals realise that the wastage of a particular blood group starts creeping up, they try to adjust (reduce) their stock levels and therefore their order information to the blood centres to reduce wastage. Similarly, when the hospitals realise that they require additional stocks to fulfil patient demand, they share the information with the blood centres to adjust to the condition. As a Biomedical Scientist at the SM Hospital suggests:

> "It's our thing, recently has been platelets, platelets have been, this is obviously because they've got a short shelf life anyway. We did go through a period where we were using a

> lot of *ad hoc* deliveries so we were feeding that back and obviously NHSBT are aware that we are using a lot of *ad hoc* deliveries. And through discussion with our customer service manager we actually decided to hold stock of platelets. And now we've adjusted that to hold the stock, two stock platelets over the weekend. So that's something we've been able to put in place, feeding back and forth between ourselves and NHSBT." *INT – Lead Biomedical Scientist SM Hospital EC 1-2*

Whilst SO+ is verified across the embedded cases in the MC-1, this principle is not verified in the MC-2. Like PF+, SO+ is only found in the EC 2-1. In this case, transparency is reflected for example when the blood centre and its associated hospitals share the temperature control document and collectively monitor the blood quality conformance. Regularity of interactions is manifested when the blood centre visits the hospitals every one to three months to audit their processes and disseminate the new blood management updates. Monthly reporting of hospitals' blood usage also reflects the regularity of interactions. Real time interactions, on the other hand, are reflected when the blood centre provides a real time access to the updated information on blood stock levels in its website and social media. Finally, ongoing operational adjustments are identified when the hospitals immediately share order information following changes in their daily stock levels. As a Laboratory Manager at the PMU Hospital describes:

> "I always monitor blood stock every day. So for example, we have 10 stock in one day. Tomorrow morning when we come, we will check how many stocks we need. We then immediately call the blood centre, that very morning we order again. We don't want the delay." *INT – Laboratory Manager PMU Hospital EC 2-1*

#### 5.3.1.5 Positive enactment of deference to expertise (DE+)

Whilst not verified across the embedded cases in the MC-1, in normal conditions, this thesis finds that IOIS behaviour enacts the principle of DE+ in the EC 1-2 (see Table 5-1 on page 128). In this thesis, DE+ is manifested in the acts of collective and expertise-based decision making. For example, collective decision making is identified when both the blood centre and one of its associated hospitals in the EC 1-2 spend a lot of time sharing information to collectively decide on the ideal stock levels. Expertise-based decision making is identified for example when the blood centre provides advice on the appropriate blood to be used whilst letting the decision be made by the clinician in the hospitals, who has the expertise and a more valid judgement. As the Hospital Services Manager at the BC 1-2 Blood Centre suggests:

> "[…] we wouldn't make that judgement call, it would be with the clinician. So we wouldn't say to the hospital that you need this instead of this. But we might advise." *INT – Hospital Services Manager BC 1-2 EC 1-2*

#### 5.3.1.6 Negative enactment of reluctance to simplify (RS-)

Beside the positive CM principles, this thesis finds a negative principle of reluctance to simplify (RS-), which is verified in the MC-1. The enactment of this principle means that IOIS behaviour can lead to no improvement or even potentially worse BSA. The data suggest that RS- is manifested when information sharing does not reflect the acts of scepticism and checks and balances. For example, a VMI-adapting hospital in the EC 1-2 is only attentive to the shared information from its associated blood centre when there is a problem with the BSA. Whilst the blood centre shares summary reports of the hospital's blood stock levels, usage, and wastage every month, this hospital feels that everything with the VMI works well so that no detailed attention to the shared information is required. The shared information is only glanced at and then deleted so it does not take up space in the hospital's email. This action represents a lack of scepticism on the shared information that could potentially lead to complacency and therefore no adjustment of operations towards BSA.

Not questioning seemingly inappropriate orders from the hospitals is also an example of no scepticism and checks and balances. For example, due to an issue in the internal operations, a hospital in EC 1-1 placed an unnecessary identical order with the blood centre to cover their stocks before the Christmas holiday. However, this unnecessary order information went undetected by the blood centre which subsequently delivered a very large amount of blood, thus creating overstock in the hospital's blood bank. As a Transfusion Practitioner at SG Hospital describes:

> "We were planning for the 4 day Christmas holiday and we knew we would have to get some extra blood in. And we knew we were gonna be relatively short staffed. So somebody

placed an order the day before. So in the evening they reviewed the blood stock, reviewed what blood we had you know what plan we had to issue blood and we knew that we were going back to the normal surgery list the day after Boxing Day. So blood was ordered for the following mid-day delivery. But there was an internal breakdown so then we had another person place an identical order for red cells and we ended up with an overstock of red cells. And you could argue that the National Blood Service [NHSBT blood centre] could have queried the fact that there was too large an order for the same delivery, but they didn't. They just delivered it in good faith and we ended up with blood so we didn't need to order in blood for 7 or 8 days after that due to that [over]stocking." *INT – Transfusion Practitioner SG Hospital EC 1-1*

Another representation of RS- is no checks and balances. For example, the NHSBT experienced a failure to deliver impactful information about the new blood safety policy (i.e. pathogen inactivation) because they did not involve the hospitals in the process of developing the policy. As a consequence, the shared information created resistance from the hospitals which led to no improvement being realised. As a National Lead Patient Blood Management Practitioner Team at the NHSBT describes:

"The hospital people on that committee were saying "why don't you come to us when you're thinking about this? This is all gonna be a big problem for us, have you thought about this, have you thought about that?" And the guy, poor guy, who was presenting went you know [surprised face] like this. He was like "oh my goodness, how, you know, we haven't thought about that, we haven't, you know". So I think sometimes, I think we do consult and I think it's vital that we consult with them and have that two-way information flow. But sometimes we think we know best and we do stuff and don't involve them early enough actually." *INT – National Lead Patient Blood Management Practitioner Team NHSBT*

However, involving the hospitals in the early stage of the policy development was seen to be difficult because the hospitals were very busy. As a result, the hospitals were so used to being spoon fed with information from the NHSBT. The hospitals' over-reliance on the NHSBT information sharing reflects the lack of checks and balances that hinder the potential improvement in BSA across the BSC. The National Lead Patient Blood Management Practitioner Team at the NHSBT emphasises:

"We shouldn't have to be spoon feeding this [standardised] information because they can go on to Blood Stocks Management Scheme and get it for themselves, but they don't. You know they expect us to turn up to their committee and give them a piece of paper […], a nice picture and they can see it, you know. But, so, they could get that information but they like to be spoon fed, they've got so used to us going to them and giving them information that if we don't turn up they just sort of sit there and don't have it quite often. So that's a bit of our own fault as well. But as I say, we need to know from them what they need now and in the future. And they need to understand you know the issues that are going on in the blood service as well. So, it really is two-way and it's vital really." *INT – National Lead Patient Blood Management Practitioner Team NHSBT*

#### 5.3.1.7 Negative enactment of sensitivity to operations (SO-)

Whilst RS- is verified in the embedded cases in the MC-1, SO- is verified across the embedded cases in the MC-2, particularly in the EC 2-2 and EC 2-3. SO- is manifested when IOIS behaviour does not reflect the act of transparency, regular interactions, real time interactions, and/or ongoing operational adjustments. The negative enactment of SO is also reflected when there is a mismatched use of the shared information. All of these can be related to the underdevelopment of the BSC processes in the MC-2.

For example, the blood centre in the EC 2-3 deliberately hides the detailed information regarding the blood expiry date for the local patients to avoid complaints from the local patients' family if it gives short-dated blood. In the MC-2, particularly in the EC 2-3, due to the big challenge of maintaining blood availability in the BSC, the patients' family are involved as the replacement donors. They are also involved in collecting the order from the blood centre and transporting it to the hospitals. The blood centre suggests that it is a cultural issue that the local people easily become angry about something they assume to be inappropriate for their family, so they often want fresh instead of short-dated blood. If the blood expiry date is not hidden, the patients' family will notice that the requested blood is short-dated and angrily ask for the fresh one. If this happens, the blood centre is running a risk of building up short-dated stock, ending up being wasted if not immediately used by patients.

Whilst hiding the blood expiry date information is a way to avoid conflicts between the blood centre and the local patients' family and therefore maintain blood availability in the EC 2-3, this lack of transparency could potentially lead to the hospitals being unaware if the blood has expired. As a Transfusion Practitioner at the BC 2-3 Blood Centre describes:

> "For people outside this area, we usually put the expiry date [on the blood pack], but in this area we cannot do that because people will complain. "Why do you give this blood which was taken on this date?" So if we do that, there will be many expired blood. So only we know when the blood was taken from donors and when the expiry date is." *WT – Transfusion Practitioner BC 2-3 EC 2-3*

SO- is also manifested when there is no regular and real time interactions between the blood centres and the hospitals in the EC 2-2 and EC 2-3. For example, all of the hospitals served by the blood centres in the EC 2-2 and EC 2-3 are bound by a memorandum of understanding (MoU), which is practically a contract stipulating that the blood centres are responsible for providing safe blood whenever needed by the hospitals. This contract is particularly critical for the hospitals that do not have a blood bank in their facilities. Due to this contract, however, regular and real time information sharing is not applicable for some hospitals because they put so much trust on the blood centres' capability to manage the BSC. The hospitals only share information when they have problems with their BSA. As the following excerpts suggest:

> "Here we do not share anything, we have MoU already." *INT – Blood Bank Staff BT Hospital EC 2-2*

> "Because here we only communicate with the blood centre when we need [the blood], otherwise there is no communication. If we don't need the blood, there is no communication." *INT – Nurse PM Hospital EC 2-3*

Another manifestation of SO- is when there is no ongoing operational adjustments towards the BSA. This act is reflected for example when the shared information from the blood centres is not responsively addressed by the hospitals, leading to potential delay of transfusion that is potentially harmful for patients. As a Transfusion Practitioner at the BC 2-3 Blood Centre describes:

> "We phone them [the hospitals], letting them know [when the blood is ready for collection]. It's difficult for the hospitals [to pick up the phone] because nurses are usually not in their ward, so we usually call the patients' family who will then convey the information to nurses.

If the nurses ask [the patients' family to collect the blood], they will come here. Otherwise, they will not come here." *WT – Transfusion Practitioner BC 2-3 EC 2-3*

Finally, SO- is manifested when there is a mismatched use of the shared information. For example, some hospitals in the MC-2 share the blood usage information with the blood centres every month, primarily for invoicing or budgeting purposes rather than understanding the trend of blood usage for the demand planning that could potentially improve the BSA. In fact, the blood centres and their associated hospitals have their own target stock levels which are not generally aligned with each other. In other words, the BSC actors in the MC-2 focus more on the accountancy of transaction rather than BSA. As a Blood Management General Affairs at the BC 2-2 Blood Centre suggests:

"[The monthly blood usage reports] is only for crosschecking with our staff, crosschecking that the blood usage in the hospitals is the same as what we have issued. That is for costing purposes." *INT – Blood Management General Affairs BC 2-2 EC 2-2*

A Blood Bank Staff at the BT Hospital confirms:

"They [the blood centre] will ask for a blood usage report every month, it's for calculating something like budgeting." *INT – Blood Bank Staff BT Hospital EC 2-2*

Whilst SO- is not verified across the embedded cases in the MC-1, the negative enactment of SO is found in the EC 1-2. For example, one hospital in this case suggests that information sharing is only conducted when the hospital experiences problems with the BSA. More often, the hospital waits for the blood centre to tell the hospital what the blood centre can do to improve the BSA. In other words, real time and two-way interactions are lacking.

Another example of SO- in the EC 1-2 is related to the downside of the VMI. Whilst the VMI provides a transparent system for sharing blood stock levels information, this practice does not currently provide a full transparency that integrates all elements of inventory management in the blood centre and its associated hospitals. For example, the VMI is not currently able to consider stock levels in the remote fridges in the hospitals. Therefore, when an automatic order is generated by the VMI information system, overstock in the hospital can happen because VMI does not consider the amount of stocks that come back from the remote fridges to the blood bank. In addition, changing stock levels is not easy in the VMI environment because the new stock levels have to be agreed by both the hospital and the blood centre, which takes some time to fully implement. Whilst this downside is considered to be acceptable by the VMI-adopting hospital, it incurs less flexibility to potentially improve the BSA in the hospital. A Laboratory Manager at the JR Hospital describes:

> "If you want to sort of change your stock levels, it's not quite as easy. […] If I were to change stock levels and we were doing our own stock, I would just say "we are now having this as our stock level" and tell everybody. I can't do that, I have to ring up NHSBT, email […] NHSBT and discuss it, whether they then agree what I want. Now they are very reactive to what I want, and they all will, because I rarely move down. So they are very pleased that I have moved down. But it just takes 2 or 3 days to implement [changes in stock levels] whereas before you could fully implement it on the same day if you wanted to. I don't change it that much, but you know that is the slight downside [of VMI]. But the positive around it totally outweighs the negatives." *INT – Laboratory Manager JR Hospital EC 1-2*

#### 5.3.1.8 Negative enactment of heedful interrelating (HI-)

Finally, beside the negative enactments of RS and SO, in normal conditions, this thesis finds the negative enactments of HI in both the MC-1 and MC-2. However, HI- is not verified across the embedded cases; it is only found in the EC 1-1 and EC 2-2 in the MC-1 and MC-2 respectively (see Table 5-1 on page 128). For example, lack of contribution, representation, and subordination are identified when the blood centre in the EC 1-1 is not being responsive in addressing complaints and suggestions from one of their associated hospitals on the need to change the delivery arrangement. As a result, potential improvement in the BSA is not achieved for years. As the Chief Biomedical Scientist the Transfusion Manager at the W Hospital describes:

> "The NHSBT as you're probably aware have this integrated transfusion service, but they are trials. And it has worked in some places. I would like to be able to participate. However we only get one routine delivery a day which means that we can't really participate unless they're going to give us more deliveries. […] I think it's NHSBT cost. I would like more deliveries. We have talked about having a change of deliveries. And because we've got internal transport across the two laboratories, I've suggested that we get one delivery in the morning just to get one delivery in the afternoon and we will share then internally with our transport links. But for 10 years I've been asking the NHSBT for this but I have still got

> nowhere. They are not very proactive if I'm honest. [It was a] discussion with the customer service manager […], face to face or by email.” *INT – Chief Biomedical Scientist the Transfusion Manager W Hospital EC 1-1*

In the EC 2-2, lack of contribution, representation, and subordination is identified for example when the hospitals share inaccurate order information with the blood centre. This order inaccuracy particularly comes from hospitals that do not have a blood bank and are allowed to store the ordered blood in the blood centre’s facility and collect the blood from the blood centre themselves. Whilst reserving the ordered blood is beneficial for these hospitals, inaccuracy of order information has significantly affected the BSA performance, particularly in the blood centre. As the Blood Donation Manager at the BC 2-2 Blood Centre describes:

> “Our [blood stock] management is dependent on our customer, dependent on hospitals. I ask for 10 [blood packs], they are not always taking all 10 from us. Many hospitals do, “this is the blood request letter”, asking for 5 [blood packs] for example, or 2, but eventually they do not take them [all] from us, we find that a lot. From 17,000 demands for blood [from hospitals], they are only fulfilled 60%, the remaining (40%) are not fulfilled. Because that’s how the hospitals work. […] Even if we put the stock back [for other patients], it might not be good as well.” *INT – Blood Donation Manager BC 2-2 EC 2-2*

### 5.3.2 IOIS behaviour and CM principles in high tempo conditions

In this thesis, high tempo conditions are defined as those where particular events happen causing sudden changes in BSA. These conditions include internal events (e.g. blood safety incidents, blood shortage, local stockouts, overstocks) and external events (e.g. Christmas, Easter, Bank Holiday, Olympic Games) that might cause “turbulence” within the BSC. Some of the high tempo events might be anticipated or cyclical in nature.

In these conditions, reluctance to simplify (RS+) and commitment to resilience (CR+) are the positive mechanisms that are commonly found across the embedded and main cases. This suggests that regardless of the case study contexts (MC-1 or MC-2), IOIS behaviour leads to positive changes in BSA when RS+ and CR+ principles are enacted in high tempo conditions. Interestingly, whilst RS+ and CR+ represent the only verified mechanisms enacted in the MC-2, another two positive mechanisms (PF+ and HI+) are enacted in the MC-1.

Consistent with the findings in normal conditions, this indicates that the BSC actors in the MC-1 are collectively more mindful when sharing or receiving information in high tempo conditions compared to those in the MC-2. This also emphasises that the underlying mechanisms explaining *how* IOIS influences BSA in high tempo conditions are different across the case study contexts. The following subsections explain each of the enacted CM principles in detail.

#### 5.3.2.1 Positive enactment of reluctance to simplify (RS+)

As in normal conditions, the enactment of RS+ in high tempo conditions is verified across the embedded cases in both the MC-1 and MC-2. In the MC-1, RS+ is manifested when the IOIS behaviour reflects the acts of redundancy, scepticism, and checks and balances, whereas in the MC-2 RS+ is manifested only by the acts of redundancy and scepticism. In the MC-1, for example, the act of redundancy is identified when the blood centres use more than one information sharing media (i.e. fax and email) to ensure that the hospitals are aware of the blood shortage and the need to use product substitutions. The combination of telephone and fax is also used to share information on product recall when there is a problem with blood in the hospitals. Whilst ensuring the BSC actors are immediately aware of the product recall, the use of combined verbal (telephone) and written (fax) ensures that there is no mistake in the sharing information process which could lead to potential blood safety incidents. As the Blood Transfusion Section Manager at the SHG Hospital describes:

> "They [NHSBT] send us forms that we have to fill in that we will email or fax back. There is a written [communication] but it is via email or fax and also by telephone conversation if we want advice or we want to alert them quickly. "We think there is a problem with this unit number", that will be a telephone conversation initially and the same back to us if they know there is a problem they will phone first and say "unit number, whatever", you need to do a recall and they will send us the fax written copy as well. So we've got not just the verbal, because you know you can't quite often hear somebody says something to you over the phone, there can be an error in what somebody hears to what somebody said. So a "g", they think it's a "t" or what happened. So we get both the verbal and the written coming through afterwards." *INT – Blood Transfusion Section Manager SHG Hospital EC 1-3*

A Head of Hospital Customer Service at the NHSBT emphasises a similar point:

"On a much lower level, if it was if for example say a specific component had to be brought back from the hospital because they might, they might have something wrong with them. It's a recall process and that's led, that's directed from one part of our organization to the customer directly. It might be they would be phoned and sent a written instruction you know by an email so they'd have double communication because you've got to be assured of a response. So we do that to make, for the certainty of safety of components." *INT – Head of Hospital Customer Service NHSBT*

Similarly, in the MC-2, to ensure the awareness of the hospitals on the blood shortage, one of the blood centres in this case share the blood shortage information using redundant information sharing media, ranging from newspaper to website. The Blood Donation Manager at the BC 2-2 Blood Centre suggests:

"The stock levels and blood groups can be accessed [publically]. We use Facebook, twitter, newspaper, […] TV running text, radio every 7 in the morning and 2 in the afternoon every day in [the radio], and [another newspaper], […] SMS, access through website. […] If I am having shortage, I will incessantly [disseminate the information]." *INT – Blood Donation Manager BC 2-2 EC 2-2*

The act of scepticism in the MC-1 is represented when the blood centre share detailed information on the implicated units that need to be traced as a result of product recall. The blood centres also share information to confirm whether the recalled product has been transfused and to understand whether there is any adverse effect on the transfused patient before taking further actions. When the bad blood product is recalled, the blood centres do not easily trust and assume that the hospitals respond appropriately, so that written evidence on the hospitals' action has to be shared with the blood centres. As the Hospital Services Team Manager at the BC 1-1 Blood Centre describes:

"And then what we probably do is we probably use this, we probably recall that unit [with 2 temperature excursions] as well because then we'd have written evidence that they discarded that unit because this bit of paper that I showed you, this one it asks us for the fate of that incident. So, they have to put the outcome. So, again from a safety point of view and we have to trust them if they've sent us back and said "discarded", then we have to assume they've thrown it away. So yeah, but again most is done by [telephone], this paperwork is sent out by fax following a phone call and then it's faxed back to us." *INT – Hospital Services Team Manager BC 1-1 EC 1-1*

In the MC-2, the act of scepticism is reflected when the hospitals do not take errors (e.g. wrong labels in blood products) for granted. Instead, to ensure the blood safety, they share the information with the blood centres to confirm whether the errors are justified and can be resolved. As the Laboratory Manager at the HM Hospital describes:

> "There might be wrong labels, so small mistakes in labelling. We crosschecked with the blood centre; there was a small mistake. […] It might be the date, expiry date, the month should be 12, but it was 11. We thought that [the blood] was expired. We confirmed there [with the blood centre] and it was actually not expired yet, only the labelling error. […] [So] we phoned and returned the product back for the label to be amended." *INT – Laboratory Manager HM Hospital EC 2-1*

Another Laboratory Manager at the PW Hospital echoes:

> "Sometimes we found [a wrong] label, it was once, twice. […] [So] for example, we ordered O; we were given A group. We phoned the blood centre "[was it] really [a mistake]?", [they said] "[it was] really [a mistake". If it was really [a mistake], we returned it, and the blood centre would replace the label." *WT – Laboratory Manager PW Hospital*

As another important example of scepticism in MC-1, to ensure blood availability during the Christmas period, the blood centres share information on the current blood inventory policy with the hospitals, asking them not to order fresh blood products with a long remaining shelf life during the Christmas period without an appropriate clinical justification. As the following excerpt suggests:

> "A lot of hospitals stock themselves, especially major trauma units like [this hospital] here, they stock platelets and they stock red cells. And when they stock, they want long life products. There is no point in them purchasing from us a stock item that expires tomorrow. So they want long life product. But over Christmas periods for example, we want our customers not to be ordering long life products. We want them to be using the stocks as they turn. We regularly as a matter of process issue an instruction, "we are in FIFO situation, please don't order for stock, if you do order for stock then give us a justification and a reason", and so on and so forth." *INT – Hospital Services Manager BC 1-3 EC 1-3*

A similar condition is also experienced by the BSC actors in the MC-2 during the Ramadhan periods when it is difficult to maintain the blood availability across the BSC. A Midwife at the SD Hospital emphasises:

"But here is the fact [when it comes to order during fasting month, the blood centre will question], "is it really going to be used? Because this is fasting month"." *INT – Midwife SD Hospital EC 2-2*

Finally, RS+ is manifested in the act of checks and balances which is particularly found across the embedded cases in the MC-1. For example, information is shared by the blood centres to advise the hospitals on the possible alternative when the ordered product is out of stock. Whilst sharing the blood shortage information, the blood centres also ask the hospitals to review the hospitals' stock levels and whether they can reduce them to adjust to the condition. As an Operational Manager Transfusion and Haematology at the NG Hospital suggests:

"We would get email and fax notification when stocks were getting low. So obviously they monitor things nationally. And when they are getting low of a particular, it's usually a particular group of a particular product, then we'll get notified. And they also request our help and they offer you know suggestions for alternative and ways that we could help review our, they ask us to review our stock holding, are we able to reduce at all." *INT – Operational Manager Transfusion and Haematology NG Hospital*

#### 5.3.2.2 Positive enactment of commitment to resilience (CR+)

Alongside the RS+, this thesis also finds CR+ as a common mechanism explaining how IOIS influences the BSA in high tempo conditions. The enactment of CR+ is manifested in the responsiveness of the BSC actors to the high tempo conditions and is verified across the embedded cases in both the MC-1 and MC-2. For example, in the MC-1, the hospitals immediately share information on the severe reactions to transfusion with the blood centres to confirm any required actions. In this situation, the telephone is preferred as the media to quickly share the urgent information. Similarly, when the blood centres find a problem with the delivered blood, the product recall instruction is immediately shared, requiring the hospitals to immediately take the product out of stock and circulation. In this situation, strict timing of information sharing is of the essence to adjust the operations and ensure blood safety for patients, particularly if the recalled product has been transfused to patients. As The Hospital Services Team Manager at the BC 1-1 Blood Centre suggests:

> "So when we get a recall we'll phone them, we'll tell them and send the paperwork through, once they receive the paperwork we expect that back within four hours. Now we used to be that strict but I think we are governed by the MHRA, medicine and health care regulatory agency. And then they make some of the rules, so I think they have decided that the hospital should respond to us within four hours because obviously sometimes it can be quite severe. You know if the donors, if it's gonna affect patient's safety then you know. So we've got the recall system as well for that. […] If it [the recalled product] is transfused and it does happen quite regularly and that's why there is, we are so strict with timings. We've got to contact the hospital within an hour of being notified and then the hospital should get back to us because it could be that at the point we contact them, that unit is on its way to a ward, and just about to be going into someone, that's why timing is quite strict. But if it is transfused, then normally the consultant will contact the hospital and discuss the outcome. […] again always by phone, normally." *INT – Hospital Services Team Manager BC 1-1 EC 1-1*

Similarly, in the MC-2, when the reaction to transfusion is found and considered to be severe, the transfusion is immediately stopped and the hospitals immediately call the blood centre to confirm the causes. Besides this example, CR+ in MC-2 is mostly enacted by the hospitals quickly contacting the blood centres in response to stockout in their facility. A Laboratory Manager at the PMU Hospital emphasises:

> "If we have stockout, we immediately [share information] with the blood centre, so we don't involve the patient's [family]." *INT – Laboratory Manager PMU Hospital EC 2-1*

A member of the Blood Bank Staff at the BT Hospital shares the same experience:

> "If there is a request [from patients] […] and we don't have the blood, stockout, we immediately call the blood centre. […] Our staff will then take the box and the request form to the blood centre." *WT – Blood Bank Staff BT Hospital EC 2-2*

#### 5.3.2.3 Positive enactment of preoccupation with failure (PF+) and heedful interrelating (HI+)

Beside the common mechanisms of RS+ and CR+, this thesis also finds the enactments of PF+ and HI+ in high tempo conditions. Whilst these enactments are not verified in the MC-2, they are commonly found across the embedded cases in the MC-1. As in normal conditions, the enactment of PF+ in the MC-1 is manifested in the IOIS behaviour that reflects the acts of precaution, failure reporting, and openness. For example, the act of precaution in the MC-1 is reflected when the hospitals share information about the blood quality issues with the blood centres with the awareness that the issues can potentially lead to blood safety incidents in other hospitals receiving the same type of blood. As Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager at the RB Hospital suggests:

> "We would have shared that information [blood quality issue] with NHSBT. We would raise a complaint or contact form with them, with the quality department. And they would send us their reference number and their actions and if necessary we will report that to MHRA. We need to make sure because you know one donation can be split into various components. So we need to make sure that no other hospitals got the other part of that component, that could be adversely affected as well. So the NHSBT are our point of reference for that." *INT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital EC 1-3*

A Blood Transfusion Coordinator and Quality Lead at the WH Hospital shares the same point:

> "If we think that it looks like it, say, bacterially contaminated units, we would be talking to NHSBT and highlighting that. And if we had a particularly nasty reaction, we would phone NHSBT up anyway. Because more than one product is made from the one donation and then, that one that we've had particularly nasty reactions, often NHSBT would then recall all the other products just to be safe." *INT - Blood Transfusion Coordinator and Quality Lead WH Hospital EC 1-1*

Whilst the above excerpts represent the hospitals' precautions regarding the blood safety issues across the BSC, they can also represent the enactment of HI+. By sharing the information, the hospitals are aware that their action will not only affect the blood safety in their facility, but potentially the blood safety across the BSC as a whole. In other words, their action represents the acts of alertness, contribution, representation, and subordination altogether.

Moreover, PF+ in the MC-1 is manifested when the hospitals openly report any failure (i.e. BSA issues and/or incidents) to the blood centres so that potential adjustment of operations can be made to maintain and assure BSA during high tempo conditions. For example, any blood-related problems were openly shared and discussed between the NHSBT and the hospitals to ensure BSA during the Olympics 2012. As an Assistant Director Governance and Resilience NHSBT describes:

> "I've actually gone in and spoken to laboratory managers, actually planned [the delivery] with them, sat down, discussed the issues, tried to work out what their problems are, that's been quite useful from that point of view. So, but the key for that is to be relatively open within that meeting, but to be clear with them. "Actually we want to box that off, so I am happy to discuss it with you, but remember that actually this is something that the government doesn't want, they don't want the Olympics to be you know super super imposed on some sort of potential terrorist event. They want everybody to enjoy the Olympics and not worry about the terrorist." You know, so it was that sort of discussion. So it was quite a boxed off discussion, but nevertheless reasonably open within that discussion as to what that might be." *INT – Assistant Director Governance and Resilience NHSBT*

Whilst PF+ is also identified in the MC-2, this principle is only enacted in one embedded case of EC 2-1. This action is reflected for example when one of the hospitals in this case reports the blood quality issue to the blood centres to raise awareness of the recurrent issues that need to be resolved. As exemplified by a Laboratory Manager at the KI Hospital:

> "If for example there is a complaint from the ward, "why are there often clots in the blood?". We receive the complaint and phone the blood centre, "why are there always clots in the blood? It's difficult to transfuse to patients"." *INT – Laboratory Manager KI Hospital EC 2-1*

#### 5.3.2.4 Positive enactment of sensitivity to operations (SO+) and deference to expertise (DE+)

Whilst this thesis does find the enactments of SO+ and DE+ in high tempo conditions, they are not verified across the embedded cases in both the MC-1 and MC-2. In fact, SO+ is only enacted in the EC 1-3, whereas DE+ is only enacted in the EC 1-2, both belong to the MC-1. SO+ is enacted by the NHSBT continuously monitoring the hospitals' stock levels and sharing the overstock information with the hospitals to reduce unnecessary wastage in their facility. SO+ is also enacted when the hospitals share real time information on the stock levels' status, including blood shortage, with the blood centre using the VMI information system. Finally, SO+ is enacted when the NHSBT share information to reflect their ongoing operational adjustment to prevent the more severe blood shortages across the BSC. As a National Lead Patient Blood Management Practitioner Team at the NHSBT describes:

> "O neg red cells, we start to see that coming down, we start to look at ways in which we can help bring that up. […] before we get a problem, we're trying to do some work. […] we're gonna ring the poly[clinic] and […] we might say, "right, we're gonna write to hospitals and tell them that we got a problem […]". We're not saying that we've got shortage, but we're just asking [the hospitals] to be extra careful and make sure that they only order it when they need it. So we sort of tackle it from both ends [supply and demand] if we're saying that the stock is drifting in a particular direction." *INT – National Lead Patient Blood Management Practitioner Team NHSBT*

On the other hand, DE+ is enacted for example when the blood centre and the hospitals share information to collectively respond to the national blood shortage by offering suggestions for actions and reviewing the current stock levels. When product recall is considered, due to a serious reaction to transfusion, the blood centre defers the decision making to the consultant haematologist, who will then collectively review the reaction with the hospitals and decide whether the units need to be recalled. As a Transfusion Practitioner at the WP Hospital describes:

> "So if we have a serious reaction, so the protocol is that we would contact NHSBT. They would give us the name of the consultant haematologist on call for NHSBT and they review that reaction with us. And then they will make the decision as to whether that unit needs to be recalled or not. If they want it recalled, we obviously quarantine that unit, already quarantined. And then they will send a box, we pack it and everything, it goes back to NHSBT, and then they will culture the units and then NHSBT then send us the report back on their findings. […] So it's a telephone conversation. And occasionally they might ask for additional information via email." *INT – Transfusion Practitioner WP Hospital EC 1-2*

### 5.3.3 IOIS behaviour and CM principles in emergency conditions

Emergency conditions in this thesis include the major unexpected events, such as major haemorrhages, fridge failures, floods, terrorist/cyber attacks, national stockouts, and/or any other unexpected events causing high disruption within the BSC. In these conditions, commitment to resilience (CR+) is the only positive mechanism that is commonly found across the embedded and main cases. This suggests that regardless of the case study contexts (MC-1 or MC-2), IOIS behaviour leads to positive changes in BSA when the CR+ principle is enacted in emergency conditions. Interestingly, whilst no other mechanisms are enacted in these conditions in the MC-2, another two positive mechanisms (RS+ and HI+) are enacted and verified across the embedded cases in the MC-1. Consistent with the findings in normal and high tempo conditions, this indicates that the BSC actors in the MC-1 are collectively more mindful when sharing or receiving information in emergency conditions compared to those in the MC-2. This also emphasises that the underlying mechanisms explaining *how* IOIS influences BSA in high tempo conditions are different across the case study contexts. The following subsections explain each of the enacted CM principles in detail.

#### 5.3.3.1 Positive enactment of commitment to resilience (CR+)

The enactment of CR+ in the MC-1 and MC-2 is manifested in the act of responsiveness to the major unexpected events. For example, in the MC-1, during major haemorrhages, when patients are heavily bleeding and have used up all of the stock available in the hospitals, the authorised blue light (emergency) order is shared with the blood centres to quickly replenish the stock levels and immediately fulfil the patients' demand. As a Lead Biomedical Scientist at the SM Hospital emphasises:

> "So anything that's urgent […] we blue light." *INT – Lead Biomedical Scientist SM Hospital EC 1-2*

A similar level of responsiveness during the emergency condition is also experienced by the hospitals in the MC-2. A Blood Bank Manager at the AK Hospital suggests:

> "So there was a case of an obstetric patient that was heavily bleeding and requires 6 packs of blood. I think it was O [pos] blood group so it was easier to fulfil. But then several hours later, this patient requires more. […] It was stockout because the need was higher than [expected]. We then immediately placed an emergency order by phoning the blood centre. We could then provide the blood." *INT – Blood Bank Manager AK Hospital EC 2-2*

In the MC-1, during a natural disaster, such as a flood in one of the manufacturing centres, information sharing is accelerated between the NHSBT and the hospitals to ensure awareness on the immediate changes whilst adjusting the operations to maintain the BSA across the BSC. In these conditions, the telephone is usually used to rapidly share information and to ensure immediate responses. As The Transfusion Operations Manager at the BNH Hospital describes:

> "The one that we have from Filton, you know we were involved obviously with Filton [flood] and then they kept us up to speed. But the local distribution centres were able to supply our components and but yes we were informed and across the Trust […]. We'd also be communicating with the NHSBT to say that "all of the deliveries and the components will be going to one site". And we may well be looking at shipping components temporarily back to them for storage and then bringing them back. […] It tends to be phone because those sort of circumstances we'll tend to need an immediate response or rapid response and I think relying on email I think is not conducive for speedy action." *INT – Transfusion Operations Manager BNH Hospital EC 1-3*

An Assistant Director Governance and Resilience at the NHSBT shares a similar point when handling an emergency event such as a terrorist attack:

> "[…] there is an awful lot of very rapid information interchange. And so some of their [the hospitals] strategic emergency response objectives might be shared all the way through. […] it didn't […] occur at Manchester [terrorist attack] but we might be saying to them "you've used up all of the whatever product it is, we are backfilling you from Liverpool and Birmingham and Newcastle", for example […]. And we would share that information with the hospital again relatively openly. […] The very hot stuff, usually it starts with the hospital, so that the channel really is almost dictated by the hospital. So that might be OBOS in which case some of those channels will be electronic or it might be a telephone call in which case some of those channels are going to be that immediate, you know, telephony type channel." *INT – Assistant Director Governance and Resilience NHSBT*

#### 5.3.3.2 Positive enactment of reluctance to simplify (RS+)

During emergency conditions, CR+ is not the only mechanism explaining how IOIS influences the BSA in the MC-1. This thesis finds that RS+ is also enacted across the embedded cases in the MC-1 and is reflected in the acts of redundancy, scepticism, and checks and balances. The acts of redundancy and scepticism are identified for example when the hospitals use not only OBOS but also telephone to share the urgent order information. The use of redundant information sharing media is crucial to confirm the order and to obtain immediate attention from the blood centres' staff. Some emergency conditions happen during the night when the number of staff processing orders in the blood centres is reduced. Some of the staff might also be busy with something else other than order processing. As an Operational Manager Transfusion and Haematology at the NG Hospital describes:

> "And then in the emergency situations, we still use OBOS, but we also follow that up with the phone call to NHSBT, to our issue department directly, hospital services I believe they are called now. We ring them directly because you know we are aware certainly overnight, there might only be one person, one member of staff. They are maybe in a fridge somewhere stocking up. They may not notice the order coming through on OBOS. So we always follow up for emergencies with a phone call." *INT – Operational Manager Transfusion and Haematology NG Hospital EC 1-2*

A Senior Biomedical Scientist at the BNH Hospital echoes:

> "If we get a blue light for example, we'd order on OBOS but we then follow it up with a phone call just to make sure they've seen it, they know it's an urgent request and they are aware of it, in case they are busy doing something else, we tend to follow them up. Or if we are finding a particularly, unusual to us in the lab, we'll say "we've ordered this, can you make sure it's ok, give us a call back if it's not"." *INT – Senior Biomedical Scientist BNH Hospital EC 1-3*

The hospitals also use the redundant information sharing media to speed up the ordering and delivery processes because a sophisticated system such as VMI is not flexible or quick enough in responding to the need for emergency blood. Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager at RB Hospital emphasises:

> "We might have to if it's really really urgent, we might have to order some by picking up the phone and ordering on OBOS, so. Because it [the VMI information system] won't be that quick if it's really really emergency. So if it's a massive, a major incident for example, then part of our action is to ring the NBS [blood centre], say we are in a major incident. And they'll automatically give us some boxes of blood that would be sent to us. So, ya, that wouldn't be dealt with via ITS [integrated transfusion services - VMI]. I mean ITS is working all the time. But because it's only a snapshot every half hour, an hour, that's not quick enough if you got a major incident going on, you need to get your stock much quicker, so we'd need to ring and use OBOS, we call them." *WT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital EC 1-3*

In addition, during emergency conditions, whilst information is shared to let the blood centres know that a major incident has been declared, to reflect the act of scepticism the hospitals will not share order information until they know the nature of the emergency. This is to ensure that they provide accurate information to avoid unnecessary overstock. As the Transfusion Practitioner at the SG Hospital suggests:

> "We have to telephone the National Blood Service to let them know an incident has been declared. If we've got any information that we can share, we would share it with them. We wouldn't necessarily order more blood stock until we know the emergency. So we would actually pause stuff in as we get to get feedback, we would then update the National Blood Service as to what particular stock we may need. […] generally by telephone." *INT – Transfusion Practitioner SG Hospital EC 1-1*

Finally, RS+ in the MC-1 is also reflected in the act of checks and balances. This can be exemplified by the NHSBT's action during the flood at a major manufacturing centre at Filton. During the unexpected and disruptive event, the NHBST shared information with the affected hospitals, explaining the event whilst checking their stock conditions and understanding their needs. As described by the National Lead Patient Blood Management Practitioner Team at the NHSBT:

> "I think people who involved, who was, two or three of them who were involved down there, and one girl was part of my team. And part of what they did initially was for hospitals that were immediately affected that morning. They rang them all up and they sort of said, "look you know we've got this big problem, we just sent you a communication, a standard communication that we're struggling, but we've got this problem. You know, how are you in terms of stocks, what's going on this morning, have you got any you know foreseen, do you think you're gonna need platelets quickly, have you got, you know anything?". So we had that conversation on a one to one level with about 30 hospitals that morning to explain, try to understand, explain to them what's happening and to understand what issues they would have." *INT – National Lead Patient Blood Management Practitioner Team NHSBT*

#### 5.3.3.3 Positive enactment of heedful interrelating (HI+)

The final mechanism in emergency conditions that is verified across the embedded cases in the MC-1 is HI+. This principle is manifested for example when the hospitals alert the blood centres about any support required when a major incident breaks out. This alert is crucial because during major incidents, the hospitals can be locked down so that the normal BSC operations are not functional, therefore affecting the blood supply to the hospitals. As the Blood Transfusion Coordinator and Quality Lead WH Hospital describes:

> "So if they [authorities] were to put the organisation into lock down so that we couldn't get into the organisation, the routine works stops because that would then conserve the blood supply. And we would then obviously alert the national blood service as to what we required, that we had some major incidents and then we would ask them for their support and we would be asking them for various products, etc." *INT - Blood Transfusion Coordinator and Quality Lead WH Hospital EC 1-1*

During major incidents, hospitals are also obligated to inform the blood centres because they are aware that the incidents are not only affecting themselves, but the whole BSC. The Hospital Services Manager at the BC 1-2 Blood Centre emphasises:

> "So an external major incident such as a motorway pile up or a plane crash or something like that. Then essentially the hospital would create a major incident. First of all, they will be the main source. The hospitals declare major incidents, they then have an obligation of informing each and every supplier that they have, that they are a part of that major incident's supply chain. So if [this hospital] got information to say, "look we've had a plane crash at [XX] Airport, we're declaring a major incident", they're obligated to inform us, I am then obligated to instigate the major incident plan in our organisation." *INT – Hospital Services Manager BC 1-3 EC 1-3*

## 5.4 Summary of the findings

The aim of this thesis is to determine and unravel the underlying mechanisms of how IOIS influences BSA in the dyadic BSC in normal, high tempo, and emergency conditions. This thesis finds that the underlying mechanisms can be explained by the dynamic enactments of CM principles that reflect the co-actions of IOIS behaviour across the operational conditions. These findings have been presented in this chapter using a theoretical framework.

Overall, it is found that more CM mechanisms are enacted in the centralised and tightly regulated BSC (MC-1) compared to that in the decentralised and loosely regulated BSC (MC-2), indicating that regardless of the operational conditions, the BSC actors in the MC-1 are collectively more mindful when sharing or receiving information than those in the MC-2. As a consequence, more positive changes in the BSA performance are observed in the MC-1 compared to those in the MC-2.

Whilst not all CM principles can serve as the underlying mechanisms, common mechanisms and context-specific mechanisms are found across a range of operational conditions. In normal conditions, when sharing or receiving information, the BSC actors in the MC-1 and the MC-2 positively enact the same principles of reluctance to simplify (RS+). Positive enactment of heedful interrelating (HI+) is also observed as an emerging principle in both cases in normal conditions. In addition, positive enactments of preoccupation with failure (PF+) and sensitivity to operations (SO+) are observed only in the MC-1. Interestingly, this thesis also finds that, in normal conditions, the relationship between IOIS and BSA in the MC-1 and the MC-2 is explained by the negative enactments of RS and SO respectively. These negatively enacted CM principles can lead IOIS to unimproved and even potentially worse BSA.

In high tempo conditions, the relationship between IOIS and BSA in both the MC-1 and the MC-2 is explained by the positive enactments of commitment to resilience (CR+) and reluctance to simplify (RS+) principles. Whilst the enactments of these principles are critical, when sharing or receiving information in high tempo conditions, the BSC actors in the MC-1 positively enact more CM principles compared to those in the MC-2 (i.e. PF+ and HI+). Finally, whilst CR+ represents the common underlying mechanism that explains how IOIS influences BSA in both the MC-1 and MC-2 in emergency conditions, the enactments of RS+ and HI+ are found as context-specific mechanisms in the MC-1.

It is also important to note that the enactments of some CM principles (i.e. PF+, RS+, and HI+) can be closely linked to the nature of blood as a precious resource which is both perishable and critical for human life. The unique characteristics of blood products mean that the enactments of PF+, RS+, and HI+ might not be applicable in other contexts of perishable product supply chains. The following chapter (Chapter 6) discusses these findings.

# 6 DISCUSSION

In this chapter, the findings from the case study analysis are discussed. The abductive nature of the theory-elaborating case study means that it is imperative that the empirical findings be given plausible theoretical interpretations (Ketokivi, 2006). The discussion in this chapter therefore mainly covers the researcher's attempts to establish plausible theoretical interpretations of the findings and discuss them in relation to high reliability theory (HRT). The findings in this discussion refer to the verified findings which have been illustrated in the theoretical framework in Figure 5-3 in Chapter 5 on page 126.

## 6.1 IOIS and the dynamic enactments of the CM principles

Theoretically, the inter-organisational information sharing (IOIS) phenomenon has gained very limited attention in the high reliability organisation's (HRO's) literature, which typically addresses the whole activity of a single HRO rather than information sharing *per se* (see Lekka, 2011; Weick and Sutcliffe, 2015, 2007; Weick *et al*., 1999). By elaborating the collective mindfulness (CM) concept, this thesis goes beyond the original unit of analysis of HRO studies (i.e. a single organisation) to capture the phenomenon of IOIS in the dyadic blood supply chain (see Lekka, 2011; Weick and Sutcliffe, 2015, 2007; Weick *et al*., 1999). This attempt is in line with what Fisher and Aguinis (2017) call the *vertical contrasting* of theory elaboration, i.e. the use of a theory developed at one level of analysis to explain a phenomenon at another level of analysis. This also concurs with the recommendation of Kembro and Näslund (2014) and Kembro *et al*. (2014) for the use of theoretical perspectives to understand the phenomenon of IOIS in supply chains.

HRT posits that the positive enactments of CM principles help an organisation to achieve high reliability performance (Lekka, 2011; Weick and Sutcliffe, 2015, 2007; Weick *et al*., 1999). According to HRT, in normal conditions, people in the organisation should be preoccupied with any failure in their system (PF+), reluctant to simplify any interpretation (RS+) and sensitive to their operations (SO+). When unexpected events break out, the organisation should be committed to resilience (CR+) and defer any decisions to people with expertise (DE+). Weick and Sutcliffe (2007) and Weick *et al*. (1999) further classify these five core CM principles into the principles of anticipation (i.e. PF+, RS+, and SO+) and containment (i.e. CR+ and DE+) of the catastrophic impacts of unexpected events. Detailed actions that reflect each of these five core principles of collective mindfulness have been presented in Table 2-1 in Chapter 2 on page 23.

Whilst providing a comprehensive discussion of HRT in a single organisational context, Weick *et al.* (1999) argue that there is a possibility of achieving high reliability performance across inter-organisational networks. They argue that “reliability will be an emerging concern as organizations increasingly participate in interorganizational networks because interorganizational coordination is so difficult to achieve and because the system becomes more complex and harder to comprehend” (Weick *et al.*, 1999:57). Despite this interesting argument, empirical support is currently lacking as to how inter-organisational coordination (i.e. IOIS) itself influences the performance of the inter-organisational networks. Through a close investigation of the IOIS phenomenon in the dyadic blood supply chain (BSC), this thesis offers an empirical research that can serve as an elaboration of Weick *et al.*’s (1999) argument on the potential adoption of HRT within the inter-organisational context.

This thesis argues that in the dyadic BSC, IOIS positively influences the BSC performance (i.e. blood safety and availability) through the dynamic positive enactments of CM principles across a range of operational conditions. This dynamic means that the positive enactments of CM principles are not only limited by a certain operational condition, but they can go beyond the conditions that have been prescribed by HRT. In other words, the segregation of the positive enactments of CM principles (i.e. PF+, RS+, and SO+ only in normal conditions; CR+ and DE+ only in unexpected conditions) does not always apply in the context of this research.

As illustrated in the theoretical framework in Figure 5-3 in Chapter 5 on page 126, in the context of centralised and tightly regulated BSC (MC-1), the principles of *preoccupation with failure* are positively enacted not only in normal, but also in high tempo conditions, whereas the principle of *reluctance to simplify* in the MC-1 is positively enacted not only in normal, but also in high tempo and emergency conditions. This indicates that the BSC actors are not only being responsive to immediately resolve blood safety and availability (BSA) problems by sharing information, but they are simultaneously trying to prevent other problems from emerging that potentially affect BSA. Their attention is not only to share information to fulfil immediate needs for BSA with a fire fighting mode of operation, but they think of other potential actions they can do for the good of the BSC. This thesis does not find this dynamic in the MC-2.

As presented in Chapter 5, the positive enactment of *preoccupation with failure* in normal conditions is observed when the hospitals in the MC-1 are being cautious by sharing information on *the weak signals* of blood quality issues (e.g. clots in blood bags or a strange look of the blood colour) with the blood centres. As such, the hospitals do not wait until it becomes clear that there is an indication of blood quality issues before reporting them to the blood centres. In high tempo conditions, the positive enactment of *preoccupation with failure* is identified when the hospitals report the blood safety incidents (e.g. severe reactions to transfusion, bacterially contaminated units) to the blood centres. This reporting is crucial because the incidents can be caused by one particular donation that is split into more than one blood product and delivered to different hospitals. In this condition, the hospitals in the MC-1 are not only trying to be resilient by immediately reporting the incidents to the blood centre, but they are also trying to be cautious in order to prevent incidents from spreading across hospitals that use blood products coming from the same donation.

Despite the positive enactment of *preoccupation with failure* principle in normal and high tempo conditions, in line with HRT, this thesis does not find the positive enactment of this principle in emergency conditions. A possible explanation for this finding is that during emergency conditions the BSC actors might put more focus on responding to the critical need for blood which involves urgently saving patients' lives. In these conditions, there is limited room for BSC actors to think of and look for other things that can potentially go wrong and share the information across the BSC. For example, it is a common practice in the hospitals across the MC-1 and MC-2 to prioritise the blood availability for immediate transfusion during the patient major haemorrhages. This prioritisation means that during this emergency condition, the hospitals usually transfuse the appropriate blood groups without fully cross-matching the patients' blood with the ordered blood from the blood centres. Whilst not fully cross-matching the blood can potentially lead to severe reactions to transfusion due to blood incompatibility, this approach is taken to avoid delays in processing the blood that can lead to patients' death without transfusion. As a Laboratory Manager at JR Hospital describes:

> "[…] in a major haemorrhage the checking process is not quite as thorough so the checking of the blood at the bedside is not quite as complete as it could be because we are giving blood that is not fully cross-matched. So it's usually in emergency, it's usually that O neg or O pos, so you've not done, we don't know if those patients have antibodies, a red cells antibody that could cause immune destruction of those red cells just transfused in, sort of, a week's time. We don't know if they have or not until after they have had the blood, so it's not as safe as giving fully cross-matched blood. But sometimes it's not the safety, sometimes it's [to] keep the patient alive so you've got time to worry about that [blood safety]. I do have a little bit of a saying to my beloved staff, "if you've got somebody with the positive antibody screened who is bleeding to death, for God's sake don't withhold them any blood. It's better [to give] some blood and keep them alive and make sure it's ABO [blood groups] compatible, than worry about an antibody and delay so much that they die because they haven't had anything. So keep them alive and worry about the reaction later", it's my motto. And they work quite well. You know we do occasionally have to do that, yeah it's a bit scary but actually most of the time because blood is in and out so quickly because they are bleeding so profusely it doesn't tend to cause too much of a bump. But you know you can monitor them for that sort of incident." *INT – Laboratory Manager JR Hospital EC 1-2*

Beside the *preoccupation with failure*, this thesis also finds the dynamic positive enactments of *reluctance to simplify* principle, which can be represented by the act of scepticism in both the MC-1 and the MC-2 across a range of operational conditions. As presented in Chapter 5, in normal conditions, it is common practice in the MC-1 that the blood centres question the out of the ordinary order information from the hospitals, to ensure that it is safe and necessary to provide the ordered blood for patients. In the MC-2, whilst the blood centres do not always guarantee blood availability for the hospitals, the act of scepticism is manifested when the hospitals share information to confirm the availability of blood before ordering from the blood centres.

It is also important to note that in normal conditions, lack of scepticism can happen, representing the negative enactment of *reluctance to simplify* principle (RS-). This lack of scepticism is commonly found in the MC-1, where despite their robust BSC system, complacency can be an emerging threat for blood safety and availability across the BSC. For example, whilst an electronic ordering system offers an efficient ordering process for the hospitals in the MC-1, complacency towards the system can lead to a blood centre's failure to spot errors such as double order information that results in overstock in one of the hospitals. The over-reliance on the automatic blood stock monitoring and replenishment system, such as vendor-managed inventory (VMI), can also cause complacency that the system is always running well. This complacency can lead to lack of attentiveness to the regularly shared information, such as blood stock levels, usage, and wastage, unless there is a problem that affects blood safety and availability across the BSC. Some hospitals in the MC-1 have been aware of this emerging threat of complacency and therefore have chosen not to adapt the VMI system to avoid this threat.

This thesis identifies that one of the root causes of the complacent actions is the lack of total exposure to the BSA incidents and BSC disruptions. As a National Lead Patient Blood Management Practitioner Team at the NHSBT suggests:

> "So, people will become quite complacent because you can give transfusions for 20 years and never see a reaction and never have a problem and you become like "ya another transfusion, whatever" so you become really complacent about the checks that you should do. And you think "ah the blood's safe, there is no point in doing this observation, it's fine". But, if you suddenly have an incident in a Trust, somebody dies, it really wakes everybody up." *INT – National Lead Patient Blood Management Practitioner Team NHSBT*

The Assistant Director Governance and Resilience at the same organisation shares a similar point:

> "Now the NHS has issued guidance to hospitals, which says they ought to have business continuity systems in place and therefore for any of their key suppliers they should be communicating with them to make sure that they have got a reasonable resilience around that key supply. My guess is that most them haven't thought about blood as a key supply. And the reason they probably haven't thought about blood as a key supply is essentially because we are actually quite good at what we do, we don't let them down very often." *INT – Assistant Director Governance and Resilience NHSBT*

This root cause is coupled with the limited transfusion-related staff in some hospitals, which make them very busy with their high day-to-day workload. Consequently, their direct involvement in the BSA-related initiatives is not optimal. Although the annual SHOT reports provide lessons learnt on the BSA incidents across the BSC, particularly in hospitals, the annual nature of the reports mean that they are not timely enough to capture the dynamic of the BSC operations. Some informants suggest that face-to-face meetings, such as the national, regional, and hospital blood transfusion committee meetings, are effective ways to disseminate the lessons learnt, as they are more frequently conducted, i.e. on a quarterly basis. However, with some hospitals' lack of participation in these meetings (Draft Minutes of Meeting of the Regional Transfusion Committee Chairs, 14th March 2016), the awareness of the BSA incidents might not be optimal.

In the high tempo conditions, scepticism is indicated when the blood centres in the MC-1 do not easily trust the recalled product information from the hospitals before they share the written information as evidence that appropriate actions have been taken on the recalled blood product. Scepticism in the MC-2 is identified during the high tempo condition such as Ramadhan when stockout usually happens due to lack of donors. In this condition, the blood centres in the MC-2 usually question the order information from the hospitals to ensure that the orders are appropriate, therefore avoiding any wastage during this critical period. Finally, scepticism is identified during the emergency conditions in the MC-1. When major haemorrhages happen overnight, for example, the hospitals in the MC-1 share urgent order information not only by using the online blood ordering system (OBOS), but also by using the telephone. By using the redundant information sharing media, the hospitals do not want to make an assumption that the blood centres' staff will check the OBOS and immediately process the information. Instead, they follow up the order information using the telephone to obtain immediate attention from the blood centres' staff who are limited in number during the night and might be occupied with any other important things, apart from processing orders.

Whilst the dynamic positive enactments of CM principles can be illustrated by the positive enactments of *preoccupation with failure* and *reluctance to simplify* beyond the normal conditions, this thesis does not find the same pattern for the remaining three principles of *sensitivity to operations*, *commitment to resilience*, and *deference to expertise* (see the theoretical framework in Figure 5-3 in Chapter 5 on page 126). In line with HRT (Weick and Sutcliffe, 2007; Weick *et al*., 1999), the principle of *sensitivity to operations* is positively enacted in the MC-1 only in normal conditions, whereas the *commitment to resilience* principle is positively enacted both in the MC-1 and the MC-2 only in high tempo and emergency conditions. In addition, this thesis does not find the positive enactment of *deference to expertise* in any operational conditions.

In line with HRT, the principle of s*ensitivity to operations* is not enacted beyond normal conditions in the MC-1. This means that during high tempo and emergency conditions, *sensitivity to operations* might be less important for the BSC actors in the MC-1. Whilst the data are limited to support this argument, an interesting fact related to transparency (i.e. one of the key elements of *sensitivity to operations* principle) has been identified from the data. For example, some of the BSC actors in the MC-1 have adapted VMI to better manage their stock levels and replenishment (see Table 4-3 in Chapter 4 on page 88). VMI allows the blood centres to transparently see the stock levels in their associated hospitals and to automatically replenish the stock to the ideal levels when they are reduced to a certain point. Whilst sharing information using VMI reflects the positive enactment of *sensitivity to operations* principle in normal conditions, some hospitals in the MC-1 suggest that VMI is not flexible and quick enough to handle the immediate demand for emergency blood. Other responsive media such as the telephone is therefore preferred to share the demand information. This indicates that without a sufficient level of responsiveness, transparency of operations might be less important for the BSC actors during emergency conditions.

In the general supply chain literature, this finding is in line with Zhao and Zhao (2015), who challenge the similar notion to transparency (i.e. supply chain visibility). Although visibility is considered as a key underlying mechanism explaining how IOIS influences the SC performance (e.g. Barrat and Oke, 2007; Scholten and Schilder, 2015), Zhao and Zhao (2015) imply that visibility does not entirely explain how IOIS influences supply chain (SC) performance in different operational conditions. They further argue that providing access to quality and relevant information does not guarantee that SC actors will make sensible decisions, particularly during unexpected conditions. Therefore, instead of merely having visibility, Zhao and Zhao (2015) suggest that during unexpected conditions, the SC actors should be more attentive to the shared information and understand the interdependency within the SC.

Whilst the positive enactment of *sensitivity to operations* is absent in the MC-2, this thesis finds the negative enactment of this principle (SO-) in normal conditions. This negative enactment of *sensitivity to operations* is driven mainly by the underdevelopment of the BSC processes between the blood centres and the hospitals in the MC-2. For example, due to a lack of regulatory enforcement on the blood supply chain process, some hospitals in the MC-2 are not provided with transparent information (e.g. expiry dates) on the blood product supplied from the blood centres. In addition, there is currently a lack of a transparent system to track and trace the blood safety incidents across the BSC. Regular and real time information sharing is not always applicable due to the lack of an effective blood transfusion committee both at the regional and national levels. When relevant information such as monthly blood usage is shared across the BSC, the information is not always appropriately used to make improvement in blood safety and availability.

Whilst the positive and negative enactments of *sensitivity to operations* are only identified in normal conditions, the positive enactment of the *commitment to resilience* principle is only found in high tempo and emergency conditions. As shown in Chapter 5, immediate sharing of information on the severe reactions to transfusion and blood product recall is commonly observed between the hospitals and blood centres in the high tempo conditions in the MC-1, whereas information sharing in response to stockout in the hospitals is identified in high tempo conditions across the embedded cases in the MC-2. In emergency conditions, sharing urgent order information during major haemorrhage reflects the positive enactment of *commitment to resilience* in the MC-1 and the MC-2. In these conditions, information sharing is also accelerated as a response to big emergency events such as flood or terrorist attacks in the MC-1.

Although HRT suggests that *commitment to resilience* should be enacted when the unexpected events break out (i.e. in high tempo and emergency conditions), this theory argues that there are some positive actions that can be developed in normal conditions to enhance the capability of the organisation to bounce back from the unwanted conditions (Weick and Sutcliffe, 2007; Weick *et al*., 1999). In other words, in line with the supply chain risk and resilience concept (SCRR – see Hohenstein *et al*., 2015), HRT encourages the act of readiness to respond to unexpected events. This readiness includes, but is not limited to, devoting resources for training and re-training people to operate complex technical systems and developing a list of important contacts that can be useful during emergency conditions (see Table 2-1 in Chapter 2 on page 23). This thesis, however, does not find the IOIS behaviour that reflects these initiatives in normal conditions.

Whilst the data are limited to understand why this happens, a possible explanation for this finding is that this thesis only focusses on the IOIS behaviour, not the total activities of the BSC. Whilst some hospitals in the MC-1 and the MC-2 mention that they have training and standard operating procedures (SOPs) for their staff on what to do under certain operational conditions, this effort to establish readiness to unexpected events is not always shared across the BSC. For example, whilst some hospitals in the MC-1 inform their associated blood centres about their need for blood when there is a lockdown during emergency events (i.e. closing access within the hospitals to prevent people from going in or out of the hospitals due to safety reasons), the detailed lockdown plans are not always coordinated beforehand with the blood centres. This lack of information sharing from the hospitals has been a concern for the NHSBT because it delays the blood supply process and potentially affects the availability of blood products in the hospitals. As an Assistant Director Governance and Resilience at the NHSBT suggests:

> "[…] so our key thing at the moment is [hospital] lockdown. Because most hospitals have got a lockdown process and haven't thought about us. […] And my concern of course is that I won't be able to get blood into the hospital because of course we are very reliable so they've sort of forgotten about us. Because we are a bit like wallpaper you know always there. And therefore their lockdown plans probably don't think about us and so we turn up with some blood and their person on the front, they are not gonna be a clinically qualified person, they are probably gonna be some […] security guard […], they just tell us to go away. You know and that bothers us. So I've shared that sort of thing to try and push some of that planning. […] So that stuff about lockdown for example, you know I am just trying to influence their behaviour. And some of that is about, is all about opening eyes really." *INT - Assistant Director Governance and Resilience NHSBT*

Finally, departing from HRT, it is found that the IOIS behaviour in the BSC does not widely reflect the positive enactment of *deference to expertise* principle across a range of operational conditions. One possible explanation for this finding is that the BSC actors in the MC-1 and MC-2 might not see this principle as a priority in their operations and take their expertise for granted. In other words, the BSC actors might know that they operate under the environment where all BSC actors understand their role and expertise, so they do not emphasise the principle of *deference to expertise* as an important concern when sharing information and managing blood safety and availability. As a Chief Biomedical Scientist the Transfusion Manager at the W Hospital suggests:

> I think we do cover the blood safety quality regulations, vein to vein traceability and safety. […] so from NHS[BT] from vein of donor all the way through to delivery to me, NHSBT are responsible for and services delivered to me until the fate of the unit, be it transfused or wasted, that's my responsibility. […] And I think between the two organisations you know they've got clear demarcation lines on what they're responsible for and likewise we've got our clear embarkation lines and I don't think there's any mix up of where their liability stops and where ours starts and finishes. I think it's quite clear and I think communication works

> quite well. I don't think we've got any issues or had any issues. […] they look after their information and we look after ours. *INT – Chief Biomedical Scientist the Transfusion Manager W Hospital EC 1-1*

The different unit of analysis between this thesis and the extant HRO's literature can be another possible explanation for this finding. In a single organisational setting, HRT posits that *deference to expertise* is about having a less orderly routine and hierarchy, having collective rather than authoritative (top-down) decision making, sharing information regardless of hierarchical rank, and allowing decision making to migrate, along with problems, to people with expertise (Weick and Sutcliffe, 2007; Weick *et al*., 1999). This setting might not be entirely applicable in the context of this research (i.e. IOIS in the BSC) and therefore the positive enactment of *deference to expertise* is difficult to identify.

The concept of hierarchy might not be applicable in the dyadic BSC because the blood centres and their associated hospitals have the same power in the relationship. They cannot force each other and are bound by the service level agreement. In addition, both blood centres and hospitals have the expertise in the area of blood management, so that the migration of decision making beyond supply and demand related issues might be limited. Typically, there are clinicians and biomedical scientists in the blood centres and the hospitals, who are responsible for ensuring blood safety and availability across a range of operational conditions. Whilst some key decisions such as blue light orders, product recalls, or blood safety incidents are consulted between blood centres and the hospitals, these actions represent their *reluctance to simplify* interpretations rather than *deference to expertise*.

Instead of *deference to expertise*, this thesis finds an emerging mechanism of *heedful interrelating* (HI+) that is positively and dynamically enacted across a range of operational conditions, particularly in the MC-1. This mechanism is important in a complex inter-organisational and interdependent system, such as the BSC (see Weick and Roberts, 1993), because it is about the understanding and awareness of the BSC actors that their actions do not only affect their own performance, but also the performance of the whole dyad. As shown in Chapter

5, in normal conditions, positive enactment of *heedful interrelating* is reflected, for example, when the hospitals in the MC-1 share information to alert the blood centres about the potential changes in their operations (e.g. merging or increasing the size of the hospitals, changing the trauma centres), which are likely to change their demand and therefore the supply of blood from the blood centres. Positive enactment of *heedful interrelating* in normal condition is also identified when the blood centres in the MC-2 alert the hospitals that the supplied blood might cause reactions in patients, so that close monitoring of the transfusion is required in the hospitals.

In high tempo conditions, the positive enactment of *heedful interrelating* is identified when the Central NHSBT alerts the hospitals when they experience a shortage of any particular blood group. The NHSBT also informs the hospitals about the likely timescale of the shortage and asks them not to order the respective blood group unless it is absolutely necessary or to use alternative blood groups that are safe for patients. In emergency conditions such as flood, the Central NHSBT positively enacts *heedful interrelating* when it shares information to update the hospitals on the status of the disaster and the likely impact on the blood availability across the BSC. In these two conditions, information sharing reflects the NHSBT's awareness that its events or operations not only affect the blood availability in the blood centres, but also in the hospitals across the country.

The emerging of the positive enactment of *heedful interrelating* across cases and operational conditions, particularly in the MC-1, suggests that this mechanism is key to explain how IOIS influences blood safety and availability in the dyadic BSC setting. In fact, the emerging of this mechanism strengthens Zhao and Zhao's (2015) argument with empirical evidence that SC performance can be improved when IOIS reflects the SC actors' attentiveness to their interrelationships with other SC actors as well as to the systematic performance across the SC. As such, IOIS makes SC actors aware that they should work together as a team to improve the SC performance across a range of operational conditions.

However, whilst prior study has linked *heedful interrelating* to the idea of having a "collective mind" (Weick and Roberts, 1993), the extant HROs literature does not explicitly discuss the importance of *heedful interrelating* alongside the five core principles of collective mindfulness (see Weick and Sutcliffe, 2015, 2007; Weick *et al*., 1999; Lekka, 2011). Although the notion of interactions in the *heedful interrelating* can be linked to the principle of *sensitivity to operations,* it has been argued in Chapter 5 that *heedful interrelating* is not merely about transparency and interactions between the BSC actors, but is more about interactions through understanding the contribution of the BSC actors and the consequence of their actions to the dyad. Whilst enriching the five core principles of collective mindfulness, this mechanism might therefore differentiate the enactment of collective mindfulness principles in the inter-organisational context from that in the single organisational context.

## 6.2 IOIS and collective mindfulness in the centralised and tightly regulated versus decentralised and loosely regulated contexts

The higher number and more dynamic positive enactments of collective mindfulness principles in the centralised and tightly regulated BSC (MC-1) suggest that the BSC actors in this case study context are collectively more mindful when sharing or receiving information compared to those in the decentralised and loosely regulated context (MC-2). As a result of this higher collective mindfulness, the blood safety and availability in the MC-1 is considered to be better than that in the MC-2. This argument is supported by the findings in Tables 5-2 and 5-3 in Chapter 5 on pages 132 and 133 respectively, which show that there are more positive changes in the blood safety and availability (i.e. more ticked areas) in the MC-1 than the MC-2 in normal, high tempo, and emergency conditions.

Compared to the MC-2, for example, more changes in blood safety and availability are observed in the MC-1 when IOIS reflects the positive enactment of *preoccupation with failure* in normal and high tempo conditions. The changes include *realised improvement* (e.g. reduced stock levels) as well as *potential* *improvement* (e.g. safer transfusion practices) after having lessons learnt from the reported incidents. More effective stock replenishment is also observed as a *realised improvement* when IOIS reflects the positive enactment of *sensitivity to operations* in normal conditions. When IOIS reflects the positive enactment of *heedful interrelating* in high tempo conditions, *adjusted* delivery arrangement is identified to fulfil the blood availability. Finally, *assurance* of blood safety and availability (e.g. ensured appropriate order) is observed during the emergency conditions when IOIS reflects the positive enactment of *reluctance to simplify*. These changes in blood safety and availability are not commonly identified in the MC-2.

The different levels of collective mindfulness and therefore different changes in blood safety and availability in the MC-1 and the MC-2 (see Appendix F on page 295 for more examples) can be explained by the degree of centralisation and decentralisation of the IOIS structure in each of the case study contexts. In a single organisational setting, HRT suggests that *customised centralisation* is required to be collectively mindful and to improve the reliability of the operations (Rijpma, 1997 as cited in Weick *et al.*, 1999). This means that centrally coordinated operations should not limit the organisation's capability to detect and quickly respond to errors that can happen in specific parts of the organisation. Whilst allowing a full understanding and control of the whole system in the organisation, centralisation should allow people at any level to become involved in detecting failure and improving the system. Without decentralised actions, centralisation is therefore not enough to achieve high reliability performance. In other words, centralisation and decentralisation should be held in a "critical balance" within the HROs (Weick and Sutcliffe, 2007).

IOIS behaviour in the MC-1 reflects the customised centralisation. Whilst the general structure of the blood supply in this context is centralised under a single national organisation (i.e. the NHSBT), extensive information sharing is identified not only between the NHSBT and all hospitals in the investigated cases, but also between the individual blood centres and their associated hospitals particularly on issues that require immediate attention and responses. In contrast, the IOIS behaviour in the MC-2 demonstrates excess decentralisation, where each blood centre operates independently with a lack of continuous national control and coordination of blood safety and availability performance. According to Weick and Sutcliffe (2007:150) this “excess decentralization can weaken the comprehension of wider threats and the capacity to coordinate responses”. This can be one explanation why the BSC actors in the MC-1 are collectively more mindful when sharing or receiving information across a range of operational conditions than those in the MC-2.

Unlike in the MC-2, the positive enactments of the context-specific collective mindfulness principles in the MC-1 all involve some elements of customised centralisation. For example, in normal conditions, *preoccupation with failure* involves the hospitals reporting blood safety incidents through the centralised national reporting platform as well as reporting the weak signals of the blood quality issues directly to their associated blood centres. *Sensitivity to operations* involves the hospitals regularly sharing blood stock levels, usage, and wastage through the centralised reporting system VANESA, as well as through the regular national, regional, and hospital transfusion committee meetings.

In high tempo conditions, *preoccupation with failure* and *heedful interrelating* involve the hospitals sharing information on blood quality issues with the blood centres, with the awareness that the issues can potentially lead to blood safety incidents across the centralised BSC network. By sharing the information, the hospitals are also aware that their action will not only affect the blood safety in their local area, but potentially the blood safety in the wider hospitals across the country. Finally, in emergency conditions, *reluctance to simplify* involves the blood centres sharing information to check the stock levels of the immediately affected hospitals using the telephone and sharing standard information using fax or email to all hospitals across the country to ensure awareness of the declared major incidents. This information sharing also underlines their awareness that local major incidents can potentially affect the whole BSC in the country (i.e. *heedful interrelating*).

In the context of the PPSC, these findings empirically builds on Ketzenberg and Ferguson (2008) and Kassahun *et al*. (2014). Whilst addressing the issue of coordination structure (i.e. centralisation versus decentralisation), none of these studies attempts to link the issue with the concept of collective mindfulness. Ketzenberg and Ferguson (2008), for example, suggest that both centralised and decentralised IOIS have their own benefits that can in fact overrule each other. Decentralised IOIS is beneficial for the retailer because they can gain benefits by receiving fresher product from the supplier, whereas centralised IOIS offers a higher increase in the SC profit, but product freshness may decrease and consequently expired products may increase.

Building on Ketzenberg and Ferguson (2008), Kassahun *et al*. (2014) argue that there should be a balance between centralised and decentralised IOIS. Kassahun *et al*. (2014) suggest that accommodating both centralised and decentralised approaches in the design of IOIS systems helps the PPSC actors realise the SC-wide transparency that potentially leads to a better guarantee of product safety, quality, and trust across the PPSC. Despite these interesting arguments, the studies of both Ketzenberg and Ferguson (2008) and Kassahun *et al*. (2014) are based on analytical research requiring empirical support.

Another plausible explanation for the different levels of collective mindfulness between the MC-1 and the MC-2 is the tightness of regulations. Tight regulations in the MC-1 support rather than limit the positive enactments of collective mindfulness principles. For example, the Blood Safety and Quality Regulations 2005 require “unambiguous traceability” of all blood products from donors to patients and the reverse, including the final fate of the products if not transfused. These regulations support the enactment of *sensitivity to operations* (i.e. transparency) and *reluctance to simplify* (i.e. scepticism regarding ambiguity of information) across a range of operational conditions.

Moreover, the reporting of severe reactions to transfusion and blood safety incidents are regulated and coordinated by the Medicines and Healthcare products Regulatory Agency (MHRA). The reports are shared across the BSC and discussed in the transfusion committee meetings as lessons learned to enhance their *preoccupation with failure* in normal conditions. MHRA also regulates the recall of blood products with safety and/or quality problems, in which, to ensure responsiveness, information sharing must be conducted between the blood centres and the hospitals within the stipulated times. This regulation supports the enactment of *commitment to resilience* during the high tempo condition. Similarly, to reflect the enactment of *commitment to resilience* and *heedful interrelating*, an emergency protocol is activated in the event of major incidents, which involves sharing standard information to ensure the BSC actors' awareness on the status of the BSC operations during the emergency conditions.

In the MC-2, whilst some regulations about the standards of the blood transfusion service from the Ministry of Health support the positive enactments of collective mindfulness principles, they are loosely implemented across the investigated cases. For example, whilst the complaint management is nationally regulated, some complaints on blood quality issues (e.g. clots in the blood bags) from the hospitals are not properly followed up by the blood centres to ensure blood safety in hospitals. Moreover, the cold chain distribution (i.e. the process of delivering blood products through a temperature-controlled environment) is not always maintained across the BSC. In EC 2-3 for example, the blood is donated and distributed from the blood centre to the associated hospitals by the patients' family using black plastic bags with no temperature control, rather than the standard cool box as required by the regulations. Some of the reasons for this are the lack of enforcement and financial support from the government, which lead to the lack of supporting facilities and competent human resources to provide blood safety and availability across a range of operational conditions. As the Director of National Blood Donation and Hospital of the Indonesian Red Cross suggests:

> "There is [a financial support from the government], yes, but minimum. […] [the improvement of performance in a certain area] depends on the [support from the] government." *INT - Director of National Blood Donation and Hospital of the Indonesian Red Cross*

In addition, the existing regulations in the MC-2 do not entirely support and enforce some essential governance aspects, such as the national guidelines on the appropriate clinical use of blood and the national haemovigilance system, to report and trace the root causes of severe reactions to transfusion and blood safety incidents across the BSC (WHO, 2017c). As a consequence, there is currently a lack of information sharing and therefore lessons learnt on the blood safety incidents between the hospitals and blood centres nationally. This can contribute to a lack of positive enactment of *preoccupation with failure* in the MC-2. In fact, the national blood transfusion committee is not effectively run to facilitate information sharing and lessons learnt, as well as to help the BSC comply with the regulations. This can contribute to the lack of positive enactment of *preoccupation with failure* and the prevalence of negative enactment of *sensitivity to operations* in normal conditions. As the following excerpt suggests:

> "The blood safety committee is actually there, established by the Ministry of Health. The committee consists of us from the Indonesian Red Cross, the Ministry of Health, and experts in blood transfusion. […] [This committee] should actually give recommendations to the Minister about the blood needs in Indonesia. […] This committee is not working." *INT - Director of National Blood Donation and Hospital of the Indonesian Red Cross*

Whilst tightness of regulations can be a plausible explanation why IOIS behaviour in the MC-1 reflects more principles of collective mindfulness than in the MC-2, the link between tightness of regulations and collective mindfulness principles has not been sufficiently discussed in the extant HROs literature (see Weick and Sutcliffe, 2015, 2007; Weick *et al*., 1999). La Porte and Rochlin (1994) assume that regulatory pressures are only intrinsic to the HRO's operations. Although in general Lekka (2011) suggests that the existence of regulations supports the positive enactments of collective mindfulness principles, whether or not tighter regulations lead to more enactments of collective mindfulness principles in HROs remains underexplored.

Some studies argue that regulations provide ways to establish measures, rules, procedures or guidelines towards high reliability operations (see La Porte and Thomas, 1995; Lekka, 2011), so they tend to encourage routine-based rather than mindful-based reliability (see Butler and Gray, 2006; Kutsch *et al*., 2013). Routine-based approaches to reliability suggest that "procedures and processes are designed in advance, usually by managers or analysts, and applied in the moment by operators. Information systems are created and training programs are prepared to lead users step-by-step through the proper routine. Procedures, routines, training, and systems are designed to decrease the need for creative human involvement in the moment, in an effort to reduce errors, unwanted variation, and waste" (Butler and Gray, 2006:214). Overemphasising on routines, however, can lead to mindless actions that can be detrimental to the organisation because they hinder the mindful detection of and actions on unexpected changes in the organisation's environment (Butler and Gray, 2006; Sitkin *et al*., 1994; Turner *et al*., 2016; Weick *et al*., 1999). For this very reason, tight regulations can limit the enactments of collective mindfulness principles across a range of operational conditions.

This thesis, for example, finds that in the MC-1 some elements of routines in the tightly regulated environment can lead to complacency amongst the BSC actors, which contributes to the negative enactments of the *reluctance to simplify* principle in normal conditions. In this regard, the BSC actors tend to assume that everything works well within the day-to-day operations, so that the shared information receives a limited scrutiny. As a result, potential failure of the BSC (e.g. failure to adapt new policies, failure to provide a continuous supply of blood) and unexpected errors, such as unnecessary double orders, can go unnoticed.

Recent studies, however, suggest that organisations are increasingly relying on a mix of routine-based and mindfulness-based reliability (Andersen and Hanstad, 2013; Butler and Gray 2006; Turner *et al*., 2016). Whilst being compliant with rules and procedures, organisations can "infuse" collective mindfulness principles not only in normal conditions, but also during times of incidents and major crises (Turner *et al*., 2016). In this regard, tight regulations can be simultaneously coupled with the positive enactments of collective mindfulness principles to create a robust system leading to high reliability performance (see La Porte and Thomas, 1995).

Whilst offering a compelling argument, the focus of these studies is only on a single organisational context. This thesis builds on these studies from the perspective of IOIS in the inter-organisational context of the BSC. It also argues that tight regulations are required to support the positive enactments of collective mindfulness principles across a range of operational conditions.

## 6.3 Summary of discussion

This chapter establishes plausible explanations for the findings using HRT. Building on this theory, this thesis argues that, in the context of dyadic BSC, IOIS influences blood safety and availability through the dynamic enactments of collective mindfulness principles across a range of operational conditions. This dynamic is mainly represented by the positive enactments of *preoccupation with failure* and *reluctance to simplify* that are identified in the MC-1 beyond the normal conditions. This thesis also argues that due to the dynamic positive enactments of *heedful interrelating* in normal, high tempo, and emergency conditions particularly in the MC-1, this emerging mechanism is relevant to explain how IOIS influences blood safety and availability in the dyadic BSC setting. *Heedful interrelating* can add to the five current core principles of collective mindfulness and therefore differentiate the enactment of collective mindfulness principles in the supply chain context from that in the single organisational context.

Furthermore, it is argued in this chapter that to have IOIS behaviour that reflects higher levels of collective mindfulness, and therefore better blood safety and availability, the BSC actors need to keep the IOIS structure critically balanced between centralisation and decentralisation. Whilst having tight regulations can lead to less mindful actions, tight regulations can also support the positive enactments of collective mindfulness principles to achieve better blood safety and availability across a range of operational conditions. This thesis supports this paradox.

Overall, this thesis contributes to HRT by demonstrating the applicability of collective mindfulness concept in a specific context of IOIS in the BSC. It also elaborates HRT by extending its original unit of analysis of a single organisation to a wider unit of analysis of supply chain. The conclusions of this thesis are presented in following chapter (Chapter 7).

# 7 CONCLUSIONS

This chapter concludes this thesis by describing how it addresses the research question, aim, and objectives. The contributions of this thesis are presented in this chapter; the limitations of this thesis are then presented together with suggestions for future research to take this thesis forward.

Whilst some studies have suggested that inter-organisational information sharing (IOIS) can potentially improve blood safety and availability, empirical research is currently lacking. The blood supply chain (BSC) can learn from the wider context of supply chain (SC) literature that SC actors do not necessarily gain benefits from IOIS and that further investigation is required to understand the underlying mechanisms of how IOIS influences SC performance across a range of operational conditions. This thesis seeks to address these two practically and conceptually relevant research gaps, by asking *how does inter-organisational information sharing (IOIS) influence blood safety and availability (BSA) in the dyadic blood supply chain (BSC) in normal, high tempo, and emergency conditions?* To answer this question, an aim has been set to determine and unravel the underlying mechanisms of the relationship between IOIS and the BSA with the following objectives:

1. To identify IOIS behaviour (i.e. what, how, with whom, and how often information is shared) associated with ensuring BSA in the dyadic BSC in normal, high tempo, and emergency conditions.

2. To identify co-actions underpinning the IOIS behaviour in the dyadic BSC in normal, high tempo, and emergency conditions.

3. To explain the co-actions underpinning the IOIS behaviour using high reliability theory, particularly its central concept of collective mindfulness in the dyadic BSC in normal, high tempo, and emergency conditions.

4. To identify and explain if there are other emerging underlying mechanisms that explain the co-actions underpinning the IOIS behaviour in the dyadic BSC in normal, high tempo, and emergency conditions.

5. To propose and explain a theoretical framework characterising the underlying mechanisms of how IOIS influences BSA in the dyadic BSC in normal, high tempo, and emergency conditions.

To address the research question, aim, and objectives, this thesis uses embedded multiple case study designed for theory elaboration. Grounded in the critical realism and high reliability theory (HRT) as the philosophical and theoretical perspectives respectively, the underlying mechanisms of how IOIS influences BSA are unravelled using basic qualitative description with retroductive-abductive strategy. As such, the research process involves going back and forth between empirical data and theory to provide plausible explanations of the phenomenon. To gain a comprehensive understanding of the underlying mechanisms across a range of operational conditions, polar or extreme cases were selected and investigated in this thesis, representing the centralised and tightly regulated BSC (MC-1) and decentralised and loosely regulated BSC (MC-2). Template analysis as well as within case and cross-cases analyses were conducted to analyse the qualitative data collected from a triangulation of semi-structured interviews, walkthroughs, and other supporting documents including archives and artefacts.

To achieve objective 1, the IOIS behaviour across cases has been identified in normal, high tempo, and emergency conditions (see Appendix B on page 226). The findings show that, whilst a wide variety of information is shared both ways between the BSC actors across a range of operational conditions, a wider range of information covering the wider aspects of the BSC is shared in the MC-1 compared to that in the MC-2. This indicates that the MC-1 is more open to sharing information than the MC-2. Moreover, compared to the MC-2, the MC-1 uses a wider variety of information sharing media, ranging from conventional to more advance information sharing systems across a range of operational conditions. This indicates a richer and more flexible nature of information sharing in the MC-1 compared to that in the MC-2.

In the MC-1, information is shared not only between the blood centres and their associated hospitals, but also between a single national organisation that manages the blood centres (i.e. NHSBT) and all hospitals served by this organisation across a range of operational conditions. In contrast, in the MC-2, information is shared only between the blood centres and their associated hospitals across a range of operational conditions, reflecting the decentralised nature of this context.

Finally, this thesis finds that, as the tempo of the operations becomes higher (i.e. towards high tempo and emergency conditions), a similar pattern of IOIS behaviour is identified for both the MC-1 and the MC-2. The higher the tempo of the operations, the fewer the content of information being shared between the blood centres and hospitals. Information is also shared using fewer but more responsive information sharing media on a more *ad hoc* rather than planned basis. These patterns represent the nature of mainly unexpected high tempo and emergency conditions requiring immediate responses to address critical blood safety and availability issues.

To achieve objective 2, the co-actions underpinning the IOIS behaviour across cases and operational conditions have been identified (see Appendix C on page 245). This thesis argues that when sharing or receiving information, the BSC actors do not only convey or receive certain facts, messages, or explicit knowledge, using certain media, with certain direction and frequency, but they are actually trying to do something (referred to in this thesis as co-action) that leads to changes in BSA. To achieve objective 3, using an *explanation building* technique, the identified co-actions have been matched with the five collective mindfulness principles of HRT (i.e. *preoccupation with failure* (PF)*, reluctance to simplify* (RS)*, sensitivity to operations* (SO)*, commitment to resilience* (CR)*, and deference to expertise* (DE)).

Through the pattern matching process, a specific mechanism of *heedful interrelating* (HI) has emerged from the data across a range of operational conditions particularly in the MC-1, which represents a key contribution of this thesis (see Chapter 5). Therefore, this thesis has achieved objective 4. Finally, to achieve objective 5, a theoretical framework explaining how IOIS influences BSA across a range of operational conditions has been proposed in this thesis (see

Figure 5-3 in Chapter 5 on page 126). Plausible explanations of this framework have been established using HRT, particularly its central concept of collective mindfulness (CM).

Overall, this thesis finds that IOIS influences BSA through the dynamic enactments of CM principles that reflect the IOIS behaviour across the operational conditions. Whilst not all CM principles can serve as underlying mechanisms, it is found that more CM principles are enacted across a range of operational conditions in the MC-1 compared to that in the MC-2. This indicates that regardless of the operational conditions, the BSC actors in the MC-1 are collectively more mindful when sharing or receiving information than those in the MC-2. As a consequence, more positive changes in the BSA performance are observed in the MC-1 compared to that in the MC-2. Therefore, it can be argued that the MC-1 has a higher reliability BSC than the MC-2. Finally, this thesis reveals an interesting fact that IOIS does not necessarily lead to positive changes in BSA. In fact, negatively enacted CM principles can lead IOIS to unimproved and even potentially worse BSA.

Using HRT, this thesis argues that the dynamic enactments of CM principles in the MC-1 and the MC-2 can be linked to the different types of IOIS structure and different tightness of regulations applied across the BSC. This thesis also suggests that a critical balance between centralised and decentralised IOIS structure is important to encourage more enactments of collective mindfulness across a range of operational conditions. In addition, current BSC regulations should be appropriately enforced and supportive towards the development of CM principles that reflect the IOIS behaviour between BSC actors.

## 7.1 Contributions to the BSC practices

This thesis contributes to the BSC practices by proposing some practical recommendations for the BSC actors across the investigated cases. The recommendations are particularly important for the BSC actors in the context of MC-2 that need to improve their BSC operations and learn some lessons from the BSC actors in the MC-1. It is expected that by applying the recommendations, the BSC actors can have more impactful information sharing practices, leading to better blood safety and availability across the BSC. Practically, this thesis recommends the BSC actors to:

1. Identify any weak signals of errors or failure that can lead to BSA incidents at any time and share the information on the weak signals across the dyad to raise awareness.
2. Share any useful proprietary information (e.g. blood stock levels, usage, and wastage) as well as changes in the BSA on a real time and regular basis.
3. Avoid over-reliant on the sophisticated and transparent information systems to share and receive information and be ready to switch to another information sharing media when the system is not working.
4. Share information using redundant information sharing media. For example, an important telephone conversation about the BSA issues can be followed up by email as written evidence and a reminder. This behaviour can reduce complacency across the BSC.
5. Embrace timeliness and prompt responses when sharing information about BSA-related incidents or any BSC disruptions.
6. Embrace two-way information sharing between the BSC actors, reflecting their awareness that their operations affect each other and therefore the BSA performance across the whole BSC.
7. Establish a centralised IOIS system and coordinate the BSA-related IOIS nationally. Information should be shared not only between the hospitals and their associated local blood centres, but most importantly between the hospitals and a central national organisation that controls and monitors the whole BSC operation across the cases.
8. Establish proper IOIS infrastructure in the MC-2 to link all BSC actors across the cases. For example, the national rather than local website should be developed to ensure transparency and updated content of BSA-related information on a real time or regular basis. The functionality of the website to spread the BSA-related issues should be supported by a centralised emailing system, fax, or other appropriate media to ensure redundancy.

9. Establish national initiatives such as the blood stocks management scheme (BSMS) to share proprietary information such as blood stock levels, usage, and wastage.
10. Establish and promote the national haemovigilance system to report and investigate any severe reactions to transfusion and blood safety related incidents across the BSC. Whilst this initiative might incur high costs of investment in the IOIS systems, it can enable a nationwide learning from the BSC performance across cases.
11. Elaborate and enforce the existing BSC regulations in the MC-2 to support the national haemovigilance system.
12. Establish a specialist organisation in the MC-2 to focus on managing the BSC across cases. The Indonesian Red Cross (PMI) is currently not specialised in the BSC as its focus.
13. Enforce the active role of the national, regional, and hospital blood transfusion committees to facilitate regular information sharing on the BSA issues. The activation of these committees can also help the BSC actors learn some lessons (e.g. blood safety incidents, near misses, best practices) from each other, creating a climate of openness to collectively improve the BSA performance.

Whilst the BC actors in the MC-1 are generally collectively more mindful when sharing or receiving information and therefore have higher reliability performance (i.e. better blood safety and availability) than those in the MC-2, the problem of complacency in the MC-1 needs to be addressed and resolved. The data from this thesis suggest that one of the root causes of complacent actions is the lack of total exposure to the BSA incidents and BSC disruptions, particularly the severe ones, so that assumptions are made that the BSC and transfusion activities are always safe. To resolve the problem of complacency in the MC-1, this thesis recommends the BSC actors to:

1. Increase the number of transfusion-related staff across the BSC to reduce the workload that occupies the staff time and to better involve them in the BSA initiatives. There is, however, a cost consequence of this recommendation to recruit skilled staff.

2. Optimise the current information sharing initiatives by having more frequent teleconferences involving both NHSBT and the hospitals to discuss the BSA issues. This approach is time and cost effective because relevant people do not have to travel to be physically present in certain locations.
3. Enforce the current regulations to make the participation of the blood transfusion committee meetings compulsory.
4. Conduct some audits to ensure that the lessons learnt are actually taken on board and implemented across the BSC actors.

Overall, the above practical recommendations reflect potential strategies to promote the CM-reflecting IOIS behaviour that can lead to better BSA across the BSC. With care, this practical implication can also be adapted in the wider SC contexts.

## 7.2 Contributions to the SC literature

This thesis contributes to the wider SC literature in the following ways:

1. Using the concept of collective mindfulness, this thesis determines and unravels the underlying mechanisms of how IOIS influences the BSA in the dyadic BSC in normal, high tempo, and emergency conditions. As such, it contributes an empirical research on the phenomenon of IOIS which is currently lacking in the BSC literature (see Beliën and Forcé, 2012).
2. Using the BSC as a context, it is amongst the few studies that contribute to the understanding of the underlying mechanisms of how IOIS influences the perishable product supply chain (PPSC) performance (see Kochan *et al*., 2018; Scholten and Schilder, 2015).
3. It provides a comprehensive understanding on the dynamic of the underlying mechanisms and the respective IOIS behaviour that represents a more realistic and complex scenario in which the PPSC might operate in normal, high tempo, and emergency conditions. This attempt has been very limited in the reviewed IOIS-PPSC literature (e.g. Kochan *et al*., 2018; Scholten and Schilder, 2015).

4. It determines and unravels the underlying mechanisms (i.e. the different enactments of collective mindfulness principles) that explain how IOIS influences PPSC performance in both centralised and decentralised IOIS structures. This attempt is currently absent from the extant PPSC literature (e.g. Kassahun *et al*., 2014; Ketzenberg and Ferguson, 2008).
5. It adds to Kassahun *et al*. (2014) by arguing that it is not enough to only take regulations as an important insight to be considered when sharing or receiving information across the PPSC, but tight regulations should be enforced to support the CM-reflecting IOIS.
6. To understand how IOIS influences BSA, this thesis follows up Kembro and Näslund's (2014) recommendation to comprehensively investigate IOIS behaviour (i.e. what, how, with whom information is shared) and to identify its impact on the supply chain performance using the notion of underlying mechanisms. The majority of the IOIS studies do not sufficiently investigate the IOIS behaviour (see Kembro and Näslund, 2014).
7. It collects and analyses the IOIS data from both blood centres and hospitals in the dyad. By doing this, it goes beyond the limited and potentially biased perspective of IOIS if the data collection and analysis are conducted only from one side of the dyad (see Kembro and Näslund, 2014).
8. This thesis uses high reliability theory (HRT) to explain how IOIS influences BSA. The use of HRT fills the gap in the IOIS-SC literature that there is a limited use of theoretical perspectives to understand the relationship between IOIS and SC performance (see Kembro *et al*., 2014).
9. The elaboration of HRT, particularly collective mindfulness principles, represents the novelty of this thesis. Whilst the idea of mindfulness is implicitly discussed by Zhao and Zhao (2015) and lightly addressed in Speier *et al.*'s (2011) research, the elaboration of collective mindfulness principles of HRT in the IOIS-SC literature is currently lacking (see Kembro and Näslund, 2014; Kembro *et al*., 2014). Neither Zhao and Zhao (2015) nor Speier *et al.* (2011) offers a deep exploration and explanation on the link between IOIS and collective mindfulness principles of HRT.

10. By investigating the notion of underlying mechanisms instead of linear relationships between the IOIS and SC performance, this thesis adds to the advancement of the use of the critical realism paradigm in SC literature. This paradigm offers a fresher view in understanding the SC phenomenon, which has been predominated by the philosophical stance of positivism (see Aastrup and Halldórsson, 2008; Gammelgaard, 2004, 2017; Mentzer and Kahn, 1995). This thesis supports this view, by arguing that it is not enough to say that information sharing can have benefits for the BSC (i.e. improved BSA) as suggested by the current BSC literature (e.g. Goodnough *et al*., 2003; Rautonen, 2007; Williamson and Devine, 2013). What is more important is to understand the IOIS behaviour and the underlying mechanisms that explain how the behaviour can lead to changes in BSA.
11. Whilst some of the findings in this thesis seem to overlap with the concept of supply chain risk and resilience (SCRR), using HRT, this thesis builds on rather than contradicts the SCRR. It considers not only the physical elements which currently become the focus of SCRR, but also the less physical elements (i.e. the "mind" of BSC actors themselves) to manage SC disruptions. It argues that managing SC disruptions is not only about mitigating the risk of big disruptive events, but is also about identifying and sharing any weak signals of errors that can potentially lead to catastrophic consequences for the BSC. It is also about avoiding making assumptions, about transparency, and about understanding that one single action can affect the whole BSC performance (see Lekka, 2011; Weick and Sutcliffe, 2015, 2007; Weick *et al*., 1999). This less physical capacity is crucial because managing unexpected events involves human behaviour that is fallible. By being collectively mindful, the catastrophic impacts of the events can be avoided or at least minimised (Weick and Sutcliffe, 2007).

In summary, using the BSC as a study context, this thesis contributes to the wider supply chain knowledge by offering a novel perspective of collective mindfulness of HRT to understand how IOIS influences SC performance across a range of operational conditions. This thesis also extends the current IOIS discussions in the extant SC literature by grounding the research in the critical realism paradigm, therefore offering an alternative philosophical stance to positivism. As such, this thesis goes beyond merely explaining the linear relationship between IOIS and SC performance. Instead, it triggers a different way of thinking about the relationship between IOIS and SC performance using the notion of underlying mechanisms.

## 7.3 Limitations of the thesis and future research

This thesis has its limitations which are regarded as opportunities for future research. First, it uses a single theoretical perspective of the HRT to unravel the underlying mechanisms of the relationship between IOIS and BSA. As a consequence, this thesis should be treated as an attempt to provide an alternative perspective instead of the best way to understand the IOIS phenomenon. Whilst the HRT, particularly its central concept of collective mindfulness, provides a relevant and compelling perspective to explain the investigated phenomenon, future research can explore the use of multiple theoretical perspectives to advance the understanding of the complex phenomenon of IOIS (see Kembro *et al*., 2014).

Using the HRT, this thesis is able to establish plausible explanations of the findings. One of the explanations suggests that the dynamic enactments of the CM principles in the MC-1 and MC-2 are linked to the nature of the IOIS structure (i.e. centralised versus decentralised) and the tightness of the BSC regulations. However, the HRT suggests that centralisation and regulations are not the only contributing factors that support the enactments of CM principles across a range of operational conditions. Weick and Sutcliffe (2007) and Lekka (2011) point out that organisational culture is an essential driving force for the enactments of CM principles in HROs.

Organisational culture in HROs is about having values, beliefs, actions, attitudes, and behaviours that reflect shared expectations, assumptions, and similar views of rationality towards promoting collective mindfulness across individuals within the organisation (Weick and Sutcliffe, 2007). To establish the CM-supporting culture, appropriate leadership style is required (Lekka, 2011; Vogus and

Sutcliffe, 2012). As such, organisational leaders should make CM a strategic priority within the organisation. The leaders should also have a holistic view of collective mindfulness by cascading the CM-based practices to the department and work-group levels (Vogus and Sutcliffe, 2012). The design of the research and the data collected for this thesis do not support the understanding of the organisational culture and leadership in the BSC, so that these elements of HROs were not captured in the thesis. Future research can be conducted to understand whether these two important notions influence the relationship between IOIS and BSA, and more importantly, the dynamic enactments of CM principles across the BSC and a range of operational conditions.

In addition, whilst the HRT recommends certain information sharing behaviour to increase collective mindfulness, such as the use of rich media (e.g. more face to face rather than telephone or written communications) to share information across the organisation (Weick and Sutcliffe, 2007), this recommendation is normative rather than empirically grounded. Although this thesis has identified the IOIS behaviour across cases and operational conditions, the purpose of this identification is not to precisely prescribe what, how, with whom, and how often information should be shared between the BSC actors. Instead, the identification of this behaviour is very important to understand whether it reflects any co-actions and therefore collective mindfulness enactments across a range of operational conditions. Therefore, this thesis does not provide a prediction that a certain way of sharing or receiving information (e.g. using face to face rather than telephone) will lead to better BSA (e.g. fewer blood safety incidents, less overstock). Future research can address this limitation.

Second, whilst a systematic literature review (SLR) is employed in this thesis, the focus of the review is limited to the phenomenon of IOIS in the PPSC, which shares many of the characteristics of the BSC. The SLR approach also leaves an important caveat. Even though the SLR provides rigorous processes, the mechanistic way in which data are collected from online databases limits the results to articles retrieved using pre-determined keywords. It is possible, therefore, that relevant articles are not captured by the search engines. To avoid missing relevant articles, the keywords have been carefully designed and additional articles have also been included through cross-referencing. Future research can improve this process and advance this SLR.

Third, the number of cases investigated in this thesis is limited by the access gained in the UK and Indonesian BSC as well as the PhD research time frame. Whilst the selected cases have provided sufficient information to answer the research question and achieve the aim of this thesis, the bigger number of cases (albeit a more complex design) with a purposive sampling technique can enhance the robustness, validity, and reliability of the findings. In addition, whilst the cases were selected by varying the attributes of the blood centres and their associated hospitals (i.e. different sizes, locations, and blood inventory management practices), this thesis was not designed to understand the impact of this variation on the relationship between IOIS and BSA (see Stanger, 2013; Scholten and Schilder, 2015). Instead, this variation is required to capture as many IOIS behaviours and mechanisms as possible to comprehensively understand how IOIS influences BSA (see Sandelowski, 1995, 2000). Future research with a more appropriate data set can therefore focus on investigating the impact of the varying attributes on the underlying mechanisms of how IOIS influences BSA.

Finally, although a multiple case study design offers stronger and more compelling empirical insights compared to a single case study design, it is the nature of the case study research that the generalisability of the findings is limited to theoretical or analytical, rather than statistical generalisation (Yin, 2014). As such, the findings of this thesis do not represent the general populations to which the investigated cases belong; instead, these findings might be applied with care to explain similar phenomena in similar study contexts, such as IOIS-PPSC and IOIS-SC.

Whilst a large scale survey design can be adopted in future research to obtain statistical generalisation, this design incurs an important caveat that is not easily matched with the purpose of understanding the underlying mechanisms of how IOIS influences SC performance. Typical survey research is conducted with a strong positivism perspective to study a phenomenon by establishing correlations or linear relationships between variables (Aastrup and Halldórsson, 2008; Blaikie, 2007; Gammelgaard, 2004, 2017; Mentzer and Kahn, 1995). This approach is considered insufficient to understand the process of how the relationships happen under the critical realism paradigm (Blaikie, 2007). In addition, survey design has also been reported to be problematic when applied to study information sharing in inter-organisational settings (Kembro and Näslund, 2014), because it might involve different perspectives of SC actors from different SC echelons.

Given these concerns, future research using surveys should aim to understand the underlying mechanisms of the IOIS phenomenon (i.e. collective mindfulness) rather than merely establishing linear regularities between IOIS-related variables. To do this, survey research can be supported by qualitative methods. Pawson and Tilley (1997) provide comprehensive examples of how the mixed methods can be conducted under the critical realism paradigm. In the SCM literature, the use of mixed methods is also recommended to better understand the complex nature of the IOIS phenomenon (see Kembro and Näslund, 2014). Further readings on different types of mixed method approaches can refer to the work of Creswell (2005), Hesse-Biber (2010), Ivankova *et al.* (2006), Johnson and Onwuegbuzie (2004) and Tashakkori and Teddlie (1998).

Other potential methods to be used in future research are simulation modelling and laboratory experiments. Whilst simulation modelling is analytical in nature, it is a safe way to model the "reality" with more complex scenarios and a controlled environment (see Robinson, 2004). For example, agent-based modelling and simulation (see Twomey and Cadman, 2002) can be used as a powerful tool for analysing complex non-linear IOIS behaviour of the SC actors and their interactions. System dynamic modelling and simulation (see Sterman, 1989) can be used to demonstrate the dynamic of events (including the unexpected events) that affect the BSA (e.g. BSC disruptions, the dynamic of demand and supply of blood products, across a range of operational conditions). The combination of these approaches might be able to show the more dynamic and complex enactments of CM principles that is reflected in the dynamic of IOIS behaviour amongst the SC actors.

Finally, laboratory experiments are helpful to study the SC behaviour in more controlled, efficient, and responsive ways (see Croson and Donohue, 2002; Siemsen, 2011; Zhao and Zhao, 2015). Such experimental studies on IOIS behaviour in SCs have been pioneered recently by Cantor and Macdonald (2009), Steckel *et al*. (2004), and Zhao and Zhao (2015), all of whom find that IOIS does not necessarily improve SC performance. Moreover, they highlight the lack of attention to the shared information as a potential underlying mechanism that explains the ineffective relationship between IOIS and SC performance. Zhao and Zhao (2015) in particular conduct an experiment, where all SC actors are played by human participants, and tentatively imply that mindfulness of the SC actors towards information sharing can explain how IOIS influences SC performance.

Whilst this thesis builds on Zhao and Zhao (2015), laboratory experiments can be conducted in future research to confirm and at the same time advance the findings of this thesis. In fact, laboratory experiments are amongst the appropriate methods recommended to unravel the underlying mechanisms of a phenomenon under the philosophical stance of critical realism. In addition, the feasibility for conducting laboratory experiments to follow up on this thesis has been discussed with and confirmed by an expert in the field of experimental studies.

# REFERENCES


Aastrup, J. and Halldórsson, A. (2008), “Epistemological role of case studies in logistics: a critical realist perspective”, *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 10, pp. 746-763.

Adamides, E.D., Papachristos, G. and Pomonis, N. (2012), “Critical realism in supply chain research: understanding the dynamics of a seasonal goods supply chain”, *International Journal of Physical Distribution & Logistics Management*, Vol. 42 No. 10, pp. 906-930.

Aggarwal, S. and Srivastava, M.K. (2016), “Towards a grounded view of collaboration in Indian agri-food supply chains: a qualitative investigation”, *British Food Journal,* Vol. 118 No. 5, pp. 1085-1106.

Åhlström, P. (2007), “Presenting qualitative research: convincing through illustrating the analysis process”, *Journal of Purchasing & Supply Management*, Vol. 13 No. 3, pp. 216-218.

Alavi, M. and Leidner, D.E. (2001), “Knowledge management and knowledge management systems: conceptual foundations and research issues”, *MIS Quarterly*, Vol. 25 No. 1, pp. 107-136.

Alftan, A., Kaipia, R., Loikkanen, L. and Spens, K. (2015), “Centralised grocery supply chain planning: improved exception management”, *International Journal of Physical Distribution & Logistics Management,* Vol. 45 No. 3, pp. 237-259.

Anastasiadis, F. and Poole, N. (2015), “Emergent supply chains in the agrifood sector: insights from a whole chain approach”, *Supply Chain Management: An International Journal,* Vol. 20, No. 4, pp. 353-368.

Andersen, S. and Hanstad, D.V. (2013), “Knowledge development and transfer in a mindful project-organization”, *International Journal of Managing Projects in Business*, Vol. 6 No. 2, pp. 236-250.

Antony, J. (2004), “Some pros and cons of six sigma: an academic perspective”, *The TQM Magazine*, Vol. 16 No. 4, pp. 303-306.

Ayres, L. (2008), “Semi-structured interview”, in Given, L.M. (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods*, SAGE Publications, Inc., Thousand Oaks, p. 811.

Bacharach, S.B. (1989), “Organizational theories: some criteria for evaluation”, *Academy of Management Review,* Vol. 14 No. 4, pp. 496-515.

Baker, D.P., Day, R. and Salas, E. (2006), "Teamwork as an essential component of high reliability organisations", *Health Research and Educational Trust*, Vol. 41 No. 4, pp. 1576-1598.

Barratt, M. and Oke, A. (2007), "Antecedents of supply chain visibility in retail supply chains: a resource-based theory perspective", *Journal of Operations Management*, Vol. 25, No. 6, pp. 1217-1233.

Baxter, P. and Jack, S. (2008), "Qualitative case study methodology: study design and implementation for novice researchers", *The Qualitative Report*, Vol. 13 No. 4, pp. 544-559.

Beamon, B.M. (1999), "Measuring supply chain performance", *International Journal of Operations & Production Management,* Vol. 19 No. 3, pp. 275-292.

Beliën, J. and Forcé, H. (2012), "Supply chain management of blood products: a literature review", *European Journal of Operations Research*, Vol. 217, pp. 1-16.

Benbasat, I., Goldstein, D.K. and Mead, M. (1987), "The case research strategy in studies of information systems", *MIS Quarterly*, September.

Bensaou, M. (1995), "Configurations of inter-organizational relationships: a comparison between U.S. and Japanese auto-makers", *Management Science*, Vol. 41 No. 9, pp. 1471-1492.

Beulens, A.J.M., Broens, D.F., Folstar, P. and Hofstede, G.J. (2005), "Food safety and transparency in food chains and networks: relationships and challenges", *Food Control,* Vol. 16, pp. 481-486.

Bevilacqua, M., Ciarapica, F.E. and Giacchetta, G. (2009), "Business process reengineering of a supply chain and a traceability system: a case study", *Journal of Food Engineering,* Vol. 93, pp. 13-22.

Bhakoo, V., Singh, P.J. and Chia, A. (2015), "Supply chain structures shaping portfolio of technologies: exploring the impact of integration through the "dual arcs" framework", *International Journal of Physical Distribution & Logistics Management,* Vol. 45 No. 4, pp. 376-399.

Bhamra, R., Dani, S. and Burnard, K. (2011), "Resilience: the concept, a literature review and future directions", *International Journal of Production Research*, Vol. 49 No. 18, pp. 5375-5393.

Bhaskar, R. (1978), *A Realist Theory of Science*, Harvester Press, Hassocks, UK.

Blaikie, N. (2007), *Approaches to Social Enquiry* (2nd Ed.), Polity Press, Cambridge, UK.

Blatt, R., Christianson, M.K., Sutcliffe, K.M. and Rosenthal, M.M. (2006), “A sensemaking lens on reliability”, *Journal of Organizational Behavior*, Vol. 27, pp. 897-917.

Brinkmann, S. and Kvale, S. (2015), *InterViews: Learning the Craft of Qualitative Research Interviewing*, SAGE Publication, Inc., California.

Bourgeois, L.J. and Eisenhardt, K.M. (1988), “Strategic decision processes in high velocity environments: four cases in the microcomputer industry”, *Management Science*, Vol. 34 No. 7, pp. 816-835.

Broekmeulen, R.A.C.M. and Van Donselaar, K.H. (2009), “A heuristic to manage perishable inventory with batch ordering, positive lead-times, and time-varying demand”, *Computers & Operations Research*, Vol. 36 No. 11, pp. 3013-3018.

Butler, B.S. and Gray, P.H. (2006), “Reliability, mindfulness, and information systems”, *MIS Quarterly*, Vol. 30 No. 2, pp. 211-224.

Cachon, G.P. and Fisher, M. (2000), “Supply chain inventory management and the value of shared information”, *Management Science*, Vol. 46 No. 8, pp. 1032–1048.

Cantor, D.E. and Macdonald, J.R. (2009), “Decision-making in the supply chain: examining problem solving approaches and information availability”, *Journal of Operations Management*, Vol. 27 No. 3, pp. 220-232.

Chapman, J. (2007), “Unlocking the essentials of effective blood inventory management”, *Transfusion*, Vol. 47, pp. 190S-196S.

Chircu, A., Sultanow, E. and Saraswat, S.P. (2014), "Healthcare RFID in Germany: an integrated pharmaceutical supply chain perspective", *Journal of Applied Business Research*, Vol. 30 No. 3, p. 737-752.

Choo, C.W., Detlor, B. and Turnbull, D. (2000), *Web Work: Information Seeking and Knowledge Work on the World Wide Web,* Kluwer Academic Publishers, Dordrecht.

Christopher, M. and Peck, H. (2004), “Building the resilient supply chain”, *The International Journal of Logistics Management*, Vol. 15 No. 2, pp. 1-14.

Clegg, B. and Wan, Y. (2013), “Managing enterprises and ERP systems: a contingency model for the enterprization of operations”, *International Journal of Operations & Production Management,* Vol. 33 No. 11/12, pp. 1458-1489.

Clements, M.D., Lazo, R.M. and Martin, S.K. (2008), "Relationship connectors in NZ fresh produce supply chains", *British Food Journal*, Vol. 110 No. 4/5, pp. 346-360.

Cool, K. and Henderson, J. (1998), "Power and firm profitability in supply chains: French manufacturing industry in 1993", *Strategic Management Journal*, Vol. 19 No. 10, pp. 909-926.

Corsten, D. and Kumar, N. (2005), "Do suppliers benefit from collaborative relationships with large retailers? An empirical investigation of efficient consumer response adoption", *Journal of Marketing*, Vol. 69, pp. 80-94.

Creswell, J.W. (2005), *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Approaches to Research* (2nd Ed.), Merrill/Pearson Education, New Jersey.

Croson, R. and Donohue, K. (2002), "Experimental economics and supply-chain management", *Interfaces*, Vol. 32 No. 5, pp. 74-82.

Davenport, T.H. (1997), *Information Ecology*, Oxford University Press, New York.

Denyer, D., Kutsch, E., Lee-Kelley, E. and Hall, M. (2011), "Exploring reliability in information systems programmes", *International Journal of Project Management*, Vol. 29, pp. 442-454.

Denyer, D. and Tranfield, D. (2009), "Producing a systematic review", in Buchanan, D.A. and Bryman, A. (Ed.), *Organizational Research Method*, SAGE Publications Ltd., London, pp. 671-689.

Denyer, D., Tranfield, D. and Van Aken, J.E. (2008), "Developing design propositions through research synthesis", *Organization Studies*, Vol. 29 No. 3, pp. 393-413.

Denzin, N.K. and Lincoln, Y.S. (1994), *Handbook of Qualitative Research*, SAGE, Thousand Oaks, CA.

Dobbin, J., Wilding, R. and Cotton, S. (2009), "True blood: challenges of the blood supply chain in England", *Focus,* November 2009.

Dodd, R., Roth, W.K., Ashford, P., Dax, E.M. and Vyas, G. (2009), "Transfusion medicine and safety", *Biologicals,* Vol. 37, pp. 62-70.

Dong, X., Jie, X. and Pin, W. (2015), "Logistics tracings in food safety emergencies based on the RFID technology", *Advance Journal of Food Science and Technology*, Vol. 7 No. 2, pp. 94-98.

Durach, C.F., Kembro, J. and Wieland, A. (2017), “A new paradigm for systematic literature reviews in supply chain management”, *Journal of Supply Chain Management*, Vol. 53 No. 4, pp. 67-85.

Eakin, B.K. (1991), “Allocative inefficiency in the production of hospital services”, *Southern Economic Journal*, Vol. 58 No. 1, pp. 240-248.

Easton, G. (2010), “Critical realism in case study research”, *Industrial Marketing Management*, Vol. 39 No. 1, pp. 118-128.

Edmondson, A.C. and McManus, S.E. (2007), “Methodological fit in management field research”, *Academy of Management Review*, Vol. 32 No. 4, pp. 1155-1179.

Eisenhardt, K.M. (1989a), “Building theories from case study research”, *The Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.

Eisenhardt, K.M. (1989b), “Making fast strategic decisions in high-velocity environments”, *Academy of Management Journal*, Vol. 32, pp. 543-576.

Eisenhardt, K.M. and Graebner, M.E. (2007), “Theory building from cases: opportunities and challenges”, *Academy of Management Journal*, Vol. 50, pp. 25-32.

Eksoz, C., Mansouri, S.A. and Bourlakis, M. (2014), “Collaborative forecasting in the food supply chain: a conceptual framework”, *International Journal of Production Economics*, Vol. 158, pp. 120-135.

Emerald Group Publishing (2016), “For reviewers: reviewer guidelines”, available at: http://www.emeraldgrouppublishing.com/reviewers/reviewer_guidelines.htm (accessed 1 September 2016).

Engelseth, P. (2013), "Multiplex uses of food-product standards”, *International Food and Agribusiness Management Review*, Vol. 16 No. 2, pp. 75-94.

Faraj, S. and Xiao, Y. (2006), “Coordination in fast-response organizations”, *Management Science,* Vol. 52 No. 8, pp. 1155-1169.

Fawcett, S.E., Osterhaus, P., Magnan, G.M., Brau, J.C. and McCarter, M.W. (2007), “Information sharing and supply chain performance: the role of connectivity and willingness”, *Supply Chain Management: An International Journal*, Vol. 12 No. 5, pp. 358-368.

Fawcett, S.E., Waller, M., Miller, J.W., Schwieterman, M.A., Hazen, B.T. and Overstreet, R.E. (2014), “A trail guide to publishing success. Tips on writing influential conceptual, qualitative and survey research”, *Journal of Business Logistics*, Vol. 35 No. 1, pp. 1-16.

Ferguson, M.E. and Ketzenberg, M.E. (2006), “Information sharing to improve retail product freshness of perishables”, *Production and Operations Management*, Vol. 15 No. 1, pp. 57-73.

Fisher, G. and Aguinis, H. (2017), “Using theory elaboration to make theoretical advancements”, *Organizational Research Methods*, Vol. 20 No. 3, pp. 438-464.

FK-UGM (2017), “Hemovigilance, data risiko transfusi pertama di Indonesia”, available at: http://fk.ugm.ac.id/hemovigilance-data-risiko-transfusi-pertama-di-indonesia/ (accessed 5 June 2018).

Flyvbjerg, B. (2006), “Five misunderstandings about case-study research”, *Qualitative Inquiry*, Vol. 12 No. 2, pp. 219-245.

Frankel, A.S., Leonard, M.W. and Denham, C.R. (2006), “Fair and just culture, team behaviour, and leadership engagement: the tools to achieve high reliability”, *Health Services Research*, Vol. 41 No. 4, pp. 1690-1709.

Forrester, J.W. (1958), “Industrial dynamics: a major breakthrough for decision makers”, *Harvard Business Review*, July-August.

Gammelgaard, B. (2017), “Editorial: the qualitative case study”, *The International Journal of Logistics Management*, Vol. 28 No. 4, pp. 910-913.

Gammelgaard, B. (2004), “Schools in logistics research? A methodology framework for analysis of the discipline”, *International Journal of Physical Distribution & Logistics Management*, Vol. 34 No. 6, pp. 479-491.

Gibbert, M., Ruigrok, W. and Wicki, B. (2008), “Research notes and commentaries: what passes as a rigorous case study?”, *Strategic Management Journal*, Vol. 29, pp.1465-1474.

Gimenez, C. (2006), “Logistics integration processes in the food industry”, *International Journal of Physical Distribution & Logistics Management*, Vol. 36 No. 3, pp. 231-249.

Glynn, S.A., Kleinman, S.H., Schreiber, G.B., Zuck, T., McCombs, S., Bethel, J., Garratty, G. and Williams, A.E. (2002), “Motivation to donate blood: demographic comparisons”, *Transfusion,* Vol. 42, pp. 216-225.

Goodman, C., Chan, S., Collins, P., Haught, R. and Chen, Y. (2003), “Ensuring blood safety and availability in the US: technological advances, costs, and challenges to payment-final report”, *Transfusion,* Vol. 43, pp. 3S-46S.

Goodnough, L.T., Shander, A. and Brecher, M.E. (2003), “Transfusion medicine: looking to the future”, *Lancet*, Vol. 361, pp. 161-169.

Goswami, S., Teo, H.H. and Chan, H.C. (2009), “Decision-maker mindfulness in IT adoption: the role of informed culture and individual personality”, in *Proceedings of the 30th international conference on information systems (ICIS)*, *2009, Phoenix.*

Goyal, S.K. and Giri, B.C. (2001), “Recent trends in modeling of deteriorating Inventory”, *European Journal of Operational Research,* Vol. 134 No. 1, p.1-16.

Grant, D.B. (2010), “Integration of supply and marketing for a blood service”, *Management Research Review*”, Vol. 33 No. 2, pp. 123-133.

Halldórsson, A. and Aastrup, J. (2003), “Quality criteria for qualitative inquiries in logistics”, *European Journal of Operational Research*, Vol. 144 No. 2, pp. 321-332.

Harland, C.M. (1996), “Supply chain management: relationships, chains, and networks”, *British Journal of Management*, Vol. 7 Special Issue, pp. S63-S80.

Harman, G.H. (1965), “The inference to the best explanation”, *Philosophical Review*, Vol. 74 No. 1, pp. 88-95.

Hedberg, B. and Jonson, S. (1978), “Designing semi-confusing information systems,” *Accounting, Organizations and Society*, Vol. 3 No. 1, pp. 47-64.

Henry, A. and Wernz, C. (2015), “A multiscale decision theory analysis for revenue sharing in three-stage supply chains”, *Annals of Operations Research*, Vol. 226 No. 1, pp. 277-300.

Hsing, Y. and Bond, E.O. (1995), “In search of optimal productivity and hospital size: a case study”, *The Health Care Supervisor*, Vol. 14 No. 2, pp. 50-55.

Hesse-Biber, S. (2010), “Qualitative approaches to mixed methods practice”, *Qualitative Inquiry*, Vol. 16 No. 6, pp. 455-468.

Hill, C.A. and Scudder, G.D. (2002), “The use of electronic data interchange for supply chain coordination in the food industry”, *Journal of Operations Management*, Vol. 20 No. 4, pp. 375-387.

Hohenstein, N., Feisel, E., Hartmann, E. and Giunipero, L. (2015), “Research on the phenomenon of supply chain resilience: a systematic review and paths for further investigation”, *International Journal of Physical Distribution & Logistics Management*, Vol. 45 No. 1/2, pp. 90-117.

Hopkins, A. (2007), “The problem of defining high reliability organisations”, working paper 51, The Australian National University, Canberra, January.

Hospital Estates and Facilities Statistics (2016/2017), available at http://hefs.hscic.gov.uk/DataFiles.asp (accessed 22 January 2019).

Huber, G.P. and Power, D.J. (1985), “Retrospective reports of strategic-level managers: guidelines for increasing their accuracy”, *Strategic Management Journal*, Vol. 6, pp. 171-180.

Ivankova, N.V., Creswell, J.W. and Stick, S.L. (2006), “Using mixed-methods sequential explanatory design: from theory to practice”, *Field Methods*, Vol. 18 No. 1, pp. 3-20.

Jick, T.D. (1979), “Mixing qualitative and quantitative methods: triangulation in action”, *Administrative Science Quarterly*, Vol. 24, pp. 602-611.

Johnson, R.B. and Onwuegbuzie, A.J. (2004), “Mixed methods research: a research paradigm whose time has come”, *Educational Researcher*, Vol. 33 No. 7, pp. 14-26.

Jraisat, L., Gotsi, M. and Bourlakis, M. (2013), "Drivers of information sharing and export performance in the Jordanian agri-food export supply chain: a qualitative study", *International Marketing Review*, Vol. 30 No. 4, pp. 323-356.

Julien, H. (2008), “Content analysis”, in Given, L.M. (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods*, SAGE Publications, Inc., Thousand Oaks, pp. 121-122.

Jüttner, U., Peck, H. and Christopher, M. (2003), “Supply chain risk management: outlining an agenda for future research”, *International Journal of Logistics: Research and Applications*, Vol. 6 No. 4, pp. 197-210.

Kähkönen, A.K. and Tenkanen, M. (2010), “The impact of power on information sharing in the Finnish food industry”, *British Food Journal*, Vol. 112 No. 8-9, pp. 821-835.

Kaipia, R., Dukovska-Popovska, I. and Loikkanen, L. (2013), “Creating sustainable fresh food supply chains through waste reduction”, *International Journal of Physical Distribution & Logistics Management*, Vol. 43 No. 3, pp. 262-276.

Karaesmen, I.Z., Scheller-Wolf, A. and Deniz, B. (2011), “Managing perishable and aging inventories: review and future research directions”, in Kempf, K.G., Keskinocak, P. and Uzsoy, R. (Eds.), *Planning Production and Inventories in the Extended Enterprise*, Springer, New York, pp. 393-436.

Karatzas, A., Johnson, M. and Bastl, M. (2017), “Manufacturer-supplier relationships and service performance in service triads”, *International Journal of Operations & Production Management,* Vol. 37 No. 7, pp. 950-969.

Kassahun, A., Hartog, R.J.M, Sadowski, T., Scholten, H., Bartram, T., Wolfert, S. and Beulens, A.J.M. (2014), “Enabling chain-wide transparency in meat supply chains based on the EPCIS global standard and cloud-based services”, *Computers and Electronics in Agriculture*, Vol. 109, pp. 179-190.

Katsaliaki, K. and Brailsford, S.C. (2007), “Using simulation to improve the blood supply chain”, *Journal of the Operational Research Society*, Vol. 58 No. 2, pp. 219-227.

Kembro, J. and Näslund, D. (2014), “Information sharing in supply chains, myth or reality? A critical analysis of empirical literature”, *International Journal of Physical Distribution and Logistics Management*, Vol. 44 No. 3, pp. 179-200.

Kembro, J., Selviaridis, K. and Näslund, D. (2014), “Theoretical perspectives on information sharing in supply chains: a systematic literature review and conceptual framework”, *Supply Chain Management: An International Journal*, Vol. 19 No. 5/6, pp. 609-625.

Ketokivi, M. (2006), “Elaborating the contingency theory of organizations: the case of manufacturing flexibility strategies”, *Production and Operations Management*, Vol. 15 No. 2, pp. 215-228.

Ketokivi, M. and Choi, T. (2014), “Renaissance of case research as a scientific method”, *Journal of Operations Management,* Vol. 32 No. 5, pp. 232-240.

Ketzenberg, M. and Ferguson, M.E. (2008), “Managing slow-moving perishables in the grocery industry”, *Production and Operations Management,* Vol. 17 No. 5, pp. 513-521.

Ketzenberg, M., Bloemhof, J. and Gaukler, G. (2015), “Managing perishables with time and temperature history”, *Production and Operations Management*, Vol. 24 No. 1, pp. 54-70.

Kim, K.K., Umanath, N.S. and Kim, B.H. (2005), “An assessment of electronic information transfer in B2B supply-channel relationships”, *Journal of Management Information Systems*, Vol. 22 No. 3, pp.293-320.

King, A. (2008), “In Vivo coding”, in Given, L.M. (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods*, SAGE Publications, Inc., Thousand Oaks, pp. 473-474.

King, N. (2012), “Doing template analysis”, in Symon, G. and Cassell, C. (Eds.), Qualitative Organizational Research: Core Methods and Current Challenges, SAGE Publications Ltd., London, pp. 426-450.

Klein, A.Z., Costa, E.G., Vieira, L.M. and Teixeira, R. (2014), “The use of mobile technology in management and risk control in the supply chain: the case of a Brazilian beef chain”, *Journal of Global Information Management*, Vol. 22 No. 1, pp. 14-33.

Kochan, C.G. Nowicki, D.R. Sauser, B. and Randall, W.S. (2018), “Impact of cloud-based information sharing on hospital supply chain performance: a system dynamics framework”, *International Journal of Production Economics*, Vol. 195, pp. 168-185.

Kopach, R., Balcioglu, B. and Carter, M. (2008), “Tutorial on constructing a red blood cell inventory management system with two demand rates”, *European Journal of Operational Research*, Vol. 185 No. 3, pp. 1051-1059.

Kottila, M.R. (2009), “Knowledge sharing in organic food supply chains”, *Journal on Chain and Network Science*, Vol. 9 No. 2, pp. 133-144.

Krishnakumar, J., Chan-Halbrendt, C., Radovich, T., Sullivan, P. and Love, K. (2009), “Supply-demand integrated management model for effective farmer-buyer coordination: case of the Hawaii avocado industry”, *Journal on Chain and Network Science*, Vol. 9 No. 1, pp. 17-23.

Kutsch, E., Denyer, D., Hall, M. and Lee-Kelley, E. (2013), “Does risk matter? disengagement from risk management practices in information systems projects”, *European Journal of Information Systems*, Vol. 22 No. 6, pp. 637-649.

Langer, E.J. (2005), *On Becoming an Artist: Reinventing Yourself through Mindful Creativity*, Ballantine, New York.

Langer, E.J. (2000), “Mindful learning”, *Current Directions in Psychological Science*, Vol. 9 No. 6, pp. 220-223.

La Porte, T. and Consolini, P. (1998), “Theoretical and operational challenges of ‘high reliability organisations’: air traffic control and aircraft carriers”, *International Journal of Public Administration*, Vol. 21 No. 6-8, pp. 847-852.

La Porte, T.R. and Rochlin, G. (1994), “A rejoinder to Perrow”, *Journal of Contingencies and Crisis Management*, Vol. 2 No. 4, pp. 221-227.

La Porte, T.R. and Thomas, C.W. (1995), “Regulatory compliance and the ethos of quality enhancement: surprises in nuclear power plant operations”, *Journal of Public Administration Research and Theory*, January 1995.

Leblanc, D.I., Villenueve, S., Beni, L.H., Otten, A., Fazil, A., McKellar, R. and Delaquis, P. (2015), “A national produce supply chain database for food safety risk analysis”, *Journal of Food Engineering*, Vol. 147, pp. 24-38.

Lee, H.L., Padmanabhan, V. and Whang, S. (1997), “The bullwhip effect in supply chains”, *Sloan Management Review*, Spring, pp. 93-102.

Lee, H.L., So, K.C. and Tang, C.S. (2000), “The value of information sharing in a two-level supply chain”, *Management Science*, Vol. 46 No. 5, pp. 626-643.

Lekka, C. (2011), “High reliability organisations: a review of the literature”, Research Report RR899, prepared for the Health and Safety Executive UK, available at http://www.hse.gov.uk/research/rrpdf/rr899.pdf (accessed 5 June 2018).

Liljestrand, K. (2017), “Logistics solutions for reducing food waste”, *International Journal of Physical Distribution & Logistics Management,* Vol. 47 No. 4, pp. 318-339.

Lin, F., Huang, S. and Lin, S. (2002), “Effects of information sharing on supply chain performance in electronic commerce”, *IEEE Transactions on Engineering Management*, Vol. 49 No. 3, pp. 258-268.

Lipton, J.P. (1977), “On the psychology of eyewitness testimony”, *Journal of Applied Psychology*, Vol. 62, pp. 90-95.

Lusiantoro, L. (2016), “Towards high reliability supply chains: a closer look at inter-organisational information sharing in a perishable product environment”, paper presented at the European Logistics Association (ELA) Doctoral Workshop, 22nd-25th June, Vienna, Austria.

Lusiantoro, L., Yates, N., Cotton, S. (2017), “Information sharing: Keep mindful and save lives!”, paper presented at the British Blood Transfusion Society (BBTS) Annual Conference, 13th-15th September, Glasgow, UK.

Lusiantoro, L., Yates, N. and Varga, L. (2018), “Comparing information sharing behaviour in high and low reliability blood supply chains: does collective mindfulness matter?”, paper presented at the 8th International Conference on Operations and Supply Chain Management (OSCM), 9th-12th September, Cranfield, UK.

Lusiantoro, L., Yates, N., Mena, C. and Varga, L. (2018), “A refined framework of information sharing in perishable product supply chains”, *International Journal of Physical Distribution and Logistics Management*, Vol. 48 No. 3, pp. 254-283.

Madsen, P., Desai, V., Roberts, K. and Wong, D. (2006), “Mitigating hazards through continuing design: the birth and evolution of a paediatric intensive care unit”, *Organization Science*, Vol. 17 No. 2, pp. 239-248.

Martin, J.A. and Eisenhardt, K.M. (2010), “Rewiring: cross-business-unit collaborations in multibusiness organizations”, *Academy of Management Journal*, Vol. 53 No. 2, pp. 265-301.

Mena, C., Adenso-Diaz, B. and Yurt, O. (2011), “The causes of food waste in the supplier-retailer interface: evidences from the UK and Spain”, *Resources, Conservation and Recycling,* Vol. 55, pp. 648-658.

Mentzer, J.T. and Kahn, K.B. (1995), “A framework of logistics research”, *Journal of Business Logistics*, Vol. 16 No. 1, pp. 231-250.

Meredith, J. (1998), “Building operations management theory through case and field research”, *Journal of Operations Management*, Vol. 16 No. 4, pp. 441-454.

Merton, R.K. (1957), “Social Theory and Social Structure”, Free Press, Glencoe, Illinois

Ministry of Health Republic of Indonesia (2018), “RS online”, available at: http://sirs.yankes.kemkes.go.id/rsonline/report/ (accessed 2 October 2018).

Ministry of Health Republic of Indonesia (2017), “Pelayanan darah di Indonesia”, *InfoDATIN*, available at: http://www.depkes.go.id/folder/view/01/structure-publikasi-pusdatin-info-datin.html (accessed 5 June 2018).

Mohr, J. and Nevin, J.R. (1990), “Communication strategies in marketing channels: a theoretical perspective”, *Journal of Marketing*, October.

Mohtadi, H. and Kinsey, J.D. (2005), “Information exchange and strategic behavior in supply chains: application to the food sector”, *American Journal of Agricultural Economics*, Vol. 87 No. 3, pp. 582-599.

Morgan, D.L. (2008), “Snowball sampling”, in Given, L.M. (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods*, SAGE Publications, Inc., Thousand Oaks, p. 816.

Morgeson, F.P. and Hofmann, D.A. (1999), “The structure of collective constructs: implications for multilevel research and theory development”, *Academy of Management Review*, Vol. 24, pp. 249-265.

Muangchoo, S. and Kritchanchai, D. (2015), “National drug information sharing in the Thailand health care supply chain”, *Therapeutic Innovation & Regulatory Science*, Vol. 49 No. 6, pp. 920-928.

Mylan, J., Geels, F.W., Gee, S., McMeekin, A. and Foster, C. (2015), “Eco-innovation and retailers in milk, beef and bread chains: enriching environmental supply chain management with insights from innovation studies”, *Journal of Cleaner Production,* Vol. 107, pp. 20-30.

Nahmias, S. (1982), “Perishable inventory theory: a review”, *Operations Research*, Vol. 30 No. 4, pp. 680-707.

Nakandala, D., Samaranayake, P., Lau, H. and Ramanathan, K. (2017), “Modelling information flow and sharing matrix for fresh food supply chains”, *Business Process Management Journal,* Vol. 23 No. 1, pp. 108-129.

NHSBT (2018a), “Blood components”, available at: https://www.blood.co.uk/why-give-blood/how-blood-is-used/blood-components/ (accessed 2 October 2018)

NHSBT (2018b), “The journey of a blood donation”, available at: https://www.blood.co.uk/the-donation-process/after-your-donation/the-journey-of-a-blood-donation/ (accessed 2 October 2018)

NHSBT (2018c), “NHS Blood and Transplant annual report and accounts 2017/2018”, available at: https://www.gov.uk/government/publications/nhs-blood-and-transplant-annual-report-and-accounts-2017-to-2018 (accessed 23 November 2018)

NHS Centre for Reviews and Dissemination (2001) as cited in Tranfield, D., Denyer D. and Smart, P. (2003), “Towards a methodology for developing evidence-informed management knowledge by means of systematic review”, *British Journal of Management*, Vol. 14, pp. 207-222.

Pagell, M. and Krause, D.R. (1999), “A multiple-method study of environmental uncertainty and manufacturing flexibility”, *Journal of Operations Management*, Vol. 17, pp. 307-325.

Papert, M., Rimpler, P. and Pflaum, A. (2016), “Enhancing supply chain visibility in pharmaceutical supply chain: solutions based on automatic identification technology”, *International Journal of Physical Distribution & Logistics Management*, Vol. 46 No. 9, pp. 859-884.

Paterson, I., Maguire, H. and Al-Hakim, L. (2008), “Analysing trust as a means of improving the effectiveness of the virtual supply chain”, *International Journal of Networking and Virtual Organisations*, Vol. 5 No. 3-4, pp. 325-348.

Pawson, R. and Tilley, N. (1997), *Realistic Evaluation*, SAGE, London.

Peng, G., Trienekens, J., Omta, S.W.F. and Wang, W. (2014), "Configuration of inter-organizational information exchange and the differences between buyers and sellers", *British Food Journal*, Vol. 116 No. 2, pp. 292-316.

Peng, G., Trienekens, J., Omta, S.W.F. and Wang, W. (2012), "The relationship between information exchange benefits and performance: the mediating effect of supply chain compliance in the chinese poultry chain", *International Food & Agribusiness Management Review*, Vol. 15 No. 4, pp. 65-91.

Perrow, C. (1994), "The limits of safety: the enhancement of a theory of accidents", *Journal of Contingencies and Crisis Management,* Vol. 2, pp. 212-220.

Perrow, C. (1984), *Normal Accidents: Living with High-risk Technologies*, Basic Books, New York.

Perry, C. (1998), "Processes of a case study methodology for postgraduate research in marketing", *European Journal of Marketing*, Vol. 32 No. 9/10, pp. 785-802.

Pettit, T.J., Fiksel, J. and Croxton, K.L. (2010), "Ensuring supply chain resilience: development of a conceptual framework", *Journal of Business Logistics*, Vol. 31 No. 1, pp. 1-21.

Pilbeam, C., Alvarez, G. and Wilson, H. (2012), "The governance of supply networks: a systematic literature review", *Supply Chain Management: An International Journal*, Vol. 17 No. 4, pp. 358-376.

Podsakoff, N.P., Shen, W. and Podsakoff, P.M. (2006), "The role of formative measurement models in strategic management research: review, critique, and implications for future research", in Ketchen, Jr., D.J. and Bergh, D.D. (Eds.), *Research Methodology in Strategy and Management Volume 3*, Elsevier JAI, Oxford, pp. 197-252.

Polyzos, N.M. (2002), "Striving towards efficiency in the Greek hospitals by reviewing case mix classifications", *Health Policy*, Vol. 61 No. 3, pp. 305-328.

Ponomarov, S.Y. and Holcomb, M.C. (2009), "Understanding the concept of supply chain resilience", *The International Journal of Logistics Management*, Vol. 20 No. 1, pp. 124-143.

Premkumar, G., Ramamurthy, K. and Saunders, C.S. (2005), "Information processing view of organizations: an exploratory examination of fit in the context of interorganizational relationships", *Journal of Management Information Systems*, Vol. 22 No. 1, pp. 257-294.

Raafat, F. (1991), “Survey of literature on continuously deteriorating inventories”, *Journal of the Operational Research Society*, Vol. 42 No. 1, pp. 27-37.

Rautonen, J. (2007), “Redesigning supply chain management together with the hospitals”, *Transfusion*, Vol. 47, pp. 197-200.

Reed McMillian, L. and McEldowney, R. (2014), “Is there really safety in numbers?”, *Nursing Management*, September, pp. 26-29.

Reynolds, E., Wickenden, C. and Oliver, A. (2001), “The impact of improved safety on maintaining a sufficient blood supply”, *Transfus Clin Biol,* Vol. 8, pp. 235-239.

Rijpma, J.A. (1997) as cited in Weick, K.E., Sutcliffe, K.M. and Obstfeld, D. (1999), “Organizing for high reliability: processes of collective mindfulness”, in Boin, A. (Ed.), *Crisis Management* (Vol. 3)*,* SAGE Publications Ltd., London, pp. 81-123.

Ringsberg, H.A. (2015), “Implementation of global traceability standards: incentives and opportunities”, *British Food Journal,* Vol. 117 No. 7, pp. 1826-1842.

Roberts, K. (1993), “Cultural characteristics of reliability enhancing organisations”, *Journal of Managerial Issues*, Vol. 5 No. 2, pp. 165-181.

Roberts, K. and Rousseau, D. M. (1989), “Research in nearly failure-free, high reliability organisations: Having the bubble”, *IEEE Transactions on Engineering Management*, Vol. 36, No. 2 Vol. 132-139.

Roberts, K., Desai, V. and Madsen, P. (2005), “Reliability enhancement and demise at Back Bay Medical Centre Children’s hospital”, In P. Carayon (Ed.), *Handbook of Human Factors and Ergonomics in Healthcare and Patient Safety*. Erlbaum, London, pp. 249-258.

Roberts, K.H. (1990), “Some characteristics of one type of high reliability organization”, *Organization Science*, Vol. 1 No. 2, pp. 160-76.

Robinson, S. (2004), *Simulation: the practice of model development and use*, John Wiley & Sons Ltd., West Sussex, England.

Rochlin, G.I. (1993), “Defining “high reliability” organizations in practice: a taxonomic prologue” in Roberts, K.H. (Ed.), *New challenges to understanding organizations*. New York: Macmillan, pp. 11-32.

Rothbauer, P.M. (2008), “Triangulation”, in Given, L.M. (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods*, SAGE Publications, Inc., Thousand Oaks, pp. 893-894.

Rutherford, C., Cheng, S.Y. and Bailie, K. (2016), “Evidence of bullwhip in the blood supply chain”, paper presented at the 23rd EurOMA Conference, 17th-22nd June, Trondheim, Norway.

Salin, V. (1998), “Information technology in agri-food supply chains”, *International Food and Agribusiness Management Review*, Vol. 1 No. 3, pp. 329-334.

Sandelowski (2000), “Focus on research methods whatever happened to qualitative description?”, *Research in Nursing & Health*, Vol. 23, pp. 334-340.

Sandelowski (1998), “Writing a good read: strategies for re-presenting qualitative data”, *Research in Nursing & Health*, Vol. 21, pp. 375-382.

Sandelowski (1995), “Sample size in qualitative research”, *Research in Nursing & Health*, Vol. 18, pp. 179-183.

Sayer, A. (2000), *Realism and Social Science*, SAGE, London.

Sayer, A. (1992), *Method in Social Science: A Realist Approach* (2nd Ed.), Routledge, London.

Scholten, K. and Schilder, S. (2015), “The role of collaboration in supply chain resilience”, *Supply Chain Management: An International Journal*, Vol. 20 No. 4, pp. 471-484.

Schreiber, G.B., Sanchez, A.M., Glynn, S.A. and Wright, D.J. (2003), “Increasing blood availability by changing donation patterns”, *Transfusion,* Vol. 43, pp. 591-597.

Schreiber, J.B. (2008), “Pilot study”, in Given, L.M. (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods*, SAGE Publications, Inc., Thousand Oaks, pp. 625-626.

Schroeder, R.G., Linderman, K., Liedtke, C. and Choo, A.S. (2008), “Six Sigma: definition and underlying theory”, *Journal of Operations Management*, Vol. 26 No. 4, pp. 536-554.

Schwarz, L.B. and Zhao, H. (2011), “The unexpected impact of information sharing on US pharmaceutical supply chains”, *Interfaces*, Vol. 41 No. 4, pp. 354-364.

Sengeh, P., Samai, O., Sidique, S.K., Kebbie, A., Fotana, P. and Stephens, S. (1997), “Improving blood availability in a district hospital, Bo, Sierra Leone”, *International Journal of Gynecology & Obstetrics,* Vol. 59 No. 2, pp. S127-S134.

Seuring, S.A. (2008), “Assessing the rigor of case study research in supply chain management”, *Supply Chain Management: An International Journal*, Vol. 13 No. 2, pp. 128-137.

Sheffi, Y. (2005), “Manage risk through resilience”, *Chief Executive*, December, pp. 28-29.

Shi, J., Zhang, J. and Qu, X. (2010), “Optimizing distribution strategy for perishable foods using RFID and sensor technologies”, *Journal of Business & Industrial Marketing*, Vol. 25 No. 8, pp. 596-606.

SHOT (2016), “Annual SHOT report 2016”, available at: https://www.shotuk.org/wp-content/uploads/SHOT-Report-2016_web_11th-July.pdf (accessed 9 May 2018).

Shukla, M. and Jharkharia, S. (2013), “Agri-fresh produce supply chain management: a state-of-the-art literature review”, *International Journal of Operations & Production Management*, Vol. 33 No. 2, pp. 114-158.

Siemsen, E. (2011), “The usefulness of behaviour laboratory experiments in supply chain management research”, *Journal of Supply Chain Management*, Vol. 47 No. 3, pp. 17-18.

Sitkin, S.B., Sutcliffe, K.M. and Schroeder, R.G. (1994), “Distinguishing control from learning in total quality management: a contingency perspective”, *Academy of Management Review*, Vol. 19 No. 3, pp. 537-564.

Smith, K. and Lawrence, G. (2014), “Flooding and food security: a case study of community resilience in Rockhampton”, *Rural Society*, Vol. 23 No. 3, pp. 216-228.

Solér, C., Bergstrom, K. and Shanahan, H. (2010), “Green supply chains and the missing link between environmental information and practice”, *Business Strategy and the Environment*, Vol. 19 No. 1, pp. 14-25.

Speier, C., Whipple, J.M., Closs, D.J. and Voss, M.D. (2011), “Global supply chain design considerations: mitigating product safety and security risks”, *Journal of Operations Management*, Vol. 29 No. 7-8, pp. 721-736.

Stanger, S.H.W. (2013), “Vendor managed inventory in the blood supply chain in Germany: evidence from multiple case studies”, *Strategic Outsourcing: An International Journal*, Vol. 6 No. 1, pp. 25-47.

Steckel, J.H., Gupta, S. and Banerji, A. (2004), “Supply chain decision making: will shorter cycle times and shared point-of-sale information necessarily help?”, *Management Science*, Vol. 50 No. 4, pp. 458-464.

Stenmark, D. (2002), “Information vs. knowledge: the role of intranets in knowledge management”, in *Proceedings of the 35th Hawaii international conference on system sciences, 2002*, IEEE, Big Island, HI.

Sterman, J.D. (1989), “Modeling managerial behavior: misperceptions of feedback in a dynamic decision making experiment”, *Management Science*, Vol. 35 No. 3, pp. 321-339.

Sutcliffe, K.M. (2011), “High reliability organizations (HROs)”, *Best Practice and Research: Clinical Anaesthesiology*, Vol. 25 No. 2, pp. 133-144.

Tamuz, M. and Harrison, M.I. (2006), “Improving safety in hospitals: contributions of high reliability theory and normal accident theory”, *Health Research and Educational Trust*, Vol. 41 No. 4, pp. 1654-1673.

Tashakkori, A. and C. Teddlie (1998), *Mixed Methodology: Combining Qualitative and Quantitative Approaches*, SAGE, California

Taylor, D.H. (2006), “Demand management in agri-food supply chains”, *The International Journal of Logistics Management,* Vol. 17 No. 2, pp. 163-186.

Taylor, D.H. and Fearne, A. (2009), “Demand management in fresh food value chains: a framework for analysis and improvement”, *Supply Chain Management: An International Journal*, Vol. 14 No. 5, pp. 379-392.

Tranfield, D., Denyer D. and Smart, P. (2003), “Towards a methodology for developing evidence-informed management knowledge by means of systematic review”, *British Journal of Management*, Vol. 14, pp. 207-222.

Trienekens, J. and Wognum, N. (2013), “Requirements of supply chain management in differentiating European pork chains”, *Meat Science*, Vol. 95 No. 3, pp. 719-726.

Trienekens, J.H., Wognum, P.M., Beulens, A.J.M. and van der Vorst, J.G.A.J. (2012), “Transparency in complex dynamic food supply chains”, *Advanced Engineering Informatics,* Vol. 26, pp. 55-65.

Turnbull, B. (1989), “Logistics in the food and drink industry”, *Management Services*, Vol. 33 No. 2, pp. 6-10.

Turner, N., Kutsch, E. and Leybourne, S.A. (2016), “Rethinking project reliability using the ambidexterity and mindfulness perspectives”, *International Journal of Managing Projects in Business*, Vol. 9 No. 4, pp. 845-864.

Turner, B. (1976), “The organizational and interorganizational development of disasters”, *Administrative Science Quarterly*, Vol. 21, pp. 378-397.

Twomey, P. and Cadman, R. (2002), “Agent-based modelling of customer behavior in the telecoms and media markets”, *Info*, Vol. 4 No. 1, pp. 56-63.

Van Donselaar, K., Woensel, T., Broekmeulen, R. and Fransoo, J. (2006), “Inventory control of perishables in supermarkets”, *International Journal of Production Economics,* Vol. 104 No. 2, p. 462-472.

Van Veen-Dirks, P.M.G. and Verdaasdonk, P.J.A. (2009), “The dynamic relation between management control and governance structure in a supply chain context”, *Supply Chain Management: An International Journal*, Vol. 14 No. 6, pp. 466-478.

Vogus, T.J. and Sutcliffe, K.M. (2012), “Organizational mindfulness and mindful organizing: a reconciliation and path forward”, *Academy of Management Learning & Education*, Vol. 11 No. 4, pp. 722-735.

Vogus, T.J. and Sutcliffe, K.M. (2007a), “The safety organizing scale”, *Medical Care*, Vol. 45 No. 1, pp. 46–54.

Vogus, T.J. and Sutcliffe, K.M. (2007b), “The impact of safety organizing, trusted leadership, and care pathways on reported medication errors in hospital nursing units”, *Medical Care*, Vol. 45 No. 10, pp. 997-1002.

Vogus, T.J., Sutcliffe, K.M. and Weick, K.E. (2010), “Doing no harm: enabling, enacting, and elaborating a culture of safety in health care”, *Academy of Management Perspectives*, Vol. 24 No. 4, pp. 60–77.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), “Case research in operations management”, *International Journal of Operations & Production Management,* Vol. 22 No. 2, pp. 195-219.

Wacker, J.G. (2004), “A theory of formal conceptual definitions: developing theory-building measurement instruments”, *Journal of Operations Management*, Vol. 22 No. 6, pp. 629-650.

Watcharasriroj, B. and Tang, J.C.S. (2004), “The effects of size and information technology on hospital efficiency”, *The Journal of High Technology Management Research*, Vol. 15 No. 1, pp. 1-16.

Watts, C., Hahn, C. and Sohn, B. (1993) as cited in D’Souza, D.E. and Williams, F.P. (2000), “Toward a taxonomy of manufacturing flexibility dimensions”, *Journal of Operations Management*, Vol. 18, pp. 577-593.

Weick, K.E. and Putnam, T. (2006), “Organizing for mindfulness: eastern wisdom and western knowledge”, *Journal of Management Inquiry*, Vol. 15 No. 3, pp. 275-287.

Weick, K.E. and Roberts, K.H. (1993), "Collective mind in organizations: heedful interrelating on flight decks", *Administrative Science Quarterly*, Vol. 38, pp. 357-381.

Weick, K.E. and Sutcliffe, K.M. (2015), *Managing the Unexpected: Sustained Performance in a Complex World*, John Wiley & Sons, Inc., Hoboken, New Jersey.

Weick, K.E. and Sutcliffe, K.M. (2007), *Managing the Unexpected: Resilient Performance in an Age of Uncertainty* (2nd Ed.), Jossey-Bass, San Francisco.

Weick, K.E. and Sutcliffe, K.M. (2001), *Managing the Unexpected: Assuring High Performance in an Age of Complexity*, Jossey-Bass, San Francisco.

Weick, K.E., Sutcliffe, K.M. and Obstfeld, D. (1999), "Organizing for high reliability: processes of collective mindfulness", in Boin, A. (Ed.), *Crisis Management* (Vol. 3), London: SAGE Publications Ltd., pp. 81-123.

WHO (2017a), "Blood safety and availability", available at: http://www.who.int/ mediacentre/factsheets/ fs279/en/ (accessed 20 October 2017).

WHO (2017b), available at: http://www.who.int/campaigns/world-blood-donor-day/2017/en/_(accessed 5 June 2018).

WHO (2017c), "Global status report on blood safety and availability 2016", Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO.

WHO (2013), "Blood: a precious resource", *Lancet,* Vol. 381, Editorial.

WHO (2010), "World blood donor day: new blood for the world", available at: http://www.who.int/mediacentre/news/releases/2010/blood_donor_day_2010 0613/en/ (accessed 25th January 2015)

Wilding, R. (2013), "Supply chain temple of resilience", *Logistics & Transport Focus*, Vol. 15, No. 11, pp. 54-59.

Williamson, L.M. and Devine, D.V. (2013), "Challenges in the management of the blood supply", *Lancet*, Vol. 381, pp. 1866-75.

Wolcott, H.F. (1994), *Transforming Qualitative Data: Description, Analysis, and Interpretation*, SAGE, Thousand Oaks, CA.

Woodside, A.G. and Wilson, E.J. (2003), "Case study research methods for theory building", *Journal of Business and Industrial Marketing*, Vol. 18 No. 6/7, pp. 493-508.

Woodside, A.G., Pattinson, H.M. and Miller, K.E. (2005), “Advancing hermeneutic research for interpreting interfirm new product development”, *Journal of Business and Industrial Marketing*, Vol. 20 No. 7, pp. 364-379.

Wong, C.W.Y., Lai, K.H. and Cheng, T.C.E. (2011), “Value of information integration to supply chain management: roles of internal and external contingencies”, *Journal of Management Information Systems*, Vol. 28 No. 3, pp. 161-199.

Wu, I., Chuang, C. and Hsu, C. (2014), “Information sharing and collaborative behaviors in enabling supply chain performance: a social exchange perspective”, *International Journal of Production Economics*, Vol. 148, pp. 122-132.

Xiao, Y. and Moss, J. (2001), “Practices of high reliability teams: Observations in trauma resuscitation”, *The 45th Human Factors and Ergonomics Society Annual Meeting Proceedings*, pp. 395-399.

Yan, B., Yan, C., Ke, C. and Tan, X. (2016), “Information sharing in supply chain of agricultural products based on the Internet of Things”, *Industrial Management & Data Systems*, Vol. 116 No. 7, pp. 1397-1416.

Yigitbasioglu, O.M. (2010), “Information sharing with key suppliers: a transaction cost theory perspective”, *International Journal of Physical Distribution & Logistics Management*, Vol. 40 No. 7, pp. 550-578.

Yin, R.K. (2014), *Case Study Research: Design and Methods* (5th Ed.), SAGE Publications, Inc., Thousand Oaks, California.

Yin, R.K. (2003), *Case Study Research: Design and Methods* (3rd Ed.), SAGE, Newbury Park, California.

Yu, Z., Yan, H. and Cheng, T.C.E. (2001), “Benefits of information sharing with supply chain partnerships”, *Industrial Management & Data Systems*, Vol. 101 No. 3, pp. 114-119.

Zelbst, P.J., Green Jr., K.W., Sower, V.E. and Baker, G. (2010), “RFID utilization and information sharing: the impact on supply chain performance”, *Journal of Business & Industrial Marketing*, Vol. 25 No. 8, pp. 582-589.

Zhang, J. and Bhatt, T. (2014), “A guidance document on the best practices in food traceability”, *Comprehensive Reviews in Food Science and Food Safety*, Vol. 13 No. 5, pp. 1074-1103.

Zhao, X., Xie, J. and Leung, J. (2002), “The impact of forecasting model selection on the value of information sharing in a supply chain”, *European Journal of Operations Research*, Vol. 142 No. 2, pp. 321-344.

Zhao, Y. and Zhao, X. (2015), “On human decision behaviour in multi-echelon inventory management”, *International Journal of Production Economics*, Vol. 161, pp. 116-128.

Zhong, B., Yang, F. and Chen, Y.L. (2015), “Information empowers vegetable supply chain: a study of information needs and sharing strategies among farmers and vendors”, *Computers and Electronics in Agriculture,* Vol. 117, pp. 81-90.

Zou, S. (2006), “Potential impact of pandemic influenza on blood safety and availability”, *Transfusion Medicine Reviews,* Vol. 20 No. 3, pp. 181-189.

# APPENDICES

The following appendices contain detailed information that is cross-referenced throughout this thesis. Due to space limitation, some acronyms are used in tables. See the list of abbreviations provided at the beginning of this thesis for details of the acronyms.

# Appendix A Data collection protocol

**Introduction**

- Name: Luluk Lusiantoro
- Status: PhD Researcher at Cranfield School of Management.
- Background and purpose of research, interview length
- Asking consent for the data collection process
- Turn on the recording
- Confirm the consent for recording

**Section 1: Questions on blood availability**

1. Could you please describe your role in the organisation?
2. To what extent are you involved in managing blood safety and availability?
3. During normal situations, how does the organisation ensure blood availability? Does the organisation share information with or use shared information from other blood centres and/or hospitals?
    - What information?
    - How?
    - With whom?
    - How often?
4. During high tempo situations (e.g. traffic accident, Olympic Games, Christmas, Easter, etc.), what challenges does the organisation face? How does the organisation ensure blood availability during that time? Does the organisation do it differently and if so how? Does the organisation share information with or use shared information from other blood centres and/or hospitals?
    - What information?
    - How?
    - With whom?
    - How often?
5. During emergency situations (e.g. flood, terrorist attacks, fridge failures, etc.), what challenges does the organisation face? How does the organisation ensure blood availability? Does the organisation do it differently and if so how? Does the organisation share information with or use shared information from other blood centres and/or hospitals?
    - What information?
    - How?
    - With whom?
    - How often?

6. If overstock is encountered, what does the organisation usually do? Does the organisation share information with or use shared information from blood centres and/or hospitals?
    - What information?
    - How?
    - With whom?
    - How often?
7. If stockout is encountered, what does the organisation usually do? Does the organisation share information with or use shared information from other blood centres and/or hospitals?
    - What information?
    - How?
    - With whom?
    - How often?

**Section 2: Questions on blood safety**

1. During normal situations, how does the organisation ensure blood safety? Does the organisation share information with or use shared information from other blood centres and/or hospitals?
    a. What information?
    b. How?
    c. With whom?
    d. How often?
2. During high tempo situations (e.g. traffic accident, Olympic Games, Christmas, Easter, etc.), what challenges does the organisation face? How does the organisation ensure blood safety during that time? Does the organisation do it differently and if so how? Does the organisation share information with or use shared information from other blood centres and/or hospitals?
    a. What information?
    b. How?
    c. With whom?
    d. How often?
3. During emergency situations (e.g. flood, terrorist attacks, fridge failures, ebola/zika virus outbreak, etc.), what challenges does the organisation face? How does the organisation ensure blood safety? Does the organisation do it differently and if so how? Does the organisation share information with or use shared information from other blood centres and/or hospitals?
    a. What information?
    b. How?
    c. With whom?
    d. How often?
4. If blood safety problems are encountered (e.g. bad quality, virus contamination, etc.), what does the organisation usually do? Does the organisation share information with or use shared information from blood centres and/or hospitals?
    a. What information?
    b. How?
    c. With whom?
    d. How often?

**Section 3: Questions on information sharing practices**

1. To what extent are information sharing practices between organisations applied in your organisation? Why?
2. Do you think sharing information with or using shared information from other blood centres and/or hospitals is important for your organisation? Why?
3. Can you think of any benefits of sharing information with or using shared information from other blood centres and/or hospitals for your organisation? Does it help the organisation to ensure blood safety and availability?
4. Can you think of any obstacles or challenges to sharing information with or using shared information from other blood centres and/or hospitals for your organisation?

**Section 4: Ask for any supporting documents related to IOIS in a hard and/or soft copy.**

**Section 5: Ask for a walkthrough, record and/or make notes of anything relevant to IOIS.**

# Appendix B IOIS behaviour in each embedded case

**Table B-1: Identified IOIS behaviour in EC 1-1**

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| Normal | • Service levels<br>• HEV testing<br>• New product (testing HEV) introduction<br>• Changes in the blood centre's system<br>• Blood centre services<br>• Blood management update<br>• Involvement in emergency response<br>• Result of customer satisfaction survey<br>• Issues on O neg<br>• New product introduction<br>• Evidence-based maximum blood ordering schedule<br>• Patient blood management<br>• Advice on appropriate use of blood<br>• Blood safety and availability issues<br>• Introduction of 100% screening for HEV<br>• Order confirmation<br>• Dispatch confirmation<br>• Blood readiness to collect<br>• Sending short-dated blood<br>• Positive patient identification<br>• Delivery arrangement<br>• General blood centre's operations<br>• Blood availability | • Regional transfusion committee meeting<br>• Transfusion practitioner regional meeting<br>• Regional transfusion committee meetings and email<br>• Hospital transfusion committee meetings<br>• Specific localised agreement<br>• NHSBT open days<br>• Email<br>• Telephone<br>• Paper-based delivery notes<br>• OBOS<br>• Controlled paperwork<br>• App<br>• Email and website<br>• Email and teleconference<br>• Survey<br>• National comparative audits<br>• Website, TLM, TP, and RBTC meetings<br>• Trauma group meeting<br>• Regional transfusion committee meeting<br>• Fax, email, OBOS, and telephone<br>• Fax<br>• Letter | • Blood centre→hospitals<br>• NHSBT→hospitals | • Monthly<br>• Quarterly<br>• Daily<br>• Annually<br>• Real time<br>• *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Platelet prescription guidelines<br>• Red cell prescription guidelines<br>• Delivery note<br>• Delivery planning<br>• Limited platelet availability<br>• Issues related to bank holiday<br>• Reasons for product recall<br>• Actions to take due to product recall | | | |
| | • Quality related incidents<br>• Blood safety and availability issues<br>• Changes in delivery arrangement<br>• Changes in hospital practices<br>• Appropriate use of blood<br>• Patient blood management practice<br>• General blood safety problems<br>• Blood centre policy of not taking blood back<br>• Planned delivery charges<br>• Reviews on blood management processes<br>• Customer satisfaction<br>• Changes in hospital practices (O neg stock levels)<br>• Good practices<br>• Blood safety issues - strategic<br>• Clinical issues<br>• Updated issues on blood management<br>• Blood wastage<br>• Good practices and problems<br>• Blood usage<br>• Stock issue data<br>• Stock levels<br>• Lessons learned from blood safety incidents | • SABRE<br>• National comparative audits<br>• Blood centre visits to hospital<br>• Transfusion laboratory managers' meetings<br>• Hospital transfusion committee meeting<br>• *Ad hoc* face to face meeting<br>• Annual review meeting<br>• Sp-ICE<br>• Transit form<br>• Survey<br>• SHOT study day<br>• Education days<br>• Face to face meetings<br>• Telephone<br>• Joint transfusion laboratory manager meetings<br>• Joint transfusion practitioners' meeting<br>• Joint hospital transfusion team meeting<br>• Service level agreement<br>• Regional laboratories' meeting<br>• Transfusion practitioner group<br>• SHOT website<br>• Email | • Hospitals→blood centre<br>• Hospitals→NHSBT | • Daily<br>• Annually<br>• Monthly<br>• Every two months<br>• 8 or 9 times a year<br>• Quarterly<br>• Regularly |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Blood safety incidents<br>• Appropriate transfusion skilled job<br>• Blood needs<br>• Feedback on the implementation of advice of appropriate use of blood<br>• Blood group testing result<br>• General laboratory operations<br>• Issues on patient's antibodies<br>• Temperature record<br>• Wastage of AB group<br>• Weak signal of blood quality issue<br>• Patient leaflet<br>• Blood safety issues<br>• Laboratory matters<br>• Special need for blood types<br>• Order information | • Telephone and email<br>• BSMS-VANESSA<br>• SHOT and SABRE<br>• Regional transfusion committee meeting<br>• OBOS | | |
| High tempo | • Outcome of transfusing recalled products<br>• Infectious disease revealed in donors<br>• Product recall<br>• Blood shortage<br>• Shortage of O neg<br>• Stockout<br>• Delay in delivery<br>• Alternative supply source<br>• Product substitution<br>• Two temperature excursion and the need to discard blood<br>• Recalled blood status<br>• Stock level status<br>• Actions on reaction to transfusion<br>• Delivery arrangement<br>• Discard authorisation<br>• General blood safety and quality | • Email and fax<br>• Fax and telephone<br>• Telephone and email<br>• Telephone<br>• Fax telephone and email<br>• Fax | • NHSBT→hospitals | • *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | issues<br>• Units with temperature excursion<br>• Reaction test results | | | |
| | • Reaction to transfusion<br>• Order information<br>• General blood safety and availability issues<br>• Blood safety incidents<br>• Wrong blood group<br>• Blood shortage<br>• Stockout<br>• Wrong blood pack<br>• The need for specific blood<br>• Blood supply chain issue<br>• *Ad hoc* order information<br>• Status of the recalled products<br>• Reaction to transfusion<br>• Product recall<br>• Severe reaction to transfusion<br>• Blood quality issue | • Telephone<br>• Fax<br>• SHOT website<br>• Product recall form<br>• OBOS<br>• Telephone and paper work<br>• SHOT and SABRE<br>• Telephone and email<br>• Telephone and fax<br>• Face to face meeting | • Hospitals→blood centre<br>• Hospitals→NHSBT | • *Ad hoc* |
| Emergency | • Dispatch confirmation<br>• Estimated time of delivery arrival<br>• Readiness of blood to collect<br>• Complete national shortage (stockout) | • Telephone<br>• Email, fax, and telephone | • NHSBT→hospitals | • *Ad hoc* |
| | • Fridge failure<br>• Blue light order information<br>• Major incidents alert<br>• Order information | • Fax<br>• Telephone and fax<br>• Telephone<br>• OBOS and telephone | • Hospitals→blood centre<br>• Hospitals→NHSBT | • *Ad hoc* |

**Table B-2: Identified IOIS behaviour in EC 1-2**

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| Normal | • Compiled hospital KPIs<br>• A new blood management guideline<br>• Blood usage<br>• Review of stock levels<br>• Wastage<br>• The latest blood management guideline<br>• Restricted stock holding<br>• Updated training information<br>• Updated blood management related information<br>• Blood matters<br>• Stock levels<br>• Blood safety service level agreement<br>• Cold chain indicators<br>• Confirmed order<br>• Urgent order confirmation<br>• Special need for blood types<br>• Blood product order detailed information<br>• Reminder to send hospital KPIs<br>• Specific blood management issue<br>• General blood management issue<br>• Potential blood safety issues<br>• Order recommendation<br>• Blood pack validation<br>• Recommended to be actioned information<br>• Change to apheresis platelets<br>• New patient information<br>• New barcode products<br>• Issuing short-dated products | • Paper-based delivery notes<br>• LIMS and EDN<br>• OBOS and electronic delivery notes (EDN)<br>• Email and regional transfusion meetings<br>• Telephone<br>• Email and fax<br>• Regional transfusion committee meeting<br>• BSMS<br>• Website<br>• Email and website<br>• Blood matters magazine<br>• Email<br>• Contract<br>• Meeting minutes | • Blood centre→hospitals<br>• NHSBT→hospitals | • Monthly<br>• Quarterly<br>• Daily<br>• *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Overstock implications<br>• Stock increase plan<br>• Limitation to order<br>• Routine deliveries<br>• Short-dated products | | | |
| | • Stock levels, usage, and wastage<br>• Demand information<br>• SHOT report<br>• Good practice and errors<br>• Blood availability incident<br>• KPIs<br>• Stock issue data<br>• Changes in stock levels<br>• Stock levels<br>• Transfusion performance<br>• Transfusion information<br>• Lessons learned<br>• Blood stock information<br>• Blood safety incidents<br>• Special need for blood types<br>• Missed blood product information<br>• Blood usage<br>• Shelf life variation<br>• Confirmed order<br>• Resolved incidents | • OBOS<br>• Regional transfusion committee meeting<br>• BBTS conference<br>• SHOT and SABRE<br>• BSMS<br>• Collaborative project with blood centre<br>• Online dashboard<br>• VMI information system<br>• Telephone and email<br>• Email<br>• Fax<br>• SHOT<br>• Transfusion practitioner group<br>• VMI and PULSE<br>• VMI<br>• Blood transfusion leaflet | • Hospitals→blood centre<br>• Hospitals→NHSBT | • Daily<br>• Annually<br>• Monthly<br>• Quarterly<br>• Real time |
| High tempo | • List of impacted units from recall<br>• Confirmed the mixed matched order<br>• Recalled blood test result<br>• Limited order<br>• Blood shortage<br>• Supply delay<br>• Blood quality issues<br>• Problems with donors | • Email and fax<br>• Fax and telephone<br>• Telephone and email<br>• Telephone<br>• Via customer services<br>• Telephone email OBOS<br>• Fax telephone and email | • Blood centre→hospitals | • *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Product recall<br>• Stock level review request<br>• Offer of expert advice<br>• Low blood stock<br>• Shortage of A neg platelets<br>• Shortage of O red cells | | | |
| | • Stock levels<br>• Reaction to transfusion<br>• Urgent blood quality issue<br>• Blood quality issue<br>• Returned AB units<br>• Severe reaction to transfusion<br>• Product recall<br>• Recalled products<br>• Status of the recalled products<br>• *Ad hoc* order information | • Telephone<br>• Electronic invoice<br>• Fax<br>• VMI information system<br>• SHOT website<br>• Fax telephone and email<br>• Product recall form<br>• OBOS-fax-telephone<br>• Fax and paper-based document | • Hospitals→blood centre<br>• Hospitals→NHSBT | • *Ad hoc* |
| Emergency | • Strategies of alleviating the unexpected situation<br>• Status of the unexpected event | • Email and fax<br>• Email-fax-OBOS | • Blood centre→hospitals | • *Ad hoc* |
| | • Serious adverse reaction or events<br>• Status of blood supply in hospital<br>• Order information<br>• Major incident alert<br>• Order information during major incident | • SABRE<br>• Telephone-OBOS-fax<br>• Telephone<br>• OBOS and telephone | • Hospitals→blood centre<br>• Hospitals→NHSBT | • *Ad hoc* |

**Table B-3: Identified IOIS behaviour in EC 1-3**

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| Normal | • Blood usage and wastage<br>• Stock management related information<br>• New product introductions<br>• Monthly report of stock level profile<br>• Delivery<br>• Blood stock management<br>• New blood management guidance<br>• Updates and changes in strategic blood management practices<br>• Wastage<br>• Stock levels<br>• Education and training<br>• SHOT symposium<br>• Patient information leaflet<br>• Order confirmation<br>• Delivery and detailed product information<br>• Confirmation of routine delivery<br>• Expiring stock<br>• Patient test results<br>• Reminder on expiring blood<br>• Upcoming training course<br>• Blood product order detailed information | • Email<br>• BSMS-VANESA<br>• Regional transfusion committee meeting<br>• Telephone<br>• Electronic delivery notes<br>• Transfusion laboratory managers' meetings<br>• VMI-ITS<br>• Sp-ICE<br>• Fax<br>• Electronic dispatch note (EDN)<br>• Face to face meeting<br>• Regional Hospital Liaison Update | • Blood centre→hospitals<br>• NHSBT→hospitals | • Monthly<br>• Quarterly<br>• Daily<br>• Regularly<br>• *Ad hoc* |
| | • Hospitals' size development<br>• Demand related information<br>• Changes in operations - organisational structure<br>• Stock management practices<br>• Policy implementation<br>• Opinions on blood management<br>• Patient blood management programme<br>• Issues on blood safety and availability<br>• Stock wastage<br>• Blood usage | • OBOS<br>• Regional transfusion committee meeting<br>• BSMS-VANESA<br>• Fax<br>• VMI and PULSE<br>• VMI - ITS<br>• Hospital transfusion committee meeting<br>• Survey<br>• Written contract | • Hospitals→blood centre<br>• Hospitals→NHSBT | • Daily<br>• Annually<br>• Monthly<br>• Every 30 minutes<br>• Quarterly<br>• Real time<br>• Twice a day<br>• Every two years<br>• At the beginning of ITS project<br>• *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Stock levels<br>• Lessons learned<br>• Blood safety incidents<br>• Reaction to transfusion<br>• Credit for faulty or unused products<br>• Complaint on the ideal stock levels<br>• Changes in blood routine delivery<br>• Additional delivery arrangement at the weekend (Saturday)<br>• Patient details requiring specific blood<br>• Order information for specialised products<br>• Blood stock information<br>• Order information<br>• Blood safety incident (major incident - trauma) | • SHOT symposium<br>• SHOT written report<br>• Regional transfusion lab managers' meeting<br>• National transfusion lab managers' meeting<br>• ITS project<br>• Face to face ITS project meeting<br>• Face to face meeting<br>• SHOT | | |
| High tempo | • O neg appropriate usage<br>• O neg waste prevention<br>• O neg stock reduction<br>• Appropriate order during high tempo situation<br>• Stock management status<br>• Stock out<br>• Actions on blood safety incidents<br>• Temperature excursion units<br>• Interrupted telephone service<br>• Actions on blood safety and quality issues<br>• Blood usage<br>• Donor sessions-blood shelf life<br>• Blood shortage<br>• Blood quality issues<br>• Product recall<br>• Stock levels<br>• Shortage of O red cells | • Email and website<br>• Letter<br>• Telephone fax and email<br>• Telephone and fax or email<br>• Email<br>• Telephone<br>• Telephone and email<br>• Fax and telephone<br>• Email and fax | • Blood centre→hospitals<br>• NHSBT→hospitals | • *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Incident investigation process and result<br>• Blood safety incidences<br>• Adverse blood safety incidents<br>• Reaction to transfusion<br>• Stock levels<br>• Severe reaction to transfusion<br>• Credit note<br>• Analyser failure<br>• Blue light order<br>• Temperature excursion units<br>• Blood safety and quality issues<br>• *Ad hoc* order information<br>• Product recall<br>• Blood quality issue | • Telephone<br>• VMI information system - ITS<br>• SHOT website<br>• Telephone and fax<br>• SHOT and SABRE<br>• Telephone and fax or email<br>• Telephone fax and email<br>• OBOS<br>• Telephone and email | • Hospitals→blood centre<br>• Hospitals→NHSBT | • Monthly<br>• *Ad hoc* |
| Emergency | • Substitution of ordered products<br>• VMI-ITS system down<br>• Ordered blood availability<br>• Emergency delivery protocol<br>• Emergency order lead time<br>• Suggestive actions<br>• Stock level status<br>• Supply contingency plan<br>• Unexpected event | • Telephone<br>• Email<br>• OBOS | • Blood centre→hospitals | • Real time<br>• *Ad hoc* |
| | • Haemonetics (blood tracking system) or Internet is down<br>• Changing operations in emergency<br>• The need for blood<br>• Blue light order confirmation<br>• Delivery placement<br>• Major incident alert<br>• Order information | • OBOS and telephone<br>• Telephone<br>• Telephone, OBOS, and fax | • Hospitals→blood centre | • *Ad hoc* |

**Table B-4: Identified IOIS behaviour across the BSC in the MC-1 (strategic view of Central NHSBT)**

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| Normal | • Staff training<br>• Public perception of blood transfusion<br>• Information standard to share<br>• ITS update<br>• Emergency communication-alternative to fax<br>• Platelet wastage<br>• Blood supply and wastage<br>• NHSBT performance<br>• SaBTO report<br>• SHOT report<br>• MHRA report<br>• PBM-appropriate use of blood<br>• Feedback on hospital complaints<br>• Updates on training information<br>• Changes in operations or practices<br>• Monthly updates for information<br>• Monthly update for training<br>• Trend in O neg usage<br>• Hospital lockdown<br>• Stock management and plans<br>• Blood shortage plan<br>• Business continuity certification document<br>• Changes in computer systems<br>• Changes in the blood components<br>• New blood safety policy to replace testing<br>• Lessons learned from blood safety incidents<br>• Blood safety incidents<br>• Appropriate use of blood<br>• Patient identification<br>• Blood safety issues | • NBTC annual report<br>• Customer satisfaction surveys<br>• Blood centre visit<br>• A letter<br>• Talks<br>• A single sheet of A4 certification document<br>• Paper-based dispatch note<br>• EDN<br>• Fax<br>• OBOS and training<br>• Face to face informal meetings<br>• Regional transfusion practitioner meeting<br>• PowerPoint presentation<br>• Fact sheets<br>• SHOT conference<br>• SHOT report<br>• Conferences<br>• Education days<br>• Presentations in hospitals<br>• Factsheets<br>• Posters<br>• Patient information leaflet<br>• Transfusion practitioner meetings<br>• Laboratory manager meetings<br>• Regional transfusion meeting<br>• National laboratory managers' committee meetings<br>• National transfusion committee meetings<br>• National campaign | • Blood centre→hospitals<br>• NHSBT→hospitals | • Monthly<br>• Quarterly<br>• Real time<br>• Annually<br>• Regularly<br>• *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Best practice of transfusion<br>• Transfusion risks<br>• General update information on NHSBT operations<br>• General long-term blood-related information<br>• Blood stock related data<br>• Reducing blood usage<br>• Trend in blood usage in hospitals<br>• Unusual trend of blood usage<br>• New product introduction or development<br>• Guidance on blood safety issues<br>• Changes in the hospitals' operations<br>• Blood usage<br>• Wastage<br>• Emergency planning<br>• Blood volume information<br>• New test update (HEV)<br>• Major haemorrhage activations<br>• Monthly update for action<br>• Transfusion contingency plans<br>• Stock position<br>• Platelet management<br>• Reduction in *ad hoc* deliveries<br>• Shortage plans data<br>• Preparation on the big event<br>• Preparation to face flu virus<br>• Delivery arrangement during high tempo<br>• Service during bank holiday<br>• Lesser service offerings during bank holiday<br>• Increase in stock levels<br>• Changes to routine deliveries<br>• Delivery plan during the high tempo<br>• Stock levels status | • National O neg group<br>• Hospital transfusion committee meeting<br>• Hospital visit<br>• Face to face meeting<br>• Educational tools<br>• Intelligence or pre-demand review<br>• Telecon<br>• Telephone<br>• Regional transfusion committee meeting<br>• BSMS<br>• Website<br>• Email and website<br>• Email<br>• Email<br>• Email, fax, website, phone<br>• Customer service publication, hospital and science website, donor magazine, regular hospital customer service meetings<br>• Planning questionnaire, telephone, face to face meetings, web based Q and A<br>• External validation exercise<br>• Face to face meeting<br>• Fax, email, telephone<br>• Hospital visit | | |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Stockout warning<br>• Blood shortage warning<br>• Root cause analysis<br>• Debrief on the implementation of emergency plan for the hospital<br>• Status of the delivery times after the emergency event<br>• Status of the emergency event | | | |
| | • Feedback on RBTC<br>• Impact on the planned changes of safety policy<br>• Near misses<br>• Blood safety problems<br>• Blood wastage<br>• Changes in hospitals' operations<br>• New product introduction or development<br>• Blood usage<br>• Stock levels<br>• Blood safety incidents<br>• Complaints<br>• Compliments<br>• Order information<br>• Delivery arrangement during high tempo<br>• Blood safety incident | • OBOS<br>• BSMS<br>• VMI<br>• Face to face meeting<br>• Another form of face to face meeting<br>• Hospital transfusion committee meetings<br>• Regional transfusion committee meetings<br>• National transfusion committee meetings<br>• Feedback form<br>• Telephone<br>• Written document<br>• Joint investigation work with NHSBT | • Hospitals→blood centre<br>• Hospitals→NHSBT | • Quarterly<br>• Regularly<br>• *Ad hoc* |
| High tempo | • Delivery status and arrangement<br>• Stock levels status<br>• Overstock<br>• Alternative supply for out of stock components<br>• Stockout of a particular component<br>• Broken down systems<br>• Increasing trend of stock levels<br>• Decreasing trend of O neg<br>• Upward trend of wastage | • Telephone<br>• Hospital visit<br>• Email<br>• Email and website<br>• Fax<br>• Website | • Blood centre→hospitals<br>• NHSBT→hospitals | • *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Shortage of AB neg below 3 days<br>• Blood shortage<br>• Product recall | | | |
| | • Reasons for wastage<br>• Wastage<br>• Delivery arrangement<br>• Confirming out of stock order<br>• Affected blood supply due to sport event | • Telephone<br>• NHSBT hospital visit<br>• Hospital visit | • Hospitals→blood centre<br>• Hospitals→NHSBT | • *Ad hoc* |
| Emergency | • Product shelf life<br>• Product issuing<br>• The impact of the event on services<br>• Alternative supply provision and delivery schedules<br>• IT operational continuity<br>• Contingency supply maintenance<br>• Order procedure and paperwork<br>• Order confirmation<br>• Availability of specifically ordered blood<br>• Supply source alteration<br>• Status of activities during emergency event<br>• Advice on emergency order and stock management<br>• Supply source alteration and possible delays in delivery<br>• Delivery status<br>• Stock levels status<br>• Unexpected event - emergency communication<br>• Status of the unexpected event | • Telephone<br>• Fax<br>• Email<br>• Email or fax and telephone<br>• Fax, email, telephone<br>• Hospital visit<br>• Social media<br>• Letter<br>• Telecon | • Blood centre→hospitals<br>• NHSBT→hospitals | • *Ad hoc* |
| | • Order information<br>• The need for platelets<br>• Detailed information on the outbreak | • Telephone<br>• Fax<br>• OBOS | • Hospitals→blood centre<br>• Hospitals→NHSBT | • *Ad hoc* |

**Table B-5: Identified IOIS behaviour in EC 2-1**

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| Normal | • Blood quality management conformance<br>• General blood stock management practices<br>• New blood management policy or regulation<br>• Blood safety and availability related concerns<br>• Blood processing cost<br>• Customer lead time<br>• Cross-matched product<br>• Lead time confirmation<br>• Potential reaction to transfusion from ordered blood<br>• Stock levels<br>• Big blood donation<br>• Recalled product status | • Delivery note<br>• Workshop<br>• Formal letter<br>• BDRS meetings<br>• Training<br>• Visit to hospitals<br>• Telephone<br>• Regional blood centre meeting<br>• Website, newspaper, social media<br>• Contract | • Blood centre→hospitals | • Real time<br>• Quarterly<br>• Every couple of months<br>• Every one or two months<br>• *Ad hoc* |
| | • Problems in blood management<br>• Blood safety and availability issues<br>• Blood donation plan<br>• Blood usage<br>• Blood quality management conformance<br>• Incompatibility issue of cross-matched products<br>• Blood-related issues<br>• Order information<br>• Wrong labels<br>• Clots in blood bag<br>• Temperature control document<br>• Patient blood sample<br>• Proposing to hold blood donation event before Ramadhan | • Written report<br>• Face to face meetings<br>• Formal letter<br>• Telephone and order form<br>• Order form<br>• Telephone<br>• Blood centre visits to hospitals<br>• Annual meetings<br>• Written proposal | • Hospitals→blood centre | • Monthly<br>• Regularly<br>• Quarterly<br>• Weekly<br>• Every one or two months<br>• Daily<br>• *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| High tempo | • Response to complaint | • Telephone | • Blood centre→hospitals | • *Ad hoc* |
| | • Reaction to transfusion<br>• Replacement donors<br>• Wrong labels<br>• Order information<br>• The need for blood<br>• Clots in blood bag<br>• Discolouration in blood | • Written report<br>• Telephone | • Hospitals→blood centre | • *Ad hoc* |
| Emergency | • Emergency cross-match test result<br>• The need for emergency blood | • Telephone | • Blood centre→hospitals | • *Ad hoc* |
| | • Order information<br>• Concessionary request<br>• The need for emergency blood | • Telephone<br>• Formal letter<br>• Telephone and order form | • Hospitals→blood centre | • *Ad hoc* |

**Table B-6: Identified IOIS behaviour in EC 2-2**

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| Normal | • Missing data of blood usage<br>• Blood-related costs<br>• Blood processing cost arrangement<br>• Training event<br>• Issues on blood safety and availability<br>• Policy on replacement donors<br>• Blood pick up arrangement<br>• Blood safety and availability provision<br>• Blood needs and usage plan<br>• Blood delivery policy<br>• Collaboration proposal<br>• Blood usage<br>• Evidence of certification<br>• Blood screening results<br>• The need for blood cover<br>• Blood donation event<br>• Overstock<br>• Blood usage<br>• Stock levels<br>• Service level agreement | • Website<br>• Telephone<br>• SMS<br>• Social media<br>• News paper<br>• Radio<br>• TV<br>• Formal letter<br>• Audience<br>• Face to face meeting<br>• Paper-based document<br>• Email and telephone<br>• MoU | • Blood centre→hospitals | • Quarterly<br>• Daily<br>• Real time<br>• Annually<br>• *Ad hoc* |
| | • Blood needs<br>• Blood usage<br>• Order information<br>• Issues on blood safety and availability<br>• Shelf life of ordered blood | • Email<br>• Order form<br>• Written paper-based report<br>• Annual MoU<br>• Telephone<br>• Telephone and order form | • Hospitals→blood centre | • Annually<br>• Monthly<br>• *Ad hoc* |
| High tempo | • Overstock<br>• Updated stock situation in Ramadhan<br>• Order information<br>• Shortage | • Telephone | • Blood centre→hospitals | • *Ad hoc* |
| | • Blood shortage and request to broadcast | • Telephone<br>• Telephone and order form | • Hospitals→blood centre | • *Ad hoc* |

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| | • Blood safety and availability issue<br>• Order information<br>• Order confirmation<br>• Blood quality issue | • Order form | | |
| Emergency | • N/A | • N/A | • N/A | • N/A |
| | • Order information during major haemorrhage | • Telephone<br>• Telephone and order form | • Hospitals→blood centre | • *Ad hoc* |

## Table B-7: Identified IOIS behaviour in EC 2-3

| Contexts | Interventions (IOIS behaviour) | | | |
|---|---|---|---|---|
| Operational conditions | Content | Modality | Direction | Frequency |
| Normal | • Suggestion on ordering process<br>• Lessons learned<br>• Blood handling procedure<br>• Patient status<br>• Readiness of ordered blood<br>• Overstock<br>• Blood usage | • Telephone<br>• Face to face meeting | • Blood centre→hospitals | • *Ad hoc* |
| | • Donation plan<br>• Patient's blood sample<br>• The need to collect blood from blood centre<br>• Readiness of ordered blood<br>• The need for order form<br>• The need for blood<br>• Stock levels<br>• Order information | • Face to face meeting<br>• Order form<br>• Telephone<br>• Order form-patient's family<br>• SMS<br>• Formal letter | • Hospitals→blood centre | • *Ad hoc* |
| High tempo | • No electricity | • Telephone | • Blood centre→hospitals | • *Ad hoc* |
| | • Reaction to transfusion<br>• Blood availability | • Telephone | • Hospitals→blood centre | • *Ad hoc* |
| Emergency | • Cross-match results<br>• Order confirmation | • Telephone | • Blood centre→hospitals | • *Ad hoc* |
| | • Order information<br>• Order information during major haemorrhage | • Telephone and order form<br>• Face to face meeting<br>• Order form | • Hospitals→blood centre | • *Ad hoc* |

# Appendix C Co-actions of IOIS behaviour and CM principles in each embedded case

**Table C-1: Identified co-actions of IOIS behaviour and CM principles in the EC 1-1**

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Normal | • Being precautious of the weak signal of blood quality issue<br>• Regularly sharing lessons learned from blood safety incidents | • Precaution | • PF+ |
| | • Mandatory reporting quality-related incidents to SABRE<br>• Reporting about the fit between expertise and the appropriate job in transfusion<br>• Formal reporting of blood safety incidents<br>• Voluntary reporting blood safety incidents to SHOT<br>• Voluntary reporting reaction to transfusion to SHOT and SABRE | • Failure reporting | |
| | • Using redundant information sharing media<br>• There is always someone ready to answer phone calls from hospitals | • Redundancy | • RS+ |
| | • Confirming dispatch of ordered product<br>• Confirming delivery of ordered product<br>• Completing audit trail for ordering products<br>• Confirming whether ordered blood has been dispatched to the hospital<br>• Providing evidence-based benchmarking audits for maximum blood ordering schedule<br>• Providing evidence-based benchmarking audits for patient blood management practice<br>• Ignoring unspecified request for fresh blood<br>• Checking and rechecking temperature record | • Scepticism | |
| | • Having service level agreement to send products with reasonably long shelf life<br>• Reassuring the involvement in emergency response in the hospital<br>• Having formal agreement considering proximity of location with hospitals<br>• Regularly discussing blood centre services with hospitals<br>• Providing reasons for initiating product recall<br>• Negotiating the planned changes of delivery charges which may affect delivery flexibility<br>• Regularly reviewing blood management processes<br>• Regularly discussing clinical issues between joint transfusion practitioners<br>• Discussing about potentially sending products back to the blood centre<br>• Regularly discussing laboratory matters with other hospitals in the region<br>• Regularly discussing updated issues in blood management | • Checks and balances | |
| | • Sharing general blood centre's operations with hospitals<br>• Gathering information from hospitals on the market for the new product | • Transparency | • SO+ |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Sharing best practice in handling major event such as Olympics<br>• Formal but voluntary reporting of daily blood usage (transfusion)<br>• Formal but voluntary reporting of daily issues of blood<br>• Having transparent results of blood group test<br>• Sharing patient blood management practice between hospitals nationally<br>• Sharing general laboratory operations with blood centre<br>• Having transparent national information sharing system on patients' antibodies<br>• Formal but voluntary and regular reporting of daily blood wastage<br>• Formal but voluntary and regular reporting of daily stock levels<br>• Disseminating feedback on the implementation of advice of the appropriate use of blood | | |
| | • Regularly notifying changes in the blood centre's system<br>• Regularly sharing blood safety and availability issues<br>• Regularly disseminating advice on appropriate use of blood<br>• Regularly discussing blood centre services with hospitals<br>• Regularly making hospitals aware of any changes in the blood centre's system<br>• Regularly sharing blood safety and availability issues with blood centre<br>• Regularly sharing good practices on stock levels with blood centre<br>• Regularly sharing practices of appropriate use of blood with other hospitals within the region<br>• Regularly discussing updated issues in blood management<br>• Regularly discussing laboratory matters with other hospitals in the region<br>• Regularly sharing good practices and problems with other hospitals within the region<br>• Regularly sharing blood safety related issues<br>• Regularly sharing good practices between hospitals nationally<br>• Formal but voluntary and regular reporting of daily blood wastage<br>• Formal but voluntary and regular reporting of daily stock levels | • Regular interactions | |
| | • Constantly liaising with hospitals on blood availability<br>• Providing real time access to blood transfusion guidelines via app | • Real time interactions | |
| | • Being responsive in addressing inflexibility of delivery arrangement<br>• Informing blood centre on the blood needs<br>• Being responsive in addressing expiring units<br>• Being responsive in addressing changes in stock levels<br>• Being responsive in addressing increased wastage<br>• Discussing about potentially sending products back to the blood centre | • Ongoing operational adjustments | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Being responsive in addressing special need for blood types | | |
| | • Notifying hospitals upon receipt of the order<br>• Informing hospitals on the new product (testing HEV) introduction<br>• Notifying hospitals that the blood is ready to collect<br>• Notifying the hospital to confirm the delivery of short-dated blood<br>• Notifying hospitals on the new updates of blood management<br>• Informing hospitals on the result of customer satisfaction survey<br>• Notifying hospitals on the new 100% HEV screening<br>• Notifying hospitals on the need for current order for HEV before changes in screening<br>• Regularly notifying changes in the blood centre's system<br>• Notifying hospitals on specific issues that need concerns during bank holidays<br>• Informing the outcomes of product recall<br>• Notifying blood centre on the need to have fresh blood | • Alertness | • HI+ |
| | • Allocating stock to ordering hospitals<br>• Producing (testing) for HEV 100%<br>• Informing actions to take due to product recall<br>• Implementing the lessons learned<br>• Notifying hospitals on the potentially limited platelet availability right after the bank holiday<br>• Notifying hospitals on the delivery plan during Olympics<br>• Notifying blood centre on the changes in practices that affect demand and stock management | • Contribution, representation, and subordination of actions | |
| | • Hit and miss of sharing information<br>• Not questioning seemingly inappropriate orders | • No scepticism | • RS- |
| | • Not being proactive in responding to complaints and suggestions from hospitals<br>• Email is not always seen by relevant staff<br>• Flimsy product recall information | • Negative contribution, representation, and subordination of actions | • HI- |
| High tempo | • Being precautious - not sure whether the bloods are safe due to system failure<br>• Involving blood centre to investigate blood safety incidents<br>• Being precautious of the impact of severe reaction to transfusion on other hospitals | • Precaution | • PF+ |
| | • Reporting blood quality issue to blood centre | • Failure reporting | |
| | • Using redundant information sharing media<br>• Using telephone because people are not always checking email | • Redundancy | • RS+ |
| | • Following up the hospital to send information on recalled products<br>• Providing details of the reaction to transfusion | • Scepticism | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Using fax as a more reliable information sharing media<br>• Confirming the hospitals' actions on the recalled products | | |
| | • Trying the best to look for an alternative supply source before notifying hospitals about stockout<br>• Providing general alternative to product substitution | • Checks and balances | |
| | • Being responsive in addressing blood safety problems with recall<br>• Being responsive in discussing the outcome of transfusing recalled products<br>• Being responsive in acting on the reaction to transfusion<br>• Being responsive in addressing product stockout<br>• Being responsive in addressing severe reaction to transfusion with recall<br>• Instructing hospitals to discard blood<br>• Being responsive in forwarding problems to someone with expertise<br>• Being responsive in addressing general blood safety and quality issues<br>• Being responsive in addressing blood shortage<br>• Being responsive in addressing stockout<br>• Being responsive in addressing blood safety incidents<br>• Being responsive in addressing blood supply chain issue<br>• Being responsive in addressing severe reaction to transfusion<br>• Being responsive in addressing blood quality issue | • Responsiveness | • CR+ |
| | • Notifying hospital on the status of the stock levels<br>• Notifying the hospital on the delay in supply<br>• Notifying hospitals on stockout<br>• Notifying hospitals on 2 temperature excursions and the need to discard blood<br>• Notifying hospitals on blood shortage in blood centre<br>• Notifying hospitals on the delivery arrangement<br>• Notifying hospitals on units with temperature excursion<br>• Notifying hospitals on the reaction test results<br>• Notifying the blood centre on the transfused recalled product | • Alertness | • HI+ |
| | • Making hospitals mindful of blood shortage and order<br>• Trying their best to look for an alternative supply source before notifying hospitals about stockout<br>• Notifying blood centre on the reaction to transfusion<br>• Notifying hospitals on the alternative supply source during stockout<br>• Notifying hospitals on infectious disease revealed by donors | • Contribution, representation, and subordination of actions | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Emergency | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Ensuring there is someone to help with unloading emergency blood<br>• Using fax as a back-up system when OBOS is down<br>• Placing emergency order only when the nature of the emergency is clearly known<br>• Using telephone as a back-up system when email is down<br>• Using telephone as a back-up system to order when computers are down<br>• Using back-up telephone designed specifically for major incident (major incident line) | • Scepticism | |
| | • Being responsive in declaring major incident<br>• Being responsive in addressing the need to order | • Responsiveness | • CR+ |
| | • Notifying hospitals on the readiness of blood to collect<br>• Alerting blood centre of major incidents | • Alertness | • HI+ |
| | • Confirming whether the ordered blood has been dispatched to the hospital<br>• Delivering blood using blue light siren<br>• Notifying blood centre on the fridge failure and the need to move stock | • Contribution, representation, and subordination of actions | |

**Table C-2: Identified co-actions of IOIS behaviour and CM principles in the EC 1-2**

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Normal | • Making easier access to important information for hospital<br>• Detecting out of ordinary order<br>• Lateral learning on errors<br>• Being mindful of not ordering too much of one group to avoid many expiries | • Precaution | • PF+ |
| | • Formal reporting of blood safety incidents | • Failure reporting | |
| | • Open to sharing lessons learned with blood centre | • Openness | |
| | • Using redundant information sharing media<br>• Having an alternative information sharing media for contingency | • Redundancy | • RS+ |
| | • Providing further information to help hospital<br>• Asking hospital to confirm orders with clinician (expert)<br>• Having in-depth communication on special needs for blood<br>• Giving minutes of meeting to hospital even though they do not come to the meeting<br>• Incorporating shared information into SOPs and practices | • Scepticism | |
| | • Ensuring reliable service to hospital<br>• Asking wider transfusion community to help solve blood-related problems in hospital<br>• Negotiating orders of short-dated products<br>• Multilayer collective work to examine KPIs<br>• Collectively examining KPIs with other hospitals | • Checks and balances | |
| | • Sharing compiled data back to hospitals<br>• Using voluntary platform to monitor blood stocks, usage, and wastage<br>• Disseminating transfusion performance figures to blood centre and nationally<br>• Collectively examining KPIs with other hospitals | • Transparency | • SO+ |
| | • Regularly sharing blood usage and wastage information<br>• Regular sharing of blood stock review<br>• Regularly sharing updated information on blood management<br>• Regularly sharing blood-related news<br>• Regularly sharing good practices and errors | • Regular interactions | |
| | • Providing updated information on blood management guidelines<br>• Sharing real time (updated) information<br>• Monitoring blood stock nationally<br>• Having automatic order generator and sharing it with blood centre<br>• Having real time information sharing on stock levels | • Real time interactions | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Addressing missing product information<br>• Addressing changes in platelets usage<br>• Addressing changes in shelf life variation<br>• Addressing changes in stock levels<br>• Being responsive in addressing special need for blood types | • Ongoing operational adjustments | |
| | • Encouraging placing order in advance<br>• Satisfying level of information<br>• Relevant information<br>• Appropriate level of information sharing<br>• Well evidenced information<br>• Self-responsibility to act on shared information<br>• Being aware that sharing information affects the donation (donors) end of blood supply chain<br>• Being aware that the hospital blood stock management can affect national blood stock management<br>• Incorporating shared information into SOPs and practices<br>• Giving hospital advance notification on issuing short-dated products<br>• Giving hospital advance notification on changes of deliveries and order policy<br>• Making hospital aware of stock increase plan and overstock implication<br>• Notifying blood centre that the incident is over<br>• Making hospital aware of the matters recommended for action<br>• Reminding the hospital to send KPI data<br>• Notifying blood centre about the prescription and administration of blood | • Contribution, representation, and subordination of actions | • HI+ |
| | • Asking hospital to confirm orders with clinician | • Expertise-based decision making | • DE+ |
| | • Multilayer collective work to examine KPIs<br>• Collectively examining KPIs with other hospitals<br>• Collectively working on the need to stock platelets<br>• Collectively working on the ideal blood stock levels<br>• Collectively working on examining transfusion information and behaviour<br>• Collectively working on improving national blood stock management | • Collective decision making | |
| | • Examining information in detail when only having a problem<br>• Passively waiting for direction from blood centre | • No scepticism | • RS- |
| | • No full transparency system to capture hospitals' specific activities | • No full transparency | • SO- |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Having transparent but less flexible VMI system for changing stock levels | • Less flexibility | |
| | • No continuous flow of information | • No fully real time interactions | |
| High tempo | • Being precautious of the impact of bacterial contamination<br>• Having a full investigation on the delay in blood supply<br>• Encouraging hospital to avoid unnecessary order | • Precaution | • PF+ |
| | • Being responsive in reporting the status of the recalled products<br>• Voluntary reporting reaction to transfusion to SHOT<br>• Reporting blood quality issue to blood centre<br>• Detecting blood quality issue<br>• Using voluntary platform to transparently report serious reaction to transfusion | • Failure reporting | |
| | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Providing detailed information on actions upon product recalls<br>• Ensuring recalled product arrives at the appropriate people | • Scepticism | |
| | • Offering expert advice<br>• Collectively reviewing and resolving blood stock levels with hospital | • Checks and balances | |
| | • Being responsive in addressing shortage in blood stock<br>• Being responsive in addressing blood quality problem with recall<br>• Being responsive in notifying problems with blood donors<br>• Being responsive in addressing blood safety problems with recall<br>• Being responsive in addressing the need for *ad hoc* delivery<br>• Being responsive in reporting the status of the recalled products<br>• Being responsive in addressing severe reaction to transfusion<br>• Being responsive in addressing blood quality issue<br>• Being responsive in addressing urgent blood quality issue | • Responsiveness | • CR+ |
| | • Deferring to expertise to decide whether to have product recall<br>• Offering expert advice | • Expertise-based decision making | • DE+ |
| | • Collectively reviewing and resolving blood stock levels with the hospital | • Collective decision making | |
| | • Notifying hospitals on the product recall<br>• Notifying the hospital on the delay in blood supply<br>• Making hospitals aware of the blood quality issue<br>• Notifying hospital on the status of the stock levels | • Alertness | • HI+ |
| | • Accuracy of information | • Contribution, | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Being responsive in addressing unused products<br>• Adhering to communication from blood centre<br>• Ensuring timeliness, accuracy, and appropriate recipient of product recall information<br>• Ensuring the appropriateness of order<br>• Notifying hospital on the status of the stock levels | representation, and subordination of actions | |
| Emergency | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Being aware of lack of resources during overnight operations to pick up order information | • Scepticism | |
| | • Being responsive in addressing the need to order | • Responsiveness | • CR+ |
| | • Alerting blood centre on major incidents<br>• Notifying blood centre on the status of blood supply<br>• Giving a notification on the status of the unexpected event<br>• Continually informing hospital on the mitigation strategies<br>• Continually informing hospital on the status of the unexpected event | • Alertness | • HI+ |

**Table C-3: Identified co-actions of IOIS behaviour and CM principles in the EC 1-3**

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Normal | • Lateral learning from wastage performance<br>• Learning from historical data of overstock<br>• Open to sharing lessons learned with blood centre<br>• Regularly sharing good practices and errors<br>• Regularly discussing blood safety incidents as lessons learned<br>• Sharing lessons learned from blood safety incidents | • Precaution | • PF+ |
| | • Using fax for sharing patient test results when they are not available on Sp-ICE | • Redundancy | • RS+ |
| | • Confirming the need for *ad hoc* or routine delivery<br>• Using fax for ordering when OBOS is down<br>• Sharing patient details requiring specific blood product | • Scepticism | |
| | • Negotiating changes in blood routine delivery to cover afternoon stock<br>• Keeping hospitals in check to ensure accountability<br>• Using contract as a way of sharing information<br>• Negotiating on the ideal target stock levels with blood centre<br>• Discussing the additional delivery arrangement for the weekend<br>• Regularly discussing issues on blood safety and availability | • Checks and balances | |
| | • Providing transparency figures and summary of wastage report<br>• Formal reporting and sharing of patient test results nationally<br>• Formal reporting and sharing patient test results with hospital<br>• Providing benchmarking report on hospitals' blood wastage<br>• Sharing information on policy implementation<br>• Discussing the additional delivery arrangement for the weekend<br>• Reporting daily stock levels | • Transparency | • SO+ |
| | • Regularly sharing useful event, education and training, and patient information leaflet<br>• Regularly highlighting blood usage and wastage figure and trend for the last one year<br>• Regularly sharing blood management related information<br>• Regularly sharing new product information<br>• Regularly sharing stock level profile<br>• Regularly sharing information on soon to be expired stock<br>• Regularly sharing stock levels, wastage, and delivery<br>• Regularly sharing updated information on blood management practices<br>• Regularly notifying blood centre on changes in operations that might affect demand | • Regular interactions | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Regularly discussing issues on blood safety and availability<br>• Regularly sharing good practices and errors | | |
| | • Having real time access on hospital stock information<br>• Having real time information sharing on stock information<br>• Having real time information sharing on stock levels | • Real time interactions | |
| | • Being responsive in addressing changes in stock levels in the hospital<br>• Being more flexible in sharing patient blood management programme<br>• Being responsive in addressing changes in stock levels<br>• Being responsive in addressing special need for blood types | • Ongoing operational adjustments | |
| | • Reminding hospital on expiring stocks and potential wastage<br>• Notifying hospitals on the delivery and detailed product information<br>• Notifying hospital on the routine delivery based on VMI-ITS<br>• Asking hospital about the need for *ad hoc* delivery<br>• Reminding hospital to use soon to be expired stock | • Alertness | • HI+ |
| | • Reacting to shared information appropriately not necessarily promptly<br>• Ensuring the sharing of information on changes in hospitals' practices that affect demand for blood<br>• Ensuring the appropriateness of order information to be shared | • Contribution, representation, and subordination of actions | |
| High tempo | • Warning to avoid inappropriate usage of blood in high tempo situations<br>• Being precautious in addressing blood quality issue | • Precaution | • PF+ |
| | • Reporting blood safety and quality issues to blood centre consultant<br>• Formal but voluntary reporting of adverse blood safety incidents<br>• Formal but voluntary reporting reaction to transfusion to SHOT<br>• Reporting blood quality issue to blood centre | • Failure reporting | |
| | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Ensuring appropriate order during high tempo condition<br>• Confirming the possible temperature excursion of delivered blood<br>• Explaining the process and results of blood safety incident investigation<br>• Checking the status of temperature excursion with blood centre (expert)<br>• Waiting for further clarification from blood centre | • Scepticism | |
| | • Having real time information sharing on stock levels | • Real time interactions | • SO+ |
| | • Addressing changes in stock levels | • Ongoing operational adjustments | |
| | • Being responsive in asking hospitals to reduce O neg stock, use it appropriately, and | • Responsiveness | • CR+ |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | reduce waste<br>• Being responsive in notifying hospitals on the O neg shortage<br>• Being responsive in advising hospitals on actions on blood safety incident<br>• Being responsive and advising hospitals on actions on blood safety and quality issues<br>• Being responsive in addressing blood quality problem with recall<br>• Being responsive in addressing blood safety problems with recall<br>• Being responsive in addressing shortage in blood stock<br>• Being responsive in addressing blood safety incidents<br>• Being responsive in addressing stock out<br>• Being responsive in addressing the need for *ad hoc* delivery<br>• Being responsive in addressing urgent blood safety and quality issue | | |
| | • Notifying hospitals on the timescale of shortage period<br>• Notifying hospitals on interrupted telephone service<br>• Alerting the blood shortage status<br>• Notifying hospitals on changes in donor sessions that will affect shelf life<br>• Notifying hospital on the status of the stock levels<br>• Notifying MHRA on equipment failure | • Alertness | • HI+ |
| | • Notifying hospitals on the stock management status<br>• Making the hospital (clinician) aware that the transfused product has a quality issue<br>• Notifying hospitals on blood shortage in blood centre<br>• Warning the hospital on low stock levels and appropriate use of blood<br>• Making sure that the hospitals are aware of potential risk of units with quality issue<br>• Notifying blood centre on recalled products | • Contribution, representation, and subordination of actions | |
| Emergency | • Alternating supply during emergency event<br>• Making a redundant effort to alert blood centre on the down of the system<br>• Using phone as an alternative to fax which can be inaccurate<br>• Using back-up system (telephone) when OBOS or Internet is down<br>• Using redundant information sharing media | • Redundancy | • RS+ |
| | • Confirming the availability of ordered blood during emergency<br>• Confirming the emergency order lead time<br>• Asking the availability of ordered blood during emergency<br>• Asking for blue light order by questioning delay<br>• Ensuring the order is received and confirmed<br>• Emphasising particular point of order | • Scepticism | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Being responsive in discussing substitution of ordered product<br>• There will always be people to call or come to help<br>• Being responsive in addressing changes in operations during emergency<br>• Being responsive in addressing changes in delivery placement<br>• Being responsive in addressing the need to order | • Responsiveness | • CR+ |
| | • Alerting hospital on the VMI-ITS system failure<br>• Informing hospitals to use phone for blue light delivery<br>• Notifying hospitals on the unexpected events<br>• Alerting blood centre on the failure of the system or Internet<br>• Alerting blood centre on major incidents | • Alertness | • HI+ |

**Table C-4: Identified co-actions of IOIS behaviour and CM principles across the BSC in the MC-1 (strategic view of Central NHSBT)**

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Normal | • Doing root cause analysis and investigation of incidents with hospitals<br>• Proactively managing complaints via hospital visits and customer satisfaction surveys<br>• Regularly analysing and providing report on blood usage and wastage back to hospitals<br>• Being credible, understanding and a supportive approach when sharing information<br>• Learning the better way to convey information with appropriate frequency<br>• Being precautious in preparing for big events<br>• Being precautious in preparing for facing flu virus<br>• Sharing lessons learned from blood safety incidents in meetings<br>• Regularly sharing blood safety incidents and lessons learned<br>• Sharing lessons learned from the unexpected emergency incident | • Precaution | • PF+ |
| | • Openly sharing blood safety incidents and near misses with NHSBT<br>• Creating openness climate by encouraging hospitals to talk about incidents | • Openness | |
| | • Using redundant ways to make a close link to hospitals<br>• Using redundant information sharing media | • Redundancy | • RS+ |
| | • Ensuring that the ordered blood is suitable for patients' conditions<br>• Being responsive in addressing the planned changes in the blood safety policy<br>• Confirming the delivery arrangement during high tempo via written document<br>• Fitting between information sharing needs (conditions) and capabilities (means of communication)<br>• Having targeted information sharing with clear scope to drive the best outcome<br>• Doing hospital visit to simplify information, make it relevant, influence behaviour, and understand what they really need<br>• Using hospital visit as a way to obtain an absolute outcome from information sharing<br>• Spoon feeding - deliberately enacting collective mindfulness of information sharing<br>• Only sharing certificate of audit to assure hospitals - simplifying information sharing which might not all be relevant to hospitals<br>• Making blood safety guidance workable and easily understood<br>• Explaining the risks of transfusion (bad practices - patient misidentification) to patients<br>• Dealing with personal sensitivity in information sharing<br>• Confirming the delivery of blood product<br>• Providing repertoire of contact details on websites for complaints<br>• Actively seeking feedback from hospitals to meet their expectation and to improve operations<br>• Making sure all relevant staff in the hospitals receive the information | • Scepticism | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Using combination of demand data, changes in practice, modifications to guidelines, and new product availability for stock planning model<br>• Understanding the pattern of hospital demand during incident response<br>• Using combination of casualty data from DH and hospitals for demand planning<br>• Checking to assure hospitals that they are safely linked on OBOS | | |
| | • Involving NHSBT in deciding future demand for components<br>• Involving NHSBT in joint investigation on blood safety incidents<br>• The application of PBM for reverse marketing to reduce demand<br>• PBM, information sharing and cost saving<br>• Benchmarking and comparison of performance as a way to being the best service in the world<br>• Influencing behaviour and collective mindfulness of the BSC members<br>• Doing hospital visits or talks in front of people is the best way to influence hospitals' behaviour<br>• Influencing hospital's behaviour to reduce O neg usage<br>• Doing hospital visit to simplify information, make it relevant, influence behaviour, and understand what they really need<br>• Using talks to share information with the purpose of influencing the hospitals' behaviour<br>• Reverse marketing the blood products to hospitals and patients<br>• Regularly discussing standardised information to share<br>• NHSBT is taking care of the appropriate use of blood in the hospitals<br>• Being involved in deciding the future demand for components from the hospitals<br>• Collectively discussing how to solve unusual trends in blood usage problems<br>• Ensuring hospitals comply with best practice of transfusion including checking patient identification<br>• Educating hospitals around blood safety issues<br>• Opening hospitals' eyes to the harmful risks of transfusions that can cause death<br>• Making hospitals less complacent about the safety of blood transfusion<br>• Making hospitals and patients aware of the harmful effect of transfusion potentially resulting in death<br>• Providing regulated, blood safety related information to hospitals<br>• Ensuring the replication of a change process in hospitals via training<br>• Showing hospitals how the blood management processes work in the blood centre<br>• Regularly reviewing NHSBT performance<br>• Ensuring that lockdown hospitals are still able to receive blood from NHSBT during Olympics<br>• Being involved in doing root cause analysis of incidences<br>• Collectively reviewing the implementation emergency plan | • Checks and balances | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Giving feedback to NHSBT, acknowledging the usefulness of the information shared<br>• Openly sharing blood safety incidents and near misses with NHSBT<br>• Sharing blood safety problems and near misses in meetings<br>• Collectively discussing how to solve unusual trends in blood usage problems<br>• Sharing information on changes in hospitals' operations, regulations, practices, helps align demand and supply<br>• Sharing information on public perception of blood transfusion | • Transparency | • SO+ |
| | • Regularly giving feedback to RBTC<br>• Regularly reporting blood stock levels to BSMS<br>• Regularly sharing blood usage and wastage with blood centre<br>• Regularly providing information on staff training<br>• Regularly updating information on the new test<br>• Regularly discussing standardised information to share<br>• Regularly sharing updates on ITS pilot results<br>• Regularly highlighting the important message for major haemorrhage activations<br>• Regularly sharing information on blood supply and wastage in the hospital by NHSBT<br>• Regularly highlighting the important content of SHOT report<br>• Regularly highlighting the important content of MHRA report<br>• Regularly highlighting the important content of SaBTO report<br>• Regularly sharing PBM-appropriate use of blood<br>• Regularly sharing updated information on training<br>• Regularly making hospitals aware of the monthly updates<br>• Regularly sharing concerns affecting blood services to the hospitals<br>• Regularly sharing strategic blood management and plans to hospitals via RBTC<br>• Regularly and strategically sharing shortage plan with hospitals via NBTC meeting<br>• Regularly providing information on education and training to hospitals<br>• Regularly asking hospitals for actions on monthly updates<br>• Regularly sharing and explaining update on NHSBT operations and suggested actions<br>• Regularly sharing and explaining general long-term information via monthly update<br>• Regularly providing blood stock related data for hospitals via transfusion committee meetings<br>• Regularly making hospitals aware of trend in blood usage<br>• Regularly sharing changes in the hospitals' operations that are likely to affect demand<br>• Regularly sharing information on changes in the hospitals' operations | • Regular interactions | |
| | • Having real time information sharing on stock levels | • Real time | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Having real time information sharing on usage and wastage for control and benchmarking purposes | interactions | |
| | • Influencing hospital's behaviour to reduce O neg usage<br>• Doing hospital visits or talks in front of people is the best way to influence hospitals' behaviour<br>• Being responsive in addressing unusual trend in blood usage and changes in practices in hospitals<br>• Explaining the risks of transfusion (bad practices - patient misidentification) to patients<br>• Being responsive in addressing problems with O neg<br>• Being responsive in addressing changes in operations or practices<br>• Discussing emergency communication and alternatives to using fax machines | • Ongoing operational adjustments | |
| | • Assuring hospitals by sharing what NHSBT are resilient at<br>• Ensuring the resilience of blood supply by sharing stock levels to hospitals<br>• Assuring hospitals on the certified business continuity planning for their benefit<br>• Involving hospitals to fully participate in the planning process and building of resilience operations strategies<br>• Testing the transfusion contingency plans<br>• Advising hospitals on the basis of decisions to prioritise demand<br>• Minimising the potential impact of operational and logistical disruption to transfusion services during Olympic Games | • Readiness | • CR+ |
| | • Being involved in deciding the future demand for components from hospitals<br>• Sharing information at all levels and depending on the tempo of operations<br>• Being involved in doing root cause analysis of incidents<br>• Involving NHSBT in deciding future demand for components<br>• Involving NHSBT for joint investigation into blood safety incidents | • Collective decision making | • DE+ |
| | • Notifying hospitals on changes to operations or practices<br>• Raising awareness on the level of wastage in the hospitals<br>• Raising awareness on the high level of O neg stock<br>• Making hospitals and patients aware of the harmful effect of transfusion potentially resulting in death<br>• Notifying hospitals on the likely service during bank holidays<br>• Notifying hospitals when the situation is resolved and activities are back to normal<br>• Raising awareness of the blood safety incidents and their lessons learned<br>• Emphasising the importance of the information by adding the word death<br>• Continuously supporting and making hospitals aware of any blood stock management issues | • Alertness | • HI+ |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Going beyond the main task of fulfilling orders - voluntary initiatives<br>• Ensuring the investigated complaints are sent back to the hospitals<br>• Collectively working to solve blood usage problems with regional audits<br>• Working together with hospitals to resolve the issues<br>• Not sharing too fine or too detailed information that has a low level impact<br>• Avoiding making hospitals worry about low level impact of potential failures<br>• Having two way of information sharing with NHSBT<br>• Being respectful in sharing trends in blood usage with hospitals<br>• Using hospital visits to build a close interaction, to clearly explain the purpose and being empathetic to understand their reality<br>• Being mindful of the role of NHSBT in the supply chain and putting patients first over personality issues<br>• Notifying hospitals on the potential blood shortage<br>• Notifying in advance any operational changes to hospitals<br>• Raising awareness on the need to save blood usage<br>• Notifying hospitals to order only when particular patients really need the blood<br>• Notifying hospitals in advance on the lesser service offerings during bank holidays<br>• Notifying hospitals on the likely status of the stock levels<br>• Warning the hospitals on the potential shortage or stockout<br>• Notifying hospitals on the need to build up stock in preparation for high tempo situation<br>• Making hospital aware of the consequences of building up stock on wastage<br>• Influencing hospitals' behaviour and opening eyes to blood safety and availability management | • Contribution, representation, and subordination of actions | |
| | • Ordering too much blood for comfort blanket<br>• Inexperience staff failing to specify the special order in the OBOS<br>• Potential for being complacent about blood as a key supply to hospitals<br>• Email is not always accurate and people do not always read emails<br>• Failed to read the specific notes on OBOS | • No scepticism | • RS- |
| | • Like being spoon fed - inactivity to find information independently<br>• Having a feeling of knowing the best and not involving hospitals in the new safety policy | • No checks and balances | |
| | • Not updating information on the blood volume with the new tested one | • No real time interactions | • SO- |
| | • Not being responsive in addressing problems with O neg | • No ongoing operational adjustments | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Seeing NHSBT as being critical of hospitals<br>• Being resistant to criticism<br>• Lack of respectful interaction when expertise is required by NHSBT | • Negative contribution, representation, and subordination of actions | • HI- |
| High tempo | • Creating openness climate to discuss delivery plans and problems faced by hospitals during high tempo | • Openness | • PF+ |
| | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Explaining to hospitals on what's causing the blood shortage and actions required<br>• Ensuring hospitals to be extra careful to order only when they need it<br>• Fitting between information sharing needs (conditions) and capabilities (means of communication)<br>• Discussing with clinicians the potential impact of potentially harmful blood on patients | • Scepticism | |
| | • Discussing reasons for wastage | • Checks and balances | |
| | • Continually monitoring wastage across the hospitals | • Transparency | • SO+ |
| | • Being responsive in notifying changes in blood stock levels and delivery arrangement<br>• Being responsive in addressing overstock in the blood centres<br>• Being responsive in addressing increasing trend in stock levels<br>• Being responsive in addressing decreasing trend in O neg stock<br>• Being responsive in addressing upward trend of wastage<br>• Being responsive in addressing shortage in blood stock<br>• Being responsive in arranging delivery from other hospitals | • Ongoing operational adjustments | |
| | • Being responsive in offering an alternative for out of stock order<br>• Confirming the order which is out of stock<br>• Being responsive in addressing blood safety problems with recall | • Responsiveness | • CR+ |
| | • Discussing with clinician the potential impact of potentially harmful blood for patient<br>• Asking for advice on the alternative supply of out of stock products in the blood centre | • Expertise-based decision making | • DE+ |
| | • Being responsive in notifying broken down systems<br>• Notifying hospitals on the blood shortage | • Alertness | • HI+ |
| | • Working together with hospitals to resolve issues<br>• Notifying NHSBT on the possible impact of the event on blood supply | • Contribution, representation, and subordination of actions | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Emergency | • Using fax as back-up media to order blood during emergencies when OBOS is down<br>• Using fax as a back-up when OBOS is down due to cyber attack<br>• Using telephone as a back-up to understand the urgency of order via OBOS<br>• Using redundant information sharing media | • Redundancy | • RS+ |
| | • Involving NHSBT in the discussion about giving detailed outbreak information to patients<br>• Having one to one conversation to explain and try to understand the situation from hospitals' and NHSBT's points of view<br>• Understanding the hospitals' need | • Checks and balances | |
| | • Using OBOS or telephone as a dedicated channel for immediate response during emergency event<br>• Being responsive in addressing the need to order<br>• Being responsive in notifying hospitals on the alternative supply provision and delivery schedules<br>• Being responsive in explaining the impact of the emergency event on services to hospitals<br>• Being responsive in ensuring operational resilience on supply and IT<br>• Being responsive in addressing confusion in ordering process during emergency<br>• Being responsive in notifying hospitals on the supply alteration and potential delay in delivery<br>• Being responsive in notifying the stock levels status in NHSBT<br>• Being responsive in altering the supply source to other blood centres<br>• Being responsive in sharing the status of activities during emergencies - when ordering systems (OBOS, telephone, fax) are not working<br>• Being responsive in giving advice on emergency order and stock management<br>• Being responsive in notifying late morning deliveries to hospitals<br>• Being responsive in notifying hospitals of the unexpected emergency event | • Responsiveness | • CR+ |
| | • Continuously but consistently and not too often updating information on the status of the unexpected event to avoid confusion<br>• Continually informing hospital on the status of delivery during emergency | • Alertness | • HI+ |
| | • Trusting the shared information and focussing the response to understanding customers<br>• Notifying wider hospitals on the status of the unexpected emergency event<br>• Notifying NHSBT on the need for platelets despite of the emergency event<br>• Notifying hospitals on the alteration of supply source and the possible impacts of events | • Contribution, representation, and subordination of actions | |

**Table C-5: Identified co-actions of IOIS behaviour and CM principles in the EC 2-1**

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Normal | • Identifying problems in blood management<br>• Warning on the need for authorising the cross-matched product and checking the patient ID<br>• Preventing stockout during Ramadhan | • Precaution | • PF+ |
| | • Reporting blood safety and availability issues to blood centre<br>• Reporting blood quality issue to blood centres<br>• Reporting wrong labels to blood centre | • Failure reporting | |
| | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Providing product details on the delivery notes<br>• Informing hospitals or patient's family on the customer lead time<br>• Checking the availability and shelf life of blood products before ordering<br>• Direct face to face order using order form<br>• Reminding hospitals on the need to have blood donations in preparation for Ramadhan | • Scepticism | |
| | • Auditing processes for ensuring blood safety and availability in hospitals<br>• Evaluating problems in blood safety and availability<br>• Providing training on blood safety and availability to blood bank | • Checks and balances | |
| | • Collective monitoring of blood safety and availability<br>• Monitoring blood quality management conformance<br>• Sharing temperature control document<br>• Monthly reporting of blood usage to blood centres | • Transparency | • SO+ |
| | • Monthly reporting of blood usage to blood centres<br>• Disseminating new blood management policy or regulation | • Regular interactions | |
| | • Sharing real time (updated) information on stock levels | • Real time interactions | |
| | • Sharing order information when needed<br>• Being responsive in addressing changes in stock levels | • Ongoing operational adjustments | |
| | • Notifying hospitals or patient family on the delay in processing blood<br>• Informing hospitals or patient family on the customer lead time<br>• Informing hospitals or patient family on the status of the stock levels in the blood centre<br>• Informing hospitals or patient family on the blood processing cost<br>• Notifying hospitals on the lead time of replacement donation<br>• Alerting hospital on the potential reaction to transfusion from ordered blood<br>• Notifying blood centre on the number of orders | • Alertness | • HI+ |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Notifying blood centre on the donation plan<br>• Notifying hospital on the status of the recalled products | | |
| High tempo | • Reporting blood quality issues to blood centre<br>• Reporting reactions to transfusion to blood centre | • Failure reporting | • PF+ |
| | • Confirming blood availability to take from the blood centre<br>• Confirming wrong labels with blood centre<br>• Confirming the use of replacement donors<br>• Confirming reasons for product recall<br>• Confirming incompatibility issue with blood centre | • Scepticism | • RS+ |
| | • Being responsive in addressing product stockout | • Responsiveness | • CR+ |
| Emergency | • Being responsive in addressing the need for emergency blood<br>• Being responsive in notifying the results of emergency cross-match<br>• Being responsive in addressing the need for blood | • Responsiveness | • CR+ |

**Table C-6: Identified co-actions of IOIS behaviour and CM principles in the EC 2-2**

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Normal | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Confirming the use of blood and therefore reserved order<br>• Ensuring service levels to hospital during Ramadhan and led al Fitr<br>• Confirming the availability of blood to be ordered | • Scepticism | |
| | • Encouraging the hospital to collaborate with blood centre - conflict resolution<br>• Using MoU as a basis for blood safety and availability provision and cost arrangement<br>• Reminding hospitals not to use replacement donors | • Checks and balances | |
| | • Notifying hospitals on the training event<br>• Being responsive in informing hospitals on the missing usage data for invoicing purposes<br>• Notifying blood centre on the need for fresher blood<br>• Informing hospitals on the blood screening results<br>• Informing hospitals on the certification results | • Alertness | • HI+ |
| | • Helping hospitals to solve day to day problems using telephone<br>• Confirming the use of blood and therefore order<br>• Cancelling the use of blood and therefore order<br>• Reminding hospitals not to use replacement donors | • Contribution, representation, and subordination of actions | |
| | • Only sharing order information<br>• MoU as a mechanism not to share information | • No real time interactions | • SO- |
| | • Sharing blood usage for invoicing purposes<br>• Sharing order information for invoicing purposes | • Mismatched use of information | |
| | • Uncoordinated information sharing on the need for blood<br>• Not following up hospital's request with policy<br>• Not using hospital usage information<br>• Not accommodating blood centre's expectation on reporting<br>• Not ensuring the appropriateness of order information to be shared<br>• Assuming that fresher product is needed<br>• Rejecting the collaboration proposal<br>• MoU-based decision making<br>• Reserving blood for later | • Negative contribution, representation, and subordination of actions | • HI- |
| High tempo | • Using redundant information sharing media | • Redundancy | • RS+ |
| | • Questioning hospitals on the appropriateness of order<br>• Ensuring stock availability by booking blood in advance | • Scepticism | |

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| | • Confirming the availability of blood to order from blood centre<br>• Ensuring the provision of rare negative rhesus blood via blood centre | | |
| | • Being responsive in addressing blood shortage<br>• Being responsive in addressing stock out<br>• Being responsive in addressing blood quality issue | • Responsiveness | • CR+ |
| Emergency | • Being responsive in addressing the need to order | • Responsiveness | • CR+ |

**Table C-7: Identified co-actions of IOIS behaviour and CM principles in the EC 2-3**

| Contexts | Co-actions of IOIS behaviour and collective mindfulness principles | | |
|---|---|---|---|
| Operational conditions | Co-actions | CM subthemes | CM principles |
| Normal | • Confirming the use of blood and therefore order<br>• Checking the patient status before reallocating blood to other patients<br>• Reminding hospitals on the blood handling procedure<br>• Asking the readiness of blood to be collected<br>• Asking blood availability in the blood centre<br>• Checking the availability of blood to be ordered<br>• Confirming the availability of blood to be ordered in advance<br>• Rechecking details of patient and product information | • Scepticism | • RS+ |
| | • Notifying hospital that the blood is ready for collection<br>• Notifying blood centre on the blood donation plan | • Alertness | • HI+ |
| | • Confirming the use of blood and therefore order | • Contribution, representation, and subordination of actions | |
| | • Hiding expiry date information due to cultural issue | • No transparency | • SO- |
| | • Sharing information only when needing blood<br>• Limited information sharing | • No regular interactions | |
| | • Not answering telephone for blood collection | • No ongoing operational adjustments | |
| High tempo | • Rechecking the blood quality<br>• Reconfirming blood availability when stock out<br>• Cross-checking the incompatibility of blood<br>• Consulting reactions to transfusion with the blood centre | • Scepticism | • RS+ |
| | • Being responsive in addressing reaction to transfusion<br>• Being responsive in addressing the need for blood when stockout | • Responsiveness | • CR+ |
| Emergency | • Being responsive in addressing incompatible cross-match<br>• Being responsive in addressing the need to order | • Responsiveness | • CR+ |

# Appendix D Results of the verification process in each embedded case

**Table D-1: Results of the verification process in the EC 1-1**

| Operational conditions | Mechanisms | FP Hospital | SG Hospital | W Hospital | WH Hospital | BC 1-1 | Central NHSBT | Verified? |
|---|---|---|---|---|---|---|---|---|
| Normal | PF+ | √ | √ | √ | √ | - | √ | √ |
| | RS+ | √ | √ | - | √ | √ | √ | √ |
| | SO+ | √ | √ | √ | √ | √ | √ | √ |
| | CR+ | - | - | - | - | - | √ | - |
| | DE+ | - | - | - | - | - | √ | - |
| | HI+ | √ | √ | - | √ | √ | √ | √ |
| | RS- | - | √ | - | √ | - | √ | √ |
| | SO- | - | - | - | - | - | √ | - |
| | DE- | - | - | - | - | - | √ | - |
| | HI- | - | - | √ | √ | √ | √ | √ |
| High tempo | PF+ | - | √ | - | √ | √ | √ | √ |
| | RS+ | √ | √ | √ | - | √ | √ | √ |
| | SO+ | - | - | - | - | - | √ | - |
| | CR+ | √ | √ | √ | √ | √ | √ | √ |
| | DE+ | - | √ | - | - | √ | √ | - |
| | HI+ | √ | √ | √ | √ | √ | √ | √ |
| | RS- | - | - | - | - | √ | - | - |
| | HI- | - | √ | - | √ | - | - | - |
| Emergency | PF+ | - | - | - | - | - | √ | - |
| | RS+ | √ | √ | √ | - | √ | √ | √ |
| | SO+ | - | - | - | - | - | √ | - |
| | CR+ | √ | √ | √ | - | √ | √ | √ |
| | DE+ | - | - | - | - | √ | √ | - |
| | HI+ | - | √ | - | √ | √ | √ | √ |
| | RS- | - | - | - | - | - | √ | - |
| | CR- | - | - | - | - | - | √ | - |

**Table D-2: Results of the verification process in the EC 1-2**

| Operational conditions | Mechanisms | JR Hospital | WP Hospital | NG Hospital | SM Hospital | BC 1-2 | Central NHSBT | Verified? |
|---|---|---|---|---|---|---|---|---|
| Normal | PF+ | - | √ | √ | - | √ | √ | √ |
| | RS+ | - | √ | √ | √ | √ | √ | √ |
| | SO+ | √ | √ | √ | √ | √ | √ | √ |
| | CR+ | - | - | - | - | - | √ | - |
| | DE+ | √ | √ | √ | √ | √ | √ | √ |
| | HI+ | √ | √ | √ | - | - | √ | √ |
| | RS- | √ | - | - | √ | - | √ | √ |
| | SO- | √ | - | - | √ | √ | √ | √ |
| | DE- | - | - | - | - | - | √ | - |
| | HI- | - | - | - | - | - | √ | - |
| High tempo | PF+ | √ | √ | √ | - | √ | √ | √ |
| | RS+ | - | - | √ | √ | √ | √ | √ |
| | SO+ | √ | - | - | - | √ | √ | - |
| | CR+ | √ | √ | √ | √ | √ | √ | √ |
| | DE+ | - | √ | √ | - | - | √ | √ |
| | HI+ | - | √ | √ | √ | √ | √ | √ |
| | RS- | √ | - | - | √ | - | - | - |
| | SO- | √ | √ | - | √ | - | - | - |
| | CR- | - | √ | - | - | - | - | - |
| Emergency | PF+ | - | - | - | - | - | √ | - |
| | RS+ | - | - | √ | - | - | √ | - |
| | SO+ | - | - | - | - | - | √ | - |
| | CR+ | - | √ | √ | √ | - | √ | √ |
| | DE+ | - | - | - | - | - | √ | - |
| | HI+ | √ | - | √ | √ | - | √ | √ |
| | RS- | - | - | - | - | - | √ | - |
| | CR- | - | - | - | - | - | √ | - |

### Table D-3: Results of the verification process in the EC 1-3

| Operational conditions | Mechanisms | RB Hospital | SHG Hospital | QA Hospital | BNH Hospital | BC 1-3 | Central NHSBT | Verified? |
|---|---|---|---|---|---|---|---|---|
| Normal | PF+ | √ | - | √ | √ | - | √ | √ |
| | RS+ | √ | - | √ | √ | - | √ | √ |
| | SO+ | √ | √ | √ | √ | √ | √ | √ |
| | CR+ | - | - | - | - | - | √ | - |
| | DE+ | - | - | - | - | - | √ | - |
| | HI+ | √ | √ | - | √ | √ | √ | √ |
| | RS- | - | - | - | - | - | √ | - |
| | SO- | - | - | - | - | - | √ | - |
| | DE- | - | - | - | - | - | √ | - |
| | HI- | - | - | - | - | - | √ | - |
| High tempo | PF+ | √ | √ | √ | √ | - | √ | √ |
| | RS+ | - | √ | √ | √ | √ | √ | √ |
| | SO+ | - | √ | √ | - | - | √ | √ |
| | CR+ | - | √ | √ | √ | √ | √ | √ |
| | DE+ | - | √ | - | - | - | √ | - |
| | HI+ | √ | √ | √ | √ | √ | √ | √ |
| | RS- | - | √ | - | - | - | - | - |
| | CR- | - | √ | - | - | - | - | - |
| Emergency | PF+ | - | - | - | √ | - | √ | - |
| | RS+ | √ | - | √ | √ | - | √ | √ |
| | SO+ | - | - | √ | - | - | √ | - |
| | CR+ | √ | √ | √ | √ | √ | √ | √ |
| | DE+ | - | √ | - | - | - | √ | - |
| | HI+ | √ | √ | √ | √ | √ | √ | √ |
| | RS- | - | - | - | - | - | √ | - |
| | CR- | - | - | - | - | - | √ | - |

## Table D-4: Results of the verification process in the EC 2-1

| Operational conditions | Mechanisms | PMU Hospital | KI Hospital | HM Hospital | PW Hospital | BC 2-1 | Verified? |
|---|---|---|---|---|---|---|---|
| Normal | PF+ | √ | √ | - | √ | √ | √ |
| | RS+ | √ | √ | √ | √ | √ | √ |
| | SO+ | √ | - | √ | √ | √ | √ |
| | CR+ | - | - | √ | - | - | - |
| | DE+ | - | - | - | - | √ | - |
| | HI+ | √ | - | √ | √ | √ | √ |
| | SO- | - | - | - | √ | - | - |
| | HI- | √ | √ | √ | √ | - | - |
| High tempo | PF+ | √ | √ | - | √ | √ | √ |
| | RS+ | - | - | √ | √ | √ | √ |
| | SO+ | - | √ | - | √ | - | - |
| | CR+ | √ | - | - | - | - | - |
| | PF- | - | √ | - | - | - | - |
| | SO- | - | √ | - | - | - | - |
| Emergency | RS+ | - | - | - | - | √ | - |
| | CR+ | √ | - | √ | - | √ | √ |

**Table D-5: Results of the verification process in the EC 2-2**

| Operational conditions | Mechanisms | PR Hospital | BT Hospital | AK Hospital | SD Hospital | BC 2-2 | Verified? |
|---|---|---|---|---|---|---|---|
| Normal | PF+ | - | - | - | - | √ | - |
| | RS+ | √ | - | - | √ | √ | √ |
| | SO+ | √ | - | - | - | √ | - |
| | HI+ | - | - | √ | √ | √ | √ |
| | PF- | √ | - | - | - | - | - |
| | RS- | - | - | - | - | √ | - |
| | SO- | √ | √ | √ | - | √ | √ |
| | CR- | √ | - | - | - | - | - |
| | DE- | - | √ | - | - | - | - |
| | HI- | √ | √ | √ | √ | √ | √ |
| High tempo | PF+ | √ | - | - | - | - | - |
| | RS+ | √ | - | √ | √ | √ | √ |
| | SO+ | - | √ | - | - | √ | - |
| | CR+ | √ | √ | √ | - | √ | √ |
| | HI+ | - | - | √ | - | - | - |
| | RS- | √ | - | - | - | √ | - |
| | HI- | - | - | √ | √ | - | - |
| Emergency | RS+ | - | - | - | √ | - | - |
| | CR+ | - | - | √ | √ | - | - |
| | HI+ | - | - | - | √ | - | - |

## Table D-6: Results of the verification process in the EC 2-3

| Operational conditions | Mechanisms | MD Hospital | TR Hospital | IS Hospital | PMA Hospital | BC 2-3 | Verified? |
|---|---|---|---|---|---|---|---|
| Normal | RS+ | √ | √ | √ | √ | √ | √ |
| | SO+ | - | - | - | √ | - | - |
| | CR+ | - | √ | - | - | - | - |
| | HI+ | - | √ | √ | √ | √ | √ |
| | SO- | √ | - | √ | √ | √ | √ |
| | RS- | - | - | - | √ | - | - |
| | HI- | - | - | - | - | √ | - |
| High tempo | RS+ | √ | √ | - | - | √ | √ |
| | CR+ | √ | √ | - | - | √ | √ |
| Emergency | RS+ | √ | - | - | - | - | - |
| | CR+ | √ | √ | - | - | √ | √ |
| | HI+ | - | - | - | - | √ | - |

# Appendix E Changes in blood safety and availability in each embedded case

**Table E-1: Changes in blood safety and availability in the EC 1-1**

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| Normal | • Reduced platelet usage (H)<br>• Increased shelf life of ordered products (H)<br>• More efficient delivery (NHSBT-H)<br>• More effective ordering and therefore reduced stock levels (H) | • Realised improvement of BSA |
| | • Lessons learned on positive patient identification (H)<br>• Lessons learned from blood safety related issues (H)<br>• Lessons learned from BSA good practice (H)<br>• Lessons learned from blood safety incidents (NHSBT-H)<br>• Reported transfusion staff expertise issues for lessons learned (NHSBT-H)<br>• Reported safety incidents for lessons learned (NHSBT-H)<br>• Confirmed reasons for product recalls (H)<br>• Understood trend in stock levels, usage, and wastage (NHSBT-H)<br>• Lessons learned on best practice of managing BSA in Olympics (NHSBT-H)<br>• Ensured disseminated advice on stock management (NHSBT-H)<br>• Ensured disseminated advice on appropriate blood usage (NHSBT-H)<br>• Continuous awareness on BSA issues (NHSBT-H, BC-H)<br>• Ensured awareness of blood supply chain process (BC-H)<br>• Ensured awareness of blood safety tests (H)<br>• Ensured awareness of updated BSA issues (H)<br>• Easily accessed blood safety test (H)<br>• Potentially reduced overstock (H)<br>• Potentially increased flexibility of delivery (H)<br>• Negotiated delivery issues (H)<br>• Potentially reduced stock levels (NHSBT-H) | • Potential improvement of BSA |
| | • Ensured implementation of the disseminated advice from BC (NHSBT-H)<br>• Ensured age of blood (BC-H)<br>• Ensured blood availability (H)<br>• Ensured appropriate age of blood (H) | • Assurance of BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured service level on BSA (NHSBT-H)<br>• Ensured responses on the need for blood (H)<br>• Ensured appropriate order of blood (BC-H)<br>• Ensured appropriate use of blood (NHSBT-H)<br>• Ensured accuracy of the product delivery data (H)<br>• Reassured availability of blood during lockdown (H)<br>• Ensured delivery of blood products (H)<br>• Controlled temperature (H)<br>• Prevented potential safety incidents (BC-H)<br>• Appropriate use of blood (H)<br>• Ensured delivery of blood products in high tempo events (NHSBT-H)<br>• Ensured blood availability during bank holidays (H)<br>• Prevented blood safety incidents (H) | |
| | • Replaced expired stock (H)<br>• Replenished stock (H)<br>• Fulfilled need for blood (H)<br>• Reduced wastage (H)<br>• Stabilised stock level (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of the need for fresh blood (BC)<br>• Ensured awareness of potential BSA issues during bank holiday (H)<br>• Ensured awareness of changing practices affecting demand and stock management (BC) | • Potential adjustment of operations towards BSA |
| | • Unchanged deliveries (H) | • No potential improvement of BSA |
| | • Overstock during Christmas (H) | • No adjustment of operations towards BSA |
| | • Staff unaware of updated BSA issues (BC-H)<br>• Potentially unnoticed blood safety incidents (BC-H) | • No potential adjustment of operations towards BSA |
| High tempo | • Investigated blood safety incidents (BC-H) | • Potential improvement of BSA |
| | • Discarded recalled blood (H)<br>• Confirmed recalled products (BC-H)<br>• Prevented potential safety incidents (BC-H)<br>• Removed potentially unsafe blood (H)<br>• Handled reactions to transfusion (H)<br>• Quarantined potentially harmful blood (H) | • Assurance of BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured appropriate order due to shortage (BC-H)<br>• Ensured blood availability (BC-H)<br>• Ensured fate of recalled products (BC-H)<br>• Ensured blood availability - alternative for stockout (BC-H)<br>• Confirmed supply alteration (H)<br>• Confirmed outcome of product recall (H)<br>• Confirmed case of infection or bacterial contamination (H)<br>• Confirmed cause of reaction to transfusion (H)<br>• Confirmed discard of recalled products (BC-H)<br>• Confirmed product recall (BC-H)<br>• Prevented safety incidents (H)<br>• Ensured delivery of blood products in high tempo events (BC-H)<br>• Monitored reactions to transfusion due to product recall (BC-H) | |
| | • Increased stock levels (H)<br>• Resolved BSA issues (H)<br>• Resolved blood availability problem (H)<br>• Replenished stock (H)<br>• Fulfilled need for blood (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of stockout (H)<br>• Ensured awareness of the delay of supply (H)<br>• Ensured awareness of shortage (H)<br>• Ensured awareness of blood shortage and substitutions (H)<br>• Potentially recalled products (BC-H)<br>• Ensured awareness of transfused recalled product (BC)<br>• Ensured awareness of contaminated blood (BC)<br>• Ensured security of product recall information (BC-H)<br>• Ensured awareness of product recalls (BC-H)<br>• Potentially resolved blood safety problem (H) | • Potential adjustment of operations towards BSA |
| Emergency | • Confirmed delivery of emergency blood (H)<br>• Ensured blood availability during emergency events (H)<br>• Ensured placement of order (H)<br>• Ensured appropriate order of blood (BC-H)<br>• Ensured blood availability during emergency events (NHSBT-BC)<br>• Confirmed order during emergency (H) | • Assurance of BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Reduced wastage (H)<br>• Reduced stock level (H)<br>• Restored stock (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of incoming orders during emergency (BC)<br>• Ensured awareness of complete stockout (H) | • Potential adjustment of operations towards BSA |

**Table E-2: Changes in blood safety and availability in the EC 1-2**

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| Normal | • More effective stock replenishment (BC-H)<br>• Reduced overstock (H)<br>• More stabilised stock levels (H)<br>• Fixed ideal stock levels (BC-H)<br>• Reduced stock levels (BC-H)<br>• Reduced wastage (H) | • Realised improvement of BSA |
| | • Ensured awareness of the latest blood safety guideline (H)<br>• Ensured awareness of the updated BSA issues (H)<br>• Ensured awareness of the recommended actions on BSA (H)<br>• Lessons learned from resolved BSA issues (NHSBT-H)<br>• Lessons learned from BSA performance of other hospitals (H)<br>• Lessons learned frpm BSA incidents (NHSBT-H)<br>• Reported safety incidents for lessons learned (H)<br>• Lessons learned from BSA good practices (H)<br>• Understood trend in stock levels, usage, and wastage (NHSBT-H)<br>• Understood transfusion behaviour (NHSBT-H) | • Potential improvement of BSA |
| | • Confirmed delivery (H)<br>• Ensured availability of special blood for patients (NHSBT-H, BC-H)<br>• Ensured accuracy of blood delivery information (H)<br>• Ensured blood safety and quality (H)<br>• Ensured appropriate order of blood (NHSBT-H, BC-H)<br>• Ensured BSA nationally (NHSBT-H)<br>• Ensured usage of short-dated blood (BC-H)<br>• Ensured placement of order (H)<br>• Prevented potential wastage (H)<br>• Prevented overstock (H)<br>• Avoided wastage (NHSBT-H)<br>• Ensured appropriate use of blood (NHSBT-H) | • Assurance of BSA |
| | • Varied shelf life (H)<br>• Replenished stock (H)<br>• Short-dated stock (H) | • Adjustment of operations towards BSA |
| | • Potentially resolved BSA issues (H) | • Potential adjustment of operations |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured awareness of increased stock levels (H)<br>• Ensured awareness of reduced shelf life (H) | towards BSA |
| | • Less flexible changes of stock levels (H)<br>• Potentially unnoticed BSA issues (BC) | • No potential improvement of BSA |
| | • Overstock (H) | • No adjustment of operations towards BSA |
| | • Staff potentially unaware of updated BSA issues (BC)<br>• Potentially complacent and unaware of detailed BSA issues (H)<br>• Unaware of real time stock level status (H) | • No potential adjustment of operations towards BSA |
| High tempo | • Increased stock levels (H)<br>• Stabilised stock levels (H) | • Realised improvement of BSA |
| | • Investigated products causing severe reactions (BC-H)<br>• Reported severe reactions to transfusion for lessons learned (H) | • Potential improvement of BSA |
| | • Prevented wastage (H)<br>• Prevented overstock (H)<br>• Removed products with quality issues from stock (H)<br>• Removed recalled products (H)<br>• Recalled products (BC-H)<br>• Ensured appropriate order of blood (BC-H)<br>• Prevented severe reactions to transfusion (H)<br>• Ensured alternative for blood supply during shortage (H)<br>• Ensured prevention of safety incidents (H)<br>• Ensured timely urgent delivery (H)<br>• Ensured actions on products causing severe reactions (H)<br>• Confirmed product recall (BC-H) | • Assurance of BSA |
| | • Adjusted stock levels (H)<br>• Increased stock levels (H)<br>• Reduced overstock (H) | • Adjustment of operations towards BSA |
| | • Potentially reduced stock levels (BC-H)<br>• Ensured awareness of blood shortage (H)<br>• Ensured awareness of urgent delivery (BC)<br>• Ensured awareness of investigated errors (H)<br>• Ensured awareness of blood quality issues (H)<br>• Ensured awareness of blood quality issues (BC) | • Potential adjustment of operations towards BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured awareness of product recall (BC)<br>• Ensured awareness of recalled products (H)<br>• Ensured awareness of actions on product recalls (H) | |
| Emergency | • Lessons learned from undisrupted blood supply (BC) | • Potential improvement of BSA |
| | • Ensured blood availability during emergency (H) | • Assurance of BSA |
| | • Increased stock levels (BC-H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of emergency order and delivery (BC)<br>• Ensured awareness of blood availability issues during emergency (H)<br>• Ensured awareness of the status of emergency events (H) | • Potential adjustment of operations towards BSA |

## Table E-3: Changes in blood safety and availability in the EC 1-3

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| Normal | • Reduced stock levels (H)<br>• More stabilised stock levels (H) | • Realised improvement of BSA |
| | • Reported blood safety incidents for lessons learned (H)<br>• Lessons learned from blood safety incidents in hospitals (H)<br>• Lessons learned from the root causes of safety incidents (NHSBT-H)<br>• Lessons learned in wastage across hospitals (H)<br>• Lessons learned from trend in stock levels and wastage across hospitals (H)<br>• Understood trend in stock levels, usage, and wastage (NHSBT-H, BC-H)<br>• Understood blood usage and wastage trend (H)<br>• Ensured awareness of wastage in hospitals (NHSBT)<br>• Ensured awareness of the trend in stock levels, usage, delivery, and wastage (H)<br>• Ensured awareness of updated BSA issues (H)<br>• Potentially improved stock level management (H)<br>• Potentially improved delivery (H) | • Potential improvement of BSA |
| | • Ensured enough stock levels (H)<br>• Controlled stock levels (H)<br>• Ensured appropriate usage of blood (NHSBT-H, BC-H)<br>• Ensured appropriate usage of special blood (H)<br>• Ensured placement of orders (H)<br>• Confirmed delivery of special blood products (H)<br>• Ensured usage of expiring blood (H)<br>• Avoided wastage (H)<br>• Confirmed impacts of new introduced product (BC)<br>• Confirmed safety test results (H)<br>• Confirmed *ad hoc* or routine delivery (H) | • Assurance of BSA |
| | • Increased stock levels (H)<br>• Replenished stock (H)<br>• Reduced order (H)<br>• Fulfilled need for special blood products (H) | • Adjustment of operations towards BSA |
| | • Potentially changed blood demand (BC-H)<br>• Easily accessed blood test results (H) | • Potential adjustment of operations towards BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Securely accessed blood test results (H)<br>• Ensured awareness of updated changes in the BSC practices (BC-H)<br>• Ensured awareness of the expiring stocks (H) | |
| High tempo | • Reported blood safety incidents for lessons learned (NHSBT-H, BC-H)<br>• Investigated blood safety incidents (H)<br>• Investigated recalled units (NHSBT, BC) | • Potential improvement of BSA |
| | • Ensured appropriate use of blood (NHSBT-H)<br>• Ensured availability of limited blood stock (NHSBT-H)<br>• Ensured appropriate order of blood (BC-H)<br>• Avoided blood safety incidents (H)<br>• Confirmed temperature excursion (BC-H)<br>• Avoided wastage (H)<br>• Confirmed actions on recalled products (H)<br>• Discarded recalled products (H)<br>• Ensured accuracy of product recall information (BC-H)<br>• Confirmed actions on blood safety incidents (H)<br>• Prevented blood safety incidents (H)<br>• Ensured the root causes of transfusion reaction (BC)<br>• Confirmed blood availability (H)<br>• Potentially prevented blood safety incidents (H)<br>• Monitored patients' conditions due to recalled products (H) | • Assurance of BSA |
| | • Reduced stock levels (NHSBT-H)<br>• Replaced order (H)<br>• Increased stock levels (H)<br>• Replenished stock (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of blood shortage (NHSBT-H, BC-H)<br>• Ensured awareness of blood products with quality issues (H)<br>• Ensured awareness of updated BSA issues (H)<br>• Ensured awareness of product recall (BC-H)<br>• Ensured awareness of product recall (H)<br>• Ensured awareness of the impact of recalled products to patients (H)<br>• Ensured awareness of short-dated delivery (H)<br>• Ensured awareness of stockout (H)<br>• Ensured awareness of blood quality issues (BC) | • Potential adjustment of operations towards BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured awareness of product recall (BC)<br>• Potentially reduced stock levels (H)<br>• Potentially reduced wastage (H) | |
| Emergency | • Avoided stockout (H)<br>• Avoided overstock (H)<br>• Ensured placement of orders (H)<br>• Ensured blood availability during emergency (BC-H)<br>• Ensured actions on urgent order (H)<br>• Ensured appropriate use of emergency blood (H)<br>• Avoided wastage (H)<br>• Resolved serious blood safety incidents (H)<br>• Confirmed order (H)<br>• Ensured timely delivery (H)<br>• Ensured actions on blood shortage during emergency (H) | • Assurance of BSA |
| | • Supplied alternative for stockout products (H)<br>• Substituted stockout products (H)<br>• Fulfilled need for blood during emergency (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of urgent order (BC)<br>• Ensured awareness of the supply source alteration (H)<br>• Ensured awareness of major incidents (BC)<br>• Ensured awareness of blood shortage during emergency (H)<br>• Ensured awareness of stock level status during emergency (H) | • Potential adjustment of operations towards BSA |

**Table E-4: Changes in blood safety and availability across the BSC in the MC-1 (strategic view of Central NHSBT)**

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| Normal | • Forecasted needs for blood (NHSBT-H)<br>• Fulfilled patients' needs (H)<br>• Mapped stock (BC)<br>• Improved services to hospitals (NHSBT-H)<br>• Improved BSC practices (H)<br>• Reduced demand for donated blood (NHSBT)<br>• Increased patient safety (H)<br>• Reduced inappropriate use of blood (NHSBT-H)<br>• Aligned demand and supply of blood (NHSBT-H) | • Realised improvement of BSA |
| | • Understood trend in stock levels, usage, and wastage (NHSBT-H)<br>• Investigated blood safety incidents (H)<br>• Lessons learned from reviewed KPIs (NHSBT)<br>• Lessons learned from blood safety incidents (H)<br>• Lessons learned from trend in blood stock levels, usage, and wastage across hospitals (H)<br>• Discussed near misses (NHSBT-H)<br>• Lessons learned from resilience episodes (NHSBT-H)<br>• Understood BSC practices and needs (NHSBT-H)<br>• Raised awareness of blood safety incidents (H)<br>• Ensured awareness of the fatal risk of transfusion (H)<br>• Ensured awareness of the updated BSA issues (H)<br>• Ensured awareness of actions on blood safety incidents (H)<br>• Ensured awareness of blood safety issues (H)<br>• Ensured awareness of transfusion risks to patients (H)<br>• Ensured awareness of actions during emergency events (H)<br>• Ensured awareness of the BC stock management (H)<br>• Ensured awareness of the impact of lockdown on blood delivery (H)<br>• Potentially reduced O neg stock levels (BC-H)<br>• Influenced behaviour towards good BSC practices (H)<br>• Potentially reduced patient misidentification (H)<br>• Reduced complacency towards blood transfusion (H) | • Potential improvement of BSA |
| | • Ensured appropriate order (H)<br>• Ensured supply of blood in lockdown (H) | • Assurance of BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured the delivery of blood (NHSBT-H)<br>• Ensured improved services affecting patients (NHSBT-H)<br>• Ensured appropriate use of blood (NHSBT-H)<br>• Ensured supply of blood whenever needed (NHSBT)<br>• Ensured received complaints (H)<br>• Ensured compliance with blood safety regulation (NHSBT-H)<br>• Ensured accuracy of delivery (H)<br>• Ensured blood availability when there is no transfusion alternative (NHSBT-H)<br>• Ensured understanding on blood safety guidelines (H)<br>• Ensured understanding on checking patient identification (H)<br>• Ensured patient safety (H)<br>• Ensured understanding of the BSC practices in hospitals (NHSBT)<br>• Ensured standardised BSA (H)<br>• Ensured fulfilment of blood needs (H)<br>• Assured BSA during emergency events (H)<br>• Assured blood availability across a range of operational situations (H)<br>• Ensured investigation of complaints from hospitals (H)<br>• Ensured blood stock sufficiency (NHSBT-H)<br>• Ensured fulfilment of forecasted hospital demand (NHSBT)<br>• Ensured timely delivery and sufficient stock (NHSBT-H)<br>• Ensured back to normal placement of orders after emergency events (H)<br>• Ensured the fulfilment of patients' needs during emergency events (NHSBT-H)<br>• Prevented radical changes in blood testing policy (NHSBT-H)<br>• Avoided wastage (H)<br>• Ensured understanding of emergency planning (H) | |
| | • Replenished stock (H)<br>• Reduced stock levels (H)<br>• Reduced O neg usage (NHSBT-H)<br>• Minimised wastage (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of blood shortage plans (H)<br>• Ensured awareness of changes in BSC practices affecting demand and supply (NHSBT-H) | • Potential adjustment of operations towards BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured awareness of BSA issues significantly affecting hospitals (H)<br>• Ensured awareness of actions during big predictable events (H)<br>• Ensured awareness of changing services during bank holiday (H)<br>• Ensured awareness of the possibility of increased stock levels and wastage (H)<br>• Ensured awareness of the possible delay of orders (H)<br>• Ensured awareness of the restored services to hospitals (H)<br>• Potentially reduced wastage (H)<br>• Potentially reduced O neg stock levels (NHSBT-H)<br>• Potentially reduced O neg usage (NHSBT-H) | |
| | • Suboptimal solution to blood safety issues (H)<br>• Unresolved BSA issues (NHSBT-H) | • No realised improvement of BSA |
| | • Staff unaware of updated BSA issues (H)<br>• Staff unaware of standardised BSA (H)<br>• Potentially complacent about blood supply (H)<br>• Lack of understanding on the updated BSA issues (H) | • No potential improvement of BSA |
| | • Insufficient blood for transfusion (H)<br>• Wasted blood (NHSBT-H)<br>• Incorrect blood component transfused (H)<br>• Wrong order and use of blood products (H)<br>• Inappropriate order (NHSBT-H) | • No adjustment of operations towards BSA |
| High tempo | • Ensured understanding of the hospitals' BSA problems (NHSBT)<br>• Recalled products (NHSBT-H)<br>• Ensured patients' safety due transfusing of the recalled product (NHSBT-H)<br>• Ensured appropriate order of blood (NHSBT-H)<br>• Ensured actions on blood shortage (H)<br>• Confirmed product substitution when stockout (NHSBT-H)<br>• Discarded recalled products (H)<br>• Ensured timely response to product recall (NHSBT-H)<br>• Ensured appropriate alternative supply (NHSBT)<br>• Confirmed actions on stockout (NHSBT-H) | • Assurance of BSA |
| | • Reduced stock levels (H)<br>• Reduced wastage (NHSBT) | • Adjustment of operations towards BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured awareness of blood shortage (H)<br>• Ensured awareness of overstock (H)<br>• Ensured awareness of changes in BSC practices affecting demand and supply (NHSBT-H)<br>• Potentially reduced wastage (H)<br>• Potentially adjusted delivery (NHSBT-H)<br>• Ensured awareness of changes in delivery (H) | • Potential adjustment of operations towards BSA |
| Emergency | • Undisrupted orders (H)<br>• Avoided confusion of changing services to hospitals during emergency (H)<br>• Ensured immediate response to urgent orders (H)<br>• Confirmed order (H)<br>• Ensured timely delivery (H)<br>• Ensured appropriate actions to ensure BSA during emergency (H)<br>• Ensured placement of order during emergency (H)<br>• Ensured the urgency of blood supply to hospitals (NHSBT-H)<br>• Ensured appropriate delivery to hospitals (H)<br>• Ensured alternative supply sources (H)<br>• Assured blood sufficiency during emergency (H)<br>• Prevented disrupted orders (NHSBT-H) | • Assurance of BSA |
| | • In time delivery of blood (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of delayed delivery (H)<br>• Ensured awareness of BSA issues during emergency (H)<br>• Ensured awareness of supply risks during emergency (H)<br>• Understood BSA issues during emergency (NHSBT-H)<br>• Discussed updated blood safety issues (NHSBT-H) | • Potential adjustment of operations towards BSA |

**Table E-5: Changes in blood safety and availability in the EC 2-1**

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| Normal | • Understood BSA problems in hospitals (BC)<br>• Understood trend in blood usage (BC)<br>• Ensured awareness of BSA problems (BC-H)<br>• Ensured awareness of blood usage in the hospital (BC)<br>• Ensured awareness of the blood safety incidents (BC) | • Potential improvement of BSA |
| | • Ensured actions following training in BSA practices (H)<br>• Ensured appropriate BSA practices (H)<br>• Ensured order accuracy (BC-H)<br>• Confirmed blood order (H)<br>• Ensured blood shelf life before ordering (H)<br>• Confirmed blood incompatibility results (H)<br>• Ensured blood availability in high tempo events (BC-H)<br>• Resolved issues with recalled products (BC-H)<br>• Ensured blood quality (H)<br>• Ensured blood safety and availability (BC-H)<br>• Controlled temperature (H)<br>• Ensured blood availability before ordering (H)<br>• Prevented stockout during high tempo (BC-H)<br>• Ensured safety of transfusion (H) | • Assurance of BSA |
| | • Fulfilled orders (H)<br>• Replenished stock (H)<br>• Replaced orders (H)<br>• Returned products (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of stock level status (H)<br>• Ensured awareness of possible reactions to transfusion (H)<br>• Ensured awareness of order lead time (H)<br>• Ensured awareness of planned and targeted blood donation (BC)<br>• Ensured awareness of the new blood management guidelines (H) | • Potential adjustment of operations towards BSA |
| | • Potentially unmatched demand and supply (BC-H)<br>• No understanding of blood usage pattern (BC-H) | • No potential improvement of BSA |
| High tempo | • Confirmed reasons for product recall (BC-H)<br>• Confirmed use of replacement donor (H) | • Assurance of BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Confirmed wrong label (BC-H)<br>• Recalled product (BC-H)<br>• Confirmed blood availability in the blood centre (H)<br>• Ensured placement of order (H) | |
| | • Confirmed actions on BSA issues (H)<br>• Replaced orders (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of BSA issues (BC) | • Potential adjustment of operations towards BSA |
| Emergency | • Fulfilled need for blood during emergency (H) | • Adjustment of operations towards BSA |
| | • Ensured awareness of incompatible blood (H) | • Potential adjustment of operations towards BSA |

**Table E-6: Changes in blood safety and availability in the EC 2-2**

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| Normal | • Ensured awareness of the blood usage in the hospitals (BC)<br>• Understood trend of hospitals' need for blood (BC)<br>• Potentially prevented overstock (BC) | • Potential improvement of BSA |
| | • Ensured provision of blood from BC (H)<br>• Ensured blood safety during transportation (H)<br>• Ensured patients' safety (H)<br>• Cancelled orders (BC-H)<br>• Resolved BSA issues (H)<br>• Ensured blood availability before ordering (H)<br>• Ensured supply of fresh blood for specific patients (H)<br>• Ensured provision of blood during high tempo events (H)<br>• Ensured blood safety supplied to hospitals (H)<br>• Ensured placement of order (H)<br>• Ensured compliance with blood safety standard (H)<br>• Ensured long-dated stock levels (H)<br>• Confirmed blood order (H) | • Assurance of BSA |
| | • Ensured awareness of the blood stock level status in the blood centre (H)<br>• Ensured awareness of training events (H)<br>• Ensured awareness of the importance of sharing blood needs and usage information (H) | • Potential adjustment of operations towards BSA |
| | • Short-dated stock (H)<br>• Overstock (BC)<br>• Wasted blood (BC)<br>• Unused reserved blood (BC)<br>• Unfulfilled blood needs (H) | • No realised improvement of BSA |
| | • Potentially unused blood usage information (H)<br>• Potentially unimproved BSA (BC-H)<br>• Potentially unaware of BSA issues (BC-H)<br>• Potentially overstock (BC) | • No potential improvement of BSA |
| | • Unquestioned blood usage in hospitals (BC-H) | • No assurance of BSA |
| High tempo | • Ensured provision of rare negative rhesus blood (H)<br>• Ensured provision of blood in high tempo events (H) | • Assurance of BSA |

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| | • Ensured appropriate use of blood (BC)<br>• Ensured blood availability (H)<br>• Ensured placement of order (H)<br>• Prevented blood safety incidents due to quality issues (H)<br>• Returned product to blood centre (H) | |
| | • Ensured awareness of blood shortage (H) | • Potential adjustment of operations towards BSA |
| | • Potentially unfulfilled order (H) | • No assurance of BSA |
| | • Potentially unaware of blood shortage in blood centre (H) | • No potential adjustment of operations towards BSA |
| Emergency | • Fulfilled need for blood during emergency (H) | • Adjustment of operations towards BSA |

## Table E-7: Changes in blood safety and availability in the EC 2-3

| Contexts | BSA performance | |
|---|---|---|
| Operational conditions | Changes in BSA (affected actors) | Classified changes in BSA |
| Normal | • Confirmed availability and readiness of ordered blood (H)<br>• Confirmed delay of blood supply (H)<br>• Ensured accuracy of ordered blood (H)<br>• Confirmed blood availability (H)<br>• Confirmed use of blood (BC)<br>• Ensured blood safety and availability particularly in emergency conditions (H) | • Assurance of BSA |
| | • Ensured awareness of the planned donation (BC)<br>• Ensured awareness of the proper blood handling (H) | • Potential adjustment of operations towards BSA |
| | • Potentially unaware of BSA issues (BC-H) | • No potential improvement of BSA |
| | • Potential delay of transfusion (H)<br>• Potential blood safety incidents (H) | • No adjustment of operations towards BSA |
| | • Potentially unaware of expired blood (H) | • No potential adjustment of operations towards BSA |
| High tempo | • Confirmed cause of reaction to transfusion (BC-H)<br>• Confirmed blood availability following delay in supply (H)<br>• Confirmed blood availability (H)<br>• Cross-checked incompatibility of blood (BC-H)<br>• Consulted reactions to transfusion (H) | • Assurance of BSA |
| Emergency | • Prevented blood safety incidents (H) | • Assurance of BSA |
| | • Fulfilled need for blood during emergency (H) | • Adjustment of operations towards BSA |

# Appendix F Examples of supporting evidence with CIMO logic in each embedded case

## Table F-1: Examples of supporting evidence with CIMO logic in EC 1-1

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | Weak signal of blood quality issue; telephone; hospital→blood centre; *ad hoc* | Being precautious of the weak signal of blood quality issue | Precaution | PF+ | Prevented potential safety incidents (BC-H) | Assurance of BSA | "Sometimes people just don't like the look of something. And you know if you don't like the look of a product, people phone up and say you know I don't like the look of the product. But it's not often that we get a quality problem." *INT – Blood Transfusion Coordinator and Quality Lead WH Hospital* | WH Hospital (INT 1, WT 1) |
| | Blood safety incidents; SHOT website; hospital→NHSBT via SHOT; annually | Formal reporting of blood safety incidents | Failure reporting | PF+ | Lessons learned from reported safety incidents (NHSBT-H) | Potential improvement of BSA | "We report everything as required to SHOT and the MHRA all the errors and SHOT reportable incidents." *WT – Chief Biomedical Scientist the Transfusion Manager W Hospital* | SG Hospital (INT 2; WT 1; DCMT 1), W Hospital (WT 1), FP Hospital (INT 1) |
| | Blood management update; regional transfusion committee meeting and email; NHSBT→hospital; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured awareness of blood safety tests (H) | Potential improvement of BSA | "We get updates from them, they attend things like the regional transfusion committee and they sit on the regional transfusion team and I also sit on the regional blood bank managers group. So we get verbal updates from them as well as we get the electronic email that comes out called "the update". Yes so we get something called "the update" so that would tell us any sort of information they want us to know. But it's generalised information about our NHSBT, such as the HCV negative blood or anything, any courses they might be running, so they do send out an electronic communication called the update and we get that." *INT – Blood Transfusion Coordinator and Quality Lead WH Hospital* | BC 1-1 (INT 4), SG Hospital (INT 2; WT 1), WH Hospital (INT 2), FP Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | Order information; OBOS; hospital→blood centre; daily | Ignoring unspecified request for fresh blood | Scepticism | RS+ | Ensured appropriate order of blood (BC-H) | Assurance of BSA | "Yeah, they do have the ability to put a maximum life on their order. Sometimes they just say fresh as possible. If they say fresh as possible then w e ignore it. Sometimes there is a clinical need for w hat actually needs to be. If they are doing for instance the sickle cell exchange then the unit normally needs to be w ithin, less than 7 days old. But from their point of view if you look, it also puts the date of time of transfusion, so 12th. So because otherw ise there is alw ays a chance that w e w ould send them platelets that is expiring today because it's only sort of 11 o'clock in the morning. But so they tell us that and then w e give them some units expiring tomorrow ." *WT – Hospital Services Team Manager BC 1-1* | WH Hospital (WT 4), SG Hospital (INT 3), BC 1-1 (WT 2) |
| | NHSBT service; transfusion practitioner regional meeting; NHSBT↔hospital; quarterly | Discussing NHSBT service | Checks and balances | RS+ | Ensured service level on BSA (NHSBT-H) | Assurance of BSA | "Well w e meet their representative so there is a regional group [...]. But it's the southern region laboratories come together, meet, and discuss. Not alw ays stocks, it's more laboratory things, so interesting antibodies, but there is a representation from NHSBT there and w e discuss their service and w hether we want them to improve, w hat they do for us or anything like that. So they are represented and they are represented on TP regional meetings so w e are sort of split into regions." *INT – Transfusion Practitioner FP Hospital* | SG Hospital (INT 6), FP Hospital (INT 4), WH Hospital (INT 2), BC 1-1 (INT 1) |
| | Blood stock levels, usage, and w astage; BSMS VANESA; hospital→NHSBT; daily | Sharing daily blood stock levels, usage and w astage to NHSBT | Transparency | SO+ | Understood trend in blood stock levels, usage, and w astage (NHSBT-H) | Potential improvement of BSA | "That said w e used the blood stocks management system and w e record that every day of w hat our stock levels are w hat w e've issued what we've transfused w hat w e've wasted. So that is a w ay of telling NHSBT but it's via the blood stock management and VANESA rather than directly to the blood centre." *INT – Chief* | SG Hospital (INT 8; WT 4), W Hospital (INT 4), FP Hospital (INT 2), WH Hospital (INT 1; WT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | *Biomedical Scientist the Transfusion Manager W Hospital* | |
| | BSA issues; hospital transfusion committee meetings; NHSBT↔hospital; quarterly | Regularly sharing BSA issues | Regularity of interactions | SO+ | Continuous awareness of BSA issues (NHSBT-H) | Potential improvement of BSA | "NHSBT patient blood management is invited to our hospital transfusion committee meetings which are every quarter. […] So they are part of our hospital transfusion committee meeting so they can feed in from NHSBT and take any of our issues back as part of that meeting. […] We talk about wastage, we talk about usage, we talk about changes to the system, any quality issues, any recall events, any shortages et cetera. So we have a, you know, an agenda meeting. Any new documents that are being produced and that were required for use, any difficulties we have." *INT – Chief Biomedical Scientist the Transfusion Manager W Hospital* | FP Hospital (INT 8), SG Hospital (INT 4; WT 5), W Hospital (INT 4), BC 1-1 (INT 2), WH Hospital (INT 1) |
| | Blood availability and need; n/a; NHSBT↔hospital; constantly | Constantly liaising on blood availability and need | Real time interactions | SO+ | Ensured blood availability (H); fulfilled need for blood (H) | Assurance of BSA; adjustment of operations towards BSA | "So it's constantly NHSBT liaise with us about what they've got available, we liaise with them about what we need." *WT – Transfusion Practitioner SG Hospital* | SG Hospital (WT 1; DCMT 2) |
| | Order information; OBOS; hospital→blood centre; *ad hoc* | Being responsive in addressing increase in wastage | Ongoing operational adjustments | SO+ | Reduced wastage (H) | Adjustment of operations towards BSA | "So if the wastage starts creeping up then obviously we start looking at what we need to do to bring the wastage down. So for example on one of our other sites, we were repeatedly wasting B positive units and that particular site has a high haemato-oncology cohort of patients. So we decided that we would only stock irradiated B positive units and therefore the wastage then decreased again. So we actively monitor it the whole time, that's my team that monitor it. But I wouldn't be involved in the actual ordering of it because that's just done via OBOS and the online thing, we will just order through that." | SG Hospital (INT 3; WT 2), WH Hospital (INT 1; WT 1), FP Hospital (INT 1), W Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | *INT – Blood Transfusion Coordinator and Quality Lead WH Hospital* | |
| | Short-dated blood; telephone; blood centre→hospital; *ad hoc* | Notifying the hospital to confirm the delivery of short-dated blood | Alertness | HI+ | Ensured shelf life of ordered blood (BC-H) | Assurance of BSA | "They have an obligation to give us blood that has a reasonable date if w e ask for specific bloods. So w e have a patient w ith an antibody and w e need a special blood for that patient, and it's a little bit short date they'll let us know , or they say to us "look w e've got some O neg that's a bit short-dated, would you accept it". You know , because if your usage is enough that you w ould go through it, it's just about w ho's going to use it. So they w ill alw ays let us know if it's a bit short-dated […] they'll often phone and ask us." *WT – Transfusion Practitioner FP Hospital* | BC 1-1 (INT 3; WT 2; AR 2), SG Hospital (INT 2), WH Hospital (INT 2), FP Hospital (INT 1) |
| | Changes in hospital practices; telephone; hospital→blood centre; *ad hoc* | Notifying blood centre on the changes of practices that affect demand and stock management | Contribution, representation, and subordination of actions | HI+ | Ensured aw areness on changing practices affecting demand and stock management (BC); stabilised stock level (H) | Potential adjustment of operations tow ards BSA; adjustment of operations tow ards BSA | "Because a hospital practice influences NHSBT, so again every year as part of the process, I say to anticipate any changing practice. So for example if w e suddenly took on liver transplant, w e would order lots more FFP. So, therefore w e would flag it and then they w ould w ork out you know based on w hat they supply to [the other hospital]. If w e said w e are now gonna be doing a patient a w eek as w ell, they w ill then sort of re-evaluate how they produce their stock, meeting this new demand. So again there is so much interaction." *INT – Transfusion Practitioner SG Hospital*<br><br>"Because as soon as w e started the helicopter project, the first thing I did w as phone up NHSBT and said "just so you know there is this national drive to drive dow n O negative stock holding, I am about to increase mine because w e are going to be supplying the helicopters". So w e update accordingly so w e still get the same amount | SG Hospital (INT 7), WH Hospital (INT 2), BC 1-1 (INT 2; WT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | in our fridge but w e obviously have to up it by the age that w e have out there. But I explained to them w hy I w as doing that and then obviously they mark that dow n on their database so they then understand w hy we order the w ay we order." *INT – Blood Transfusion Coordinator and Quality Lead WH Hospital* | |
| | Order information; OBOS; hospital→blood centre; *ad hoc* | Not questioning seemingly inappropriate orders | No scepticism | RS- | Overstock during Christmas (H) | No adjustment of operations tow ards BSA | "We w ere planning for the 4 day Christmas holiday and w e knew we would have to get some extra blood in. And w e knew we were gonna be relatively short staffed. So somebody placed an order the day before. So in the evening they reviewed the blood stock, review ed what blood w e had you know w hat plan w e had to issue blood and w e knew that w e were going back to the normal surgery list the day after boxing day. So blood w as ordered for the following midday delivery. But there w as an internal breakdow n so then w e had another person place an identical order for red cells and w e ended up w ith an overstock of red cells. And you could argue that the National Blood Service could have queried the fact that there w as too large an order for the same delivery, but they didn't, they just delivered it in good faith and w e ended up w e had blood that w e didn't need to order in, blood for 7 or 8 days after that due to that stocking." *INT – Transfusion Practitioner SG Hospital* | SG Hospital (INT 1), WH Hospital (INT 1) |
| | Changes in delivery arrangement; face to face meetings, email; hospital→NHSBT; *ad hoc* | Not being responsive in addressing complaints and suggestions from the hospital | Negative contribution, representation and subordination of actions | HI- | Unchanged deliveries (H) | No potential improvement of BSA | "The NHSBT as you're probably aw are have this integrated transfusion service, but they are trials. And it has w orked in some places. I w ould like to be able to participate. How ever w e only get one routine delivery a day w hich means that w e can't really participate unless they're going to give us more deliveries. […] I | W Hospital (INT 1), WH Hospital (INT 1), BC-1 (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | think it's NHSBT cost. I would like more deliveries. We have talked about having a change of deliveries. And because we've got internal transport across the two laboratories. I've suggested that we get one delivery in the morning just to get one delivery in the afternoon and we will share then internally with our transport links. But for 10 years I've been asking the NHSBT for this, [but I've] still got nowhere. They are not very proactive if I'm honest. [It was a] discussion with the customer service manager […], face to face or by email." *INT – Chief Biomedical Scientist the Transfusion Manager W Hospital* | |
| High tempo | Severe reaction to transfusion; telephone; hospital→NHSBT; *ad hoc* | Being precautious of the impact of severe reaction to transfusion on other hospitals | Precaution | PF+ | Ensured awareness of contaminated blood (NHSBT); prevented potential blood safety incident (H) | Potential adjustment of operations towards BSA; assurance of BSA | "If we think that it looks like it, say, bacterially contaminated units, we would be talking to NHSBT and highlighting that. And if we had a particularly nasty reaction, we would phone NHSBT up anyway. Because more than one product is made from the one donation and then, that one that we've had particularly nasty reactions to, often NHSBT would then recall all the other products just to be safe." *INT - Blood Transfusion Coordinator and Quality Lead WH Hospital* | SG Hospital (INT 1), WH Hospital (INT 1), BC 1-1 (INT 1) |
| | Blood quality issue; telephone, fax, and email; hospital→blood centre; *ad hoc* | Reporting blood quality issue to blood centre | Failure reporting | PF+ | Potentially recalled product (BC-H) | Potential adjustment of operations towards BSA | "The incident in question was that certain bags of FFP were leaking at the ports. You've got two ports, and on one of the seals there was a little leak. Now you only notice that when you defrost the FFP. And what happened was that we fed back to the National Blood Service that we were getting leakage and their quality system looked for trends. So they were getting reports back, so they then make a decision whether they are gonna recall it or they are just accepting that a certain number of FFP that were gonna leak on defrosting until that particular batch of | SG Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | bags has gone out. So generally there would be a telephone call and that will be backed up with a fax to our secure fax in the lab, plus an email currently goes to the hospital transfusion team." *INT – Transfusion Practitioner SG Hospital* | |
| | Blood shortage and product substitution; fax and email; blood centre→hospital; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured awareness on blood shortage and substitution (H) | Potential adjustment of operations towards BSA | "So generally we will get a fax and an email to say that there is a shortage of the blood component and we are advised to use substitutions." *INT – Transfusion Practitioner SG Hospital* | BC 1-1 (INT 4), W Hospital (INT 3), SG Hospital (INT 3), FP Hospital (INT 2) |
| | Product recall; telephone and fax; blood centre↔hospital; *ad hoc* | Confirming the hospitals' actions on the recalled products | Scepticism | RS+ | Ensured awareness on product recall (BC-H); confirmed the discarding of the recalled product (BC-H) | Potential adjustment of operations towards BSA; assurance of BSA | "And then what we probably do is we probably use this, we probably recall that unit [with 2 temperature excursions] as well because then we'd have written evidence that they discarded that unit because this bit of paper that I showed you, this one it asks us for the fate of that incident. So, they have to put the outcome. So, again from a safety point of view and we have to trust them if they've sent us back and said "discarded", then we have to assume they've thrown it away. So yeah but again most is done by [telephone], this paperwork is sent out by fax following a phone call and then it's faxed back to us." *INT – Hospital Services Team Manager BC 1-1* | BC 1-1 (INT 2), SG Hospital (INT 2), FP Hospital (INT 1) |
| | Stockout and product substitution; telephone; blood centre→hospital; *ad hoc* | Providing general alternative to stockout and product substitution | Checks and balances | RS+ | Ensured blood availability as an alternative for stockout (BC-H) | Assurance of BSA | "Sometimes we ring them up as well because also we are not scientists here within the department. So we don't want to influence their product. So if for instance they want a product that we don't have, rather than say to them "well we haven't got that, we've got this", we don't do that. So we'll say "well we haven't got that, what will you take as a substitution" and let them make their decision. The only thing that we can definitely | BC 1-1 (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | do is offer negative to positive. So that's standard. So if the hospitals are ringing up for an O pos platelet and we haven't got it, we can offer them an O neg platelet without any harm coming to the patient for certain things. So yes, that's the communication just by phone on stock availability." *INT – Hospital Services Team Manager BC 1-1* | |
| | Product recall, outcome of transfusing the recalled product; telephone; blood centre→hospital; *ad hoc* | Being responsive in addressing blood safety problems with recall | Responsive-ness | CR+ | Ensured awareness on product recall (H); prevented blood safety incident (H) | Potential adjustment of operations towards BSA; assurance of BSA | "If it [the recalled product] is transfused and it does happen quite regularly and that's why there is, we are so strict with timings. We got to contact the hospital within an hour of being notified and then the hospital should get back to us because it could be that at the point we contact them, that unit is on its way to a ward, and just about to be going into someone, that's why timing is quite strict. But if it is transfused, then normally the consultant will contact the hospital and discuss the outcome. […] again always by phone, normally." *INT – Hospital Services Team Manager BC 1-1* | SG Hospital (INT 9; WT 1), WH Hospital (INT 8), BC 1-1 (INT 6), W Hospital (INT 3), FP Hospital (INT 2) |
| | Status of and action on the recalled product; fax; hospital↔blood centre; *ad hoc* | Notifying the status of and action on the transfused recalled product | Alertness | HI+ | Ensured awareness of the transfused recalled product (BC); monitored reactions to transfusion due to transfusing the recalled product (H) | Potential adjustment of operations towards BSA; assurance of BSA | "If the [recalled] unit has been transfused to patients, we obviously let them know with the form [fax]. They will then get back in touch with us to say whether we need to inform the patients or not. If the patient has had no reaction to the unit, it may be a decision is taken not to inform the patient." *INT – Transfusion Practitioner SG Hospital* | BC 1-1 (INT 4), SG Hospital (INT 2), WH Hospital (INT 2), FP Hospital (INT 2), W Hospital (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | |
| | Reaction to transfusion; telephone and email; hospital↔blood centre; *ad hoc* | Notifying blood centre on the reaction to transfusion possibly related to bacterial contamination; suggesting actions on reaction to transfusion | Contribution, representation, and subordination of actions | HI+ | Ensured awareness of contaminated blood (BC); confirmed cause of reaction to transfusion (H) | Potential adjustment of operations towards BSA; assurance of BSA | "There would be certain instances when we would need to communicate with NHSBT as well if we thought that the reaction was possibly related to bacterial contamination or transfusion-related acute lung injury. So they would then need to look at their stock, [look] for other donations from that donor, "do we need to recall those from other hospitals?" perhaps. And we would get, the NHSBT consultants would become involved as well and talk us through what we need to get from the patients and what we need to send back and forms to fill in and those sorts of stuff. […] that's generally telephone and email." *INT – Lead Transfusion Practitioner FP Hospital* | BC 1-1 (INT 2; WT 1), WH Hospital (INT 1), FP Hospital (INT 1), W Hospital (INT 1) |
| Emergency | Complete shortage (stockout); email, fax, and telephone; blood centre→hospital; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured awareness of complete shortage (stockout) (H) | Potential adjustment of operations towards BSA | "But if there's a complete shortage, where there is no blood of a particular group, called the shortage of a particular group, then they need to let us know and then they will send us, you know that would be email, fax, telephone call usually to say that they are in a red zone of stock for that particular group." *INT – Chief Biomedical Scientist the Transfusion Manager W Hospital* | W Hospital (INT 2), SG Hospital (INT 1; WT 1), FP Hospital (INT 1) |
| | Order information; telephone; hospital→blood centre; *ad hoc* | Placing emergency order only when the nature of the emergency is clearly known | Scepticism | RS+ | Ensured appropriate order of blood (BC-H) | Assurance of BSA | "We have to telephone the National Blood Service to let them know an incident has been declared. If we've got any information that we can share, we would share it with them. We wouldn't necessarily order more blood stock until we know the emergency. So we would actually pause stuff in as we get feedback we would then update the National Blood Service as to what particular stock we may need. […] generally by telephone." *INT – Transfusion Practitioner SG Hospital* | FP Hospital (INT 2), SG Hospital (INT 1; WT 1), W Hospital (INT 2), BC 1-1 (INT 1) |
| | Order information; OBOS and telephone; | Being responsive in addressing the need | Responsive-ness | CR+ | Ensured awareness on | Potential adjustment of | "So if the patient is O neg and they are bleeding very heavily, then we probably | BC 1-1 (WT 1; DCMT 1), SG |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | hospital→blood centre; *ad hoc* | to order during emergency | | | incoming order during emergency (BC); confirmed order during emergency (H) | operations towards BSA; assurance of BSA | would need to get some blood down very quickly for them. If they are O pos, we've probably get plenty of stock to support them until, and then we may need to get some more afterwards. If someone very complicated, or they are going to [use up] our stock like nobody's business, then we would order blue light from NHSBT. And you have to have a consultant, named consultant, to authorise a blue light delivery. And it's very clear on the OBOS, you can click blue light, you have to put all those details in and then you click send and then you follow it up with a phone call, just to let them know that it's coming through." *INT – Transfusion Practitioner FP Hospital* | Hospital (WT 2), FP Hospital (INT 1), W Hospital (INT 1) |
| | Major incident alert; n/a; hospital→blood centre; *ad hoc* | Alerting blood centre on major incidents | Alertness | HI+ | Ensured blood availability during emergency events (H) | Assurance of BSA | "So if they [authorities] were to put the organisation into lockdown so that we couldn't get into the organisation, the routine work stops because that would then conserve the blood supply. And we would then obviously alert the national blood service as to what we required, that we had some major incidents and then we would ask them for their support and we would be asking them for various products etc." *INT - Blood Transfusion Coordinator and Quality Lead WH Hospital*<br><br>"And things like I think Filton is more of a challenge because when you are looking at a terrorist attack, like the one in Westminster, it's often within about 3 or 4 hours, the hospitals contacted us, we were stood up for a major incident. And then 4 hours later it's finished." *INT – Hospital Services Team Manager BC 1-1* | BC 1-1 (INT 2), SG Hospital (INT 1; WT 1), WH Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | Fridge failure; n/a; hospital→blood centre; *ad hoc* | Notifying blood centre on the fridge failure and the need to move stock | Contribution, representation, and subordination of actions | HI+ | Reduced stock level (H); reduced wastage (H) | Adjustment of operations towards BSA | "The only time that it would involve information sharing with NHSBT is if you ended up with fridge failure or freezer failure. So if we ended up with fridge or freezer failure we of course would notify NHSBT that that's what we'd had because we would be requiring stocks to be coming down quite quickly because obviously we would have just discarded an awful lot of products." *INT - Blood Transfusion Coordinator and Quality Lead WH Hospital* | SG Hospital (INT 1), WH Hospital (INT 1), BC 1-1 (WT 1) |

## Table F-2: Examples of supporting evidence with CIMO logic in EC 1-2

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | BSA errors/problems; regional transfusion committee meetings, SHOT website; hospital↔NHSBT via SHOT; real time, quarterly | Lateral learning on BSA errors/problems | Precaution | PF+ | Lessons learned on BSA performance from other hospitals (H) | Potential improvement of BSA | "Things like the benchmarking are available [on annual SHOT report], you just log on, you pull off your data for your area. And then again we share it and we discuss those things at regional meetings. And it allows us to benchmark ourselves and get a feel for where our errors are occurring and whether we've got a particular problem. It focuses on what area you need to tackle." *INT – Transfusion Practitioner WP Hospital* | WP Hospital (INT 2), NG Hospital (INT 1; WT 1), BC 1-2 (INT 1) |
| | BSA incidents; SHOT report; hospital→NHSBT via SHOT; annually | Formal reporting of BSA incidents | Failure reporting | PF+ | Reported BSA incidents for lessons learned (H) | Potential improvement of BSA | "They [blood safety incidents] are also all reported to SHOT and obviously any delays or failure to supply blood in a timely manner, we will look all of those." *INT – Transfusion Practitioner WP Hospital* | WP Hospital (INT 1), NG Hospital (INT 1) |
| | BSA incidents; SHOT report; hospital↔NHSBT via SHOT; annually | Open to sharing lessons learned on BSA incidents | Openness | PF+ | Lessons learned on BSA incidents (H) | Potential improvement of BSA | "We are really really keen to share lessons learnt. And that's why we don't hide anything. You know we are perfectly happy to hang our dirty laundry up in public. You know yes we've got cases of ours in the [annual] SHOT report, you know we can find them because it's important that as a community as a national transfusion community we learn and we improve. That's actually one of our trust values that we learn and we improve. So we have very open culture for that. *INT – Operational Manager Transfusion and Haematology NG Hospital*<br><br>And we look at that, sort of both, with sort of TP group, but also at the south central RTC [RBTC] that data is reviewed. We also from the regional transfusion committee, we look at wastage, we look at stock holding and all those sorts of parameters. And we discuss those openly at meetings, you know and we | NG Hospital (INT 1), WP Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | try to share good practice. […] so if w e know w e've not done very w ell, w e are quite open about it. And in doing that hopefully w e get sort of ideas from other trusts about how w e can maybe improve practice. *INT – Transfusion Practitioner WP Hospital* | |
| | Routine deliveries, limitation to orders; email and fax; NHSBT→hospital; monthly | Using redundant information sharing media | Redundancy | RS+ | Confirmed deliveries during bank holiday (H); ensured appropriate order of blood during bank holiday (NHSBT-H) | Assurance of BSA | "Well, communication that they send out, communication prior to bank holiday, making it say "this is w hen your routine deliveries w ill be, making request that you only order platelets on a named patients basis", and that kind of thing. […] That's sent by email, yes, and I think they also send by fax at the moment." *INT – Operational Manager Transfusion and Haematology NG Hospital* | NG Hospital (INT 2), SM Hospital (INT 2), WP Hospital (WT 2) |
| | Order information; OBOS; hospital↔blood centre; *ad hoc* | Questioning out of ordinary order | Scepticism | RS+ | Ensured appropriate order of blood (BC-H) | Assurance of BSA | "So w e wouldn't say to the hospital that you need this instead of this. But w e might advise. If w e notice that something is out of the ordinary that they have ordered, w e might question and say "did you w ant to speak w ith the clinician?", and w e might question it and if they order really out of ordinary." *INT – Hospital Services Manager BC 1-2* | NG Hospital (INT 3), BC 1-2 (INT 3) |
| | Short-dated products; telephone; blood centre↔hospital; *ad hoc* | Negotiating order of short-dated products | Checks and balances | RS+ | Ensured usage of short-dated blood (BC-H); prevented potential w astage (H); short-dated stock (H) | Assurance of BSA; adjustment of operations tow ards BSA | "Well NHSBT, the only big overstock situation I remember w as post 2012 Olympics. And as I said if they w anted if we'd ordered 10, let's say for instance we'd ordered 10 A pos, they w ould ring us and say, "are you able to accept them w ith maybe a 10 day expiry". And there w ill be a negotiation, it w ould be "ok, w ell of those 10, w e could accept 4 that are short-dated", for instance. So that w as done over the telephone on a case by case basis." *INT – Operational Manager Transfusion and Haematology NG Hospital* | NG Hospital (INT 3; DCMT 1), WP Hospital (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | Blood stock levels, usage, wastage; BSMS; hospital↔NHSBT via BSMS; daily | Using voluntary platform to monitor blood stocks, usage, and wastage | Transparency | SO+ | Understood trend in blood stock levels, usage, and wastage (NHSBT-H) | Potential improvement of BSA | "The Blood Stocks Management Scheme (BSMS) monitors blood stocks, use and wastage nationally and is a voluntary scheme. Data is collected on Blood Stocks Management Scheme form by the blood bank staff and then submitted to the BSMS on line by BT support worker. Entry to VANESA is password controlled and can be extracted and used for audit purposes." *DCMT – SOP of inputting blood stocks management scheme data onto VANESA NG Hospital* | WP Hospital (INT 2), JR Hospital (INT 1), NG Hospital (DCMT 1) |
| | Blood usage and wastage; email and regional transfusion committee meetings; NHSBT→hospital; monthly, quarterly | Regularly sharing blood usage and wastage information | Regularity of interactions | SO+ | Understood trend in blood usage and wastage (NHSBT-H) | Potential improvement of BSA | "So they send monthly reports, so save us from doing it, they send us monthly reports so we can see exactly what our usage is and wastage and we monitor that and obviously sort of monitor that. […] That's via email and as I said that gets discussed in sorts of regional transfusion meetings. So that's all done between NHSBT and us." *INT – Transfusion Practitioner WP Hospital* | NG Hospital (INT 2), SM Hospital (INT 2), WP Hospital (INT 2) |
| | Stock levels; VMI information system; hospital→blood centre; every 30 minutes | Having real time information sharing on stock levels | Real time interactions | SO+ | More effective stock replenishment (BC-H) | Realised improvement of BSA | "So NHSBT [has] our access to what my stock levels are. And they can see them so they get a download of what my stock is every 30 minutes. So they've got plenty of data if they wanted to use it. I guess they would ask my permission if they wanted to use it other than for replenishment purposes, but they never have." *INT – Laboratory Manager JR Hospital* | BC 1-2 (INT 3), JR Hospital (INT 2), NG Hospital (INT 2), SM Hospital (INT 1) |
| | Blood usage; n/a; hospital→blood centre; *ad hoc* | Addressing changes in platelets usage | Ongoing operational adjustments | SO+ | Adjusted (increased) stock level (H) | Realised improvement of BSA; adjustment of operations towards BSA | "It's, our thing recently has been platelets, platelets have been, this is obviously because they've got a short shelf life anyway. We did go through a period where we were using a lot of *ad hoc* deliveries so we were feeding that back and obviously NHSBT are aware that we are using a lot of *ad hoc* deliveries. And through discussion with our | SM Hospital (INT 3), NG Hospital (INT 1; WT 2), WP Hospital (INT 1; WT 1), JR Hospital (INT |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | customer service manager w e actually decided to hold a stock of platelets. And now w e've adjusted that to hold the stock, tw o stock platelets over the w eekend. So that's something w e've been able to put in place, feeding back and forth betw een ourselves and NHSBT." *INT – Lead Biomedical Scientist SM Hospital* | 1), BC 1-2 (INT 1) |
| | Stock increase plan, overstock implication, issuing short-dated products; regional transfusion managers meetings; NHSBT→hospital; *ad hoc* | Making hospital aw are of stock increase plan, overstock implication, and issuing short-dated products due to Olympics | Contribution, representation , and subordination of actions | HI+ | Increased aw areness of increased stock levels and reduced shelf life (H) | Potential adjustment of operations tow ards BSA | "But w e were as a regional group of transfusion lab managers, w e meet w ith, w e try to meet w ith NHSBT 2 or 3 times a year, sometimes w e only manage it once. But w e do try and meet. And I remember, excuse me, being made aw are prior to the 2012 Olympics that NHSBT w ere planning a stocking increase and they, and they also [expected] to use the implication post Olympics if their stocks haven't been required and the fact that there w ould be a reduction in red cells age issue. And also that they w ould telephone us if they w anted to issue particularly large amounts of particularly short-dated products. So they made us aw are of that ahead of the situation and it's exactly w hat happened." *INT – Operational Manager Transfusion and Haematology NG Hospital* | NG Hospital (INT 15; DCMT 1), WP Hospital (INT 1), JR Hospital (INT 1) |
| | Order information; n/a; blood centre→hospital; *ad hoc* | Asking hospital to confirm orders w ith clinician | Expertise-based decision making | DE+ | Ensured appropriate order of blood (BC-H) | Assurance of BSA | "With the concession, yeah, w e wouldn't make that judgement call, it w ould be w ith the clinician. So w e wouldn't say to the hospital that you need this instead of this. But w e might advise. If w e notice that something is out of the ordinary that they have ordered, w e might question and say did you w ant to speak w ith the clinician and w e might question it and if they order really out of ordinary." *INT – Hospital Services Manager BC-2* | BC-2 (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | Stock issue; n/a; hospital→blood centre; *ad hoc* | Collectively working on the ideal blood stock levels | Collective decision making | DE+ | Fixed ideal stock levels (BC-H) | Realised improvement of BSA | "We [the hospital and blood centre] spent a lot of time looking at what our ideal stock levels should be. We actually provided the years of issue data including date and time we are issuing stock." *INT – Laboratory Manager JR Hospital* | JR Hospital (INT 4), WP Hospital (INT 2), NG Hospital (INT 2), SM Hospital (INT 1) |
| | Stock levels and wastage; email; NHSBT→hospital; monthly | Examining information in detail if only having a problem | No scepticism | RS- | Potentially complacent and unaware of detailed BSA issues (H) | No potential adjustment of operations towards BSA | "Just because they take up space and to be honest it's working really well. If I have a problem I will study them in a bit more detail. But I don't have a problem with it, so I just sort of glance at them and delete them. But I could have as many reports, you know, if I want more reports I've just got to send them email and say "can you send me reports on this and that to me?"." *INT – Laboratory Manager JR Hospital* | JR Hospital (INT 1), SM Hospital (INT 1) |
| | Stock levels; VMI and PULSE information systems; hospital→blood centre; real time | No full transparent system to capture hospitals' specific activities | No full transparency | SO- | Overstock (H) | No adjustment of operations towards BSA | "We are not quite there yet not as an integrated […]. So the VMI generates an order straight into PULSE for us. You know the PULSE system, so that generates an order trend so we just go with that and we issue that order. But if on hospital sites they have some stock back from, you know, they have remote fridges, if they have some stocks back from there we can't see that so we can't see their stock levels. So in that, those sorts of instances they might get overstock and we wouldn't necessarily know." *INT – Hospital Services Manager BC-2* | BC-2 (INT 1) |
| | BSA problems; face to face review meetings; hospital→blood centre; *ad hoc* | No continuous flow of information | No fully real time interactions | SO- | Potentially unnoticed BSA issues (BC); staff potentially unaware of updated BSA issues (BC) | No potential improvement of BSA; no potential adjustment of operations towards BSA | "We would talk to NHSBT and mainly it's their information flows from them to us rather than the other way around. So we would talk to our customer service manager at our review, for example I might say "we are having problems with something", we, it's not a continuous flow of information. It's more we | SM Hospital (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | are waiting for them to tell us what they can do essentially." *INT – Lead Biomedical Scientist SM Hospital* | |
| | Changes in stock levels; telephone and email; hospital→blood centre; *ad hoc* | Having transparent but less flexible VMI system for changing stock levels | Less flexibility | SO- | Less flexible changes in stock levels (H) | No potential improvement of BSA | "If you want to sort of change your stock levels, it's not quite as easy. […] If I were to change stock levels and we were doing our own stock, I would just say "we are now having this as our stock level" and tell everybody. I can't do that, I have to ring up NHSBT, email […] NHSBT and discuss it whether they then agree what I want. Now they are very reactive to what I want and they all will, because I rarely move down. So they are very pleased that I am moved down. But it just takes 2 or 3 days to implement [changes in stock levels] whereas before you could fully implement it on the same day if you wanted to. I don't change it that much, but you know that is the slight downside [of VMI]. But the positive around it totally outweighs the negatives." *INT – Laboratory Manager JR Hospital* | JR Hospital (INT 1) |
| High tempo | Blood shortage, limited order; email, telephone, and OBOS; blood centre→hospital; *ad hoc* | Encouraging hospital to avoid unnecessary order | Precaution | PF+ | Ensured awareness on blood shortage (H); ensured appropriate order of blood (BC-H) | Potential adjustment of operations towards BSA; assurance of BSA | "So if we were low on a group of platelets and that was going to continue for a couple of days, customer service will put out an announcement to say that we are particularly low on this product, please could you order for patients only. Sometimes we've done that. […] I think it's both [via email and telephone]. And they can make an announcement on OBOS […] they've got a little section we can put a comment in." *INT – Hospital Services Manager BC 1-2* | WP Hospital (INT 2), BC 1-2 (INT 2) |
| | Blood quality issue; telephone; hospital→blood centre; *ad hoc* | Reporting blood quality issue to blood centre | Failure reporting | PF+ | Ensured awareness on blood quality issue (BC) | Potential adjustment of operations towards BSA | "It would involve information sharing with them if we had a quality issue. So if we detected a quality issue then that would be reported back through our customer, they call customer liaison, hospital liaison, I am not | NG Hospital (INT 2; DCMT 1), JR Hospital (INT 1), WP |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | sure of that. I can't remember their particular, I know who it is, I know it's […], but I don't know her particular title because they keep changing them. But yes, that would be, always be, my first port of call for a particular, if I had a quality issue." *INT – Operational Manager Transfusion and Haematology NG Hospital* | Hospital (INT 1) |
| | Blood shortage; fax and email; blood centre→hospital; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured awareness on blood shortage (H) | Potential adjustment of operations towards BSA | "For instance they've got a shortage of A neg platelets for instance or a shortage of O red cells, they are very good at communicating and they do that via fax and email. So even if I am not here, the fax will come through to the lab. And even though faxes are I think, from an information governance point of view, quite antiquated I suppose, you know we are, most hospitals don't allow the generic profile for an email for instance. So at least having the fax or physical copy of that information arrives in the lab to be actioned even if I am not here, so I think that's actually quite a positive thing really." *INT – Operational Manager Transfusion and Haematology NG Hospital* | NG Hospital (INT 3; DCMT 3), BC 1-2 (INT 3) |
| | Recalled products; product recall form; blood centre→hospital; *ad hoc* | Providing detailed information on actions upon product recalls | Scepticism | RS+ | Ensured awareness on action on product recall (H) | Potential adjustment of operations towards BSA | "The List of Implicated units form [from the blood centre] shows all units that need to be traced." *DCMT – SOP of external product recall NG Hospital* | NG Hospital (DCMT 2), SM Hospital (INT 1) |
| | Offer for stock management advice, stock level review; email and fax; NHSBT→hospital; *ad hoc* | Collectively reviewing and resolving blood stock levels with hospital | Checks and balances | RS+ | Ensured alternative for blood supply when shortage (H); potentially reduced stock levels (NHSBT-H) | Assurance of BSA; potential adjustment of operations towards BSA | "We would get email and fax notification when stocks were getting low. So obviously they monitor things nationally. And when they are getting low on a particular, it's usually a particular group of a particular product, then we'll get notified. And they also request our help and they offer, you know, suggestions for alternatives and ways that we could help review our, they ask us to review our stock | NG Hospital (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | holding, are we able to reduce at all." *INT – Operational Manager Transfusion and Haematology NG Hospital* | |
| | Severe reactions to transfusion; telephone; hospital→blood centre; *ad hoc* | Being responsive in addressing severe reaction to transfusion | Responsive-ness | CR+ | Ensured actions on products causing severe reactions to transfusion (H); investigated products causing severe reactions to transfusion (BC-H) | Assurance of BSA; potential improvement of BSA | "If the patient did have much more severe reactions, then we would contact NHSBT for their advice, we'd actually contact the medic, the NHSBT medic, to ask for their advice and also to ask what they want us to do with the remaining product. Because sometimes they want it back for their own investigation purposes. […] Oh yeah, by phone because it's the most direct, in those situations it's the most direct method of getting in touch with people." *INT – Operational Manager Transfusion and Haematology NG Hospital* | NG Hospital (INT 8; DCMT 1), SM Hospital (INT 4), WP Hospital (INT 4), JR Hospital (INT 1), BC 1-2 (INT 1) |
| | Serious reaction to transfusion; telephone and email; hospital↔blood centre; *ad hoc* | Deference to expertise to decide whether to have product recall | Expertise-based decision making | DE+ | Confirmed product recall (BC-H) | Assurance of BSA | "So if we have a serious reaction, so the protocol is that we would contact NHSBT. They would give us the name of the consultant haematologist on call for NHSBT and they review that reaction with us. And then they will make the decision as to whether that unit needs to be recalled or not. If they want it recalled, we obviously quarantine that unit, already quarantined. And then they will send a box, we pack it and everything, it goes back to NHSBT, and then they will culture the units and then NHSBT send us the report back on their findings. […] So it's a telephone conversation. And occasionally they might ask for additional information via email." *INT – Transfusion Practitioner WP Hospital* | WP Hospital (INT 1), NG Hospital (INT 1) |
| | Stock level review; email and fax; blood centre→hospital; *ad hoc* | Collectively reviewing and resolving blood stock levels with the hospital | Collective decision making | DE+ | Potentially reduced stock levels (BC-H) | Potential adjustment of operations towards BSA | "We would get email and fax notification when stocks were getting low. So obviously they monitor things nationally. And when they are getting low on a particular, it's usually a particular group of a particular product, then we'll get notified. And they also request our | NG Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | help and they offer you know suggestions for alternatives and ways that we could help review our, they ask us to review our stock holding, are we able to reduce at all. So yeah, it's a two way process." *INT – Operational Manager Transfusion and Haematology NG Hospital* | |
| | Product recall; telephone and fax; NHSBT→hospital; *ad hoc* | Notifying hospital on the product recall | Alertness | HI+ | Ensured awareness of recalled products (H) | Potential adjustment of operations towards BSA | "NHSBT will notify the laboratory if there is a recall on any product. This contact is by phone and is followed with a fax and that should arrive directly to the Transfusion laboratory fax." *DCMT – SOP of external product recall NG Hospital* | NG Hospital (INT 1; DCMT 1), SM Hospital (INT 1), WP Hospital (INT 1) |
| | Blood shortage; email; NHSBT→hospital; *ad hoc* | Notifying hospital on the status of the stock levels | Contribution, representation, and subordination of actions | HI+ | Ensured awareness of blood shortage (H); ensured appropriate order of blood (NHSBT-H) | Potential adjustment of operations towards BSA; assurance of BSA | "Obviously we get communication from NHSBT with regard to shortages, if they are running into a difficulty in supplying, for example, I don't know, A negative platelets for example, they'll send emails out to us saying, "actually we are experiencing shortages in A negative platelets". So under those circumstances we try not to order that product unless we absolutely have to." *INT – Transfusion Practitioner WP Hospital* | NG Hospital (INT 4), SM Hospital (INT 1), WP Hospital (INT 1), BC 1-2 (INT 1) |
| Emergency | Order information; OBOS and telephone; hospital→blood centre; *ad hoc* | Using redundant information sharing media; being aware of lack of resources during overnight operations to pick up order information | Redundancy; scepticism | RS+ | Ensured awareness of emergency order and delivery (BC); ensured blood availability during emergency (H) | Potential adjustment of operations towards BSA; assurance of BSA | "And then in the emergency situations, we still use OBOS, but we also follow that up with the phone call to NHSBT, to our issue department directly, hospital services I believe they are called now. We ring them directly because you know we are aware, certainly overnight, there might only be one person, one member of staff. They are maybe in a fridge somewhere stocking up. They may not notice the order coming through on OBOS. So we always follow up for emergencies with the phone call." *INT – Operational Manager Transfusion and Haematology NG Hospital* | NG Hospital (INT 3; DCMT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | Order information; OBOS and telephone; hospital→blood centre; *ad hoc* | Being responsive in addressing the need to order during emergency | Responsive-ness | CR+ | Ensured awareness of emergency order and delivery (BC); ensured blood availability during emergency (H) | Potential adjustment of operations towards BSA; assurance of BSA | "So anything that's urgent, so if we blue light, if we are blue lighting then we phone and if it's out of hours then we phone. Because they are not waiting for orders to come through, whereas obviously during the day they are expecting the orders to come through." *INT – Lead Biomedical Scientist SM Hospital* | NG Hospital (INT 1; DCMT 2), SM Hospital (INT 1), WP Hospital (INT 1) |
| | Status of the operations during flood disaster; email; NHSBT→hospital; regularly | Continually informing hospital on the status of the unexpected event | Alertness | HI+ | Ensured awareness of the status of emergency event (H) | Potential adjustment of operations towards BSA | "They were amazing; they were absolutely amazing during that. Communication was very fluid, we were informed regularly by email what was going on and we noticed absolutely no disruption to our blood supply at all and I did feed that back to them because I thought that was absolutely outstanding service, not we had noticed no difference at all." *INT – Operational Manager Transfusion and Haematology NG Hospital* | NG Hospital (INT 4), SM Hospital (INT 2), JR Hospital (INT 2) |

## Table F-3: Examples of supporting evidence with CIMO logic in EC 1-3

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | Blood safety incidents; SHOT symposium, SHOT annual report; hospital↔NHSBT via SHOT; annually | Regularly discussing blood safety incidents as lessons learned | Precaution | PF+ | Lessons learned from blood safety incidents in hospitals (H) | Potential improvement of BSA | "So incidents, there is you know, there is a SHOT symposium which is every year and that is, it's held in July and it's a national. That's where all the incidents that happen due to blood and blood products are shared. So all the incidents that we report into SHOT and MHRA are then discussed there and you have a handbook or a report, SHOT report for each year of where the incidents happen and how many. I have got the SHOT report, I can show you the 2015. So it was, they are anonymous, it's just letting people know that maybe somebody, so many hospitals had wrong blood in tube, somebody was given the wrong blood, somebody died from a transfusion reaction. So all those things are shared and discussed at the annual meeting." *INT – Blood Transfusion Operations Manager QA Hospital* | QA Hospital (INT 5), BNH Hospital (INT 3), RB Hospital (INT 1) |
| | Patient blood test results; fax; NHSBT→hospital; *ad hoc* | Using fax for sharing patient blood test results when they are not available on Sp-ICE | Redundancy | RS+ | Confirmed blood test results (H); securely accessed blood test results (H) | Assurance of BSA; potential adjustment of operations towards BSA | "So when we haven't got an NHS.net account you can't be transferring information, patients' information, via email because it can be intercepted. So we use fax very rarely really because for [blood test] result from NHSBT there is Sp-ICE which is electronic. And we only want them to fax us interim results if they are not available on Sp-ICE." *INT – Blood Transfusion Operations Manager QA Hospital* | QA Hospital (INT 1) |
| | Confirmation on *ad hoc* or routine delivery; telephone; blood centre→hospital; *ad hoc* | Confirming the need for *ad hoc* or routine delivery | Scepticism | RS+ | Confirmed *ad hoc* or routine delivery (H) | Assurance of BSA | "When we do meet that trigger point, they will either top up by ringing us and saying "do you want an *ad hoc* delivery?" or they'll say "right you know that's gonna come up on a routine delivery", which is twice a day." *INT – Transfusion Head Biomedical Scientist and* | QA Hospital (INT 2), RB Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | *Clinical Transfusion Services Manager RB Hospital* | |
| | Blood w astage; BSMS, email; hospital↔NHSBT; monthly | Keeping hospitals in check to ensure accountability | Checks and balances | RS+ | Prevented w astage (H) | Assurance of BSA | "Well BSMS is like an accountability isn't it? So it means you are recording, because at the end of the day blood and platelets are donations. Somebody [gives] their, their time you know . So, you don't w ant to be w asting it. You w ant to utilise it as best as you can. So, that BSMS helps a lot in giving us accountability. So w hen you have those transparency figures and you can see how much you are w asting and when we have summary reports like [the NHSBT administrator sends] us. It's those things that make you share the information, keep you in check I think." *INT – Blood Transfusion Operations Manager QA Hospital* | QA Hospital (INT 4; WT 1), BNH Hospital (INT 1), RB Hospital (INT 1) |
| | Blood w astage, stock levels; BSMS, email; hospital↔NHSBT; monthly | Providing benchmarking report on hospitals' blood w astage | Transparency | SO+ | Lessons learned from trend in w astage and stock levels across hospitals (H) | Potential improvement of BSA | "Built into that [VANESA] are reports from the NHSBT w hich indicate on a regular basis our w astage levels and our O level, O negative stock level, and w here we are, again comparing us w ith the recommended level so that w e can compare ourselves with other trusts in the south central region particularly, and also nationally. […] We get a monthly report from the NHSBT administrator for south central. […] That's sent through email." *INT – Transfusion Operations Manager BNH Hospital* | QA Hospital (INT 5), BNH Hospital (INT 3), SHG Hospital (INT 1) |
| | Soon to be expired stock; email; blood centre→hospital; daily | Regularly sharing information on soon to be expired stock | Regularity of interactions | SO+ | Ensured aw areness on the soon to be expired stock (H); more stabilised stock level (H) | Realised improvement of BSA | "But then w e have a daily thing that's sent to us from NBS [NHSBT], its this one [via email]. And then this is a stock in hand and expiry time for us. So, it basically tells us really w hat w e've got in the fridge every morning, about 7.30 in the morning." *WT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital* | RB Hospital (INT 2; WT 3), BC 1-3 (INT 3), BNH Hospital (INT 1; DCMT 2), SHG Hospital (INT 2), QA Hospital (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | "And so every day I do get an email from them telling me what stock is expiring and we're topped up automatically to our basic stock level that's been agreed with them." *INT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital* | |
| | Stock levels; VMI-ITS; hospital→blood centre; every 30 minutes | Having real time information sharing on stock levels | Real time interactions | SO+ | More stabilised stock levels (H) | Realised improvement of BSA | "They [the blood centre] see it through the virtual system. They can see what's in my fridges and what's available stock. So what they can't see is when we issue some blood or some platelets or some fresh frozen plasma, they will see that being removed from our stock and then it will hit the trigger point and at that point, so every 30 minutes they're checking, "have you met that trigger point or not [to be replenished]?"." *INT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital* | RB Hospital (INT 3; WT 2), SHG Hospital (INT 4), BC 1-3 (INT 1) |
| | The need to increase stock level; n/a; hospital→blood centre; *ad hoc* | Being responsive in addressing changes in stock levels | Ongoing operational adjustments | SO+ | Increased stock levels (H); more stabilised stock levels (H) | Adjustment of operations towards BSA; realised improvement of BSA | "So if we had lots of concerns and we were running low down here, we would communicate with NBS [NHSBT] and say "well we're not very happy with this, we need to increase our stock holding, we're not happy to go as low as 20". But you can see that they're managing to keep us between those lines most of the time." *WT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital* | RB Hospital (INT 2; WT 3), QA Hospital (INT 2), BNH Hospital (INT 1), SHG Hospital (INT 1) |
| | Soon to be expired stock; VMI-ITS; blood centre→hospital; *ad hoc* | Reminding hospital to use soon to be expired stock | Alertness | HI+ | Ensured usage of soon to be expired blood (H); prevented wastage (H) | Assurance of BSA | "So when the national blood service [the blood centre] can interrogate our stock, when we have the system in place, they'll be able to see "oh you've got ten O negs that are gonna expire in two days, maybe we'll send | RB Hospital (INT 3; WT 2), SHG Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | them a reminder to use them".” *INT – Blood Transfusion Section Manager SHG Hospital* | |
| | Changes in hospitals practices; n/a; hospital→blood centre; *ad hoc* | Ensuring the sharing of information on changes in hospitals' practices that affect demand for blood | Contribution, representation, and subordination of actions | HI+ | Ensured awareness of updated changes in hospitals' practices (BC); potentially changed demand for blood (BC-H) | Potential adjustment of operations towards BSA | “In terms of sharing information with hospitals, yes, it's all important. We've got to do several things. One is we need hospitals to be talking to us. When trusts are merged and changed and trauma centres are set up like [this hospital] here for example that changes the demand. And it's also as I was explaining, we've got 15 distribution centres, but only five processing centres. So those five processing centres are splitting what their processes are between 15 distribution points. So the equitable distribution of work in progress stocks is all important to us. So we must have information from our hospitals, accurate information from our hospitals, in terms of any future changes that might change the demand that our hospitals might make and so on, so forth.” *INT – Hospital Services Manager BC 1-3* | BNH Hospital (INT 4), BC 1-3 (INT 1) |
| High tempo | Blood quality issue; n/a; hospital→blood centre; *ad hoc* | Being precautious in addressing blood quality issue | Precaution | PF+ | Prevented blood safety incidents (H) | Assurance of BSA | “We would have shared that information [blood quality issue] with NHSBT. We would raise a complaint or contact form with them, with the quality department. And they would send us their reference number and their actions and if necessary we will report that to MHRA. We need to make sure because you know one donation can be split into various components. So we need to make sure that no other hospitals got the other part of that component, which could be adversely affected as well. So the NHSBT are our point of reference for that.” *INT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital* | RB Hospital (INT 1), SHG Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | Reactions to transfusion; telephone, email, fax; hospital→blood centre; *ad hoc* | Reporting blood safety and quality issues to blood centre | Failure reporting | PF+ | Confirmed actions on blood safety incidents (H) | Assurance of BSA | "Say it's something like we think we've had a reaction that might be related to an infected unit, we'd go straight to NHSBT consultant. So we have those numbers, it's a verbal conversation, we'll telephone them and have a discussion about what needs to be done. Going on from there, then there will be a written confirmation, email and faxes, or that sort of thing following up on the incidents." *INT – Blood Transfusion Section Manager SHG Hospital* | QA Hospital (INT 3; WT 2), SHG Hospital (INT 2), RB Hospital (INT 2), BNH Hospital (INT 1) |
| | Product recall; telephone, fax, email; hospital↔blood centre; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured awareness of product recall (BC-H); ensured accuracy of product recall information (BC-H) | Potential adjustment of operations towards BSA; assurance of BSA | "We let them know if we've got an issue in the same way as they let us know if it's been an issue with other components via their recall process. And we experienced a number of those. So again we have a process in place for when NHSBT recall components. […] We telephone initially, if it's an NHSBT recall, they tend to phone and then fax. We'll receive and send it back. Erm if it's us querying a unit, again we will phone them and they will send us a fax again to recall it. So it's telephone and fax." *INT – Transfusion Operations Manager and Senior Biomedical Scientist BNH Hospital*<br><br>"They [NHSBT] send us forms that we have to fill in that we will email or fax back. There is a written, but it is via email or fax and also by telephone conversation if we want advice or we want to alert them quickly. "We think there is a problem with this unit number", that will be a telephone conversation initially and the same back to us if they know there is a problem they will phone first and say "unit number, whatever", you need to do a recall and they will send us the fax written copy as well. So we've got not just the verbal cause you know you can't quite often hear when | BNH Hospital (INT 2; DCMT 2), QA Hospital (INT 3), SHG Hospital (INT 3) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | somebody says something to you over the phone, there can be an error in w hat somebody hears to w hat somebody said. So a "g", they think it's a "t" or w hat happened. So w e get both the verbal and the w ritten coming through afterwards." *INT – Blood Transfusion Section Manager SHG Hospital* | |
| | Stock management status, appropriate order; n/a; blood centre→hospital; *ad hoc* | Ensuring appropriate order during high tempo condition | Scepticism | RS+ | Ensured appropriate order of blood (BC-H) | Assurance of BSA | "A lot of hospitals stock themselves, especially major trauma units like [this hospital] here, they stock platelets and they stock red cells. And w hen they stock, they w ant long life products. There is no point in them purchasing from us a stock item that expires tomorrow . So they w ant long life product. But over Christmas periods for example, w e w ant our customers not to be ordering long life products. We w ant them to be using the stocks as they turn. We regularly, as a matter of process, issue an instruction, "w e are in FIFO situation, please don't order for stock, if you do order for stock then give us a justification and a reason", and so on and so forth." *INT – Hospital Services Manager BC 1-3* | QA Hospital (INT 5), BC 1-3 (INT 1) |
| | Stock levels; VMI information system – ITS; hospital→blood centre; *ad hoc* | Having real time information sharing on stock levels | Real time interactions | SO+ | Replenished stock (H) | Adjustment of operations tow ards BSA | "Again going forward w hen w e've signed, once w e've completed this project, they w ill know and w e'll have a red level set and w e'll get an immediate delivery for if w e get into low level stock." *INT – Blood Transfusion Section Manager SHG Hospital* | SHG Hospital (INT 1) |
| | Order information; OBOS; hospital→blood centre; *ad hoc* | Addressing changes in stock levels | Ongoing operational adjustments | SO+ | Increased stock levels (H) | Adjustment of operations tow ards BSA | "Yeah w e have to place an order there. So they know that Fridays w ill actually have an increased order because there is no coverage for the w eekend or for the bank holiday." *INT – Blood Transfusion Operations Manager QA Hospital* | QA Hospital (INT 1) |
| | Blood safety and quality issues, product | Being responsive in addressing blood | Responsive-ness | CR+ | Confirmed actions on blood | Assurance of BSA | "Say it's something like w e think w e've had a reaction that might be related to an infected | QA Hospital (INT 6), BNH |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | recall; telephone, email, fax; hospital↔blood centre; *ad hoc* | safety and quality issues with recall | | | safety and quality issues (H); discarded recalled products (H) | | unit, we'd go straight to NHSBT consultant. So we have those numbers, it's a verbal conversation, we'll telephone them and have a discussion about what needs to be done. Going on from there, then there will be a written confirmation, email and faxes, or that sort of thing following up on the incidents." *INT – Blood Transfusion Section Manager SHG Hospital*<br><br>"And also if there is a product recall, say the NHSBT finds a reactive patient and they phone us to say "can you, we are recalling this product, take it out of stock!" We will quickly take it out of circulation and quarantine it or waste it according to instruction from NHSBT, so that it doesn't get given the patient." *INT – Blood Transfusion Operations Manager QA Hospital* | Hospital (INT 2; DCMT 2), SHG Hospital (INT 4), BC 1-3 (INT 1) |
| | Blood shortage; letter; blood centre→hospital; *ad hoc* | Notifying hospitals on blood shortage and the timescale of shortage period | Alertness | HI+ | Ensured awareness of blood shortage (H) | Potential adjustment of operations towards BSA | "So if we've been short, if NHSBT is short of a particular group, then they will send us a letter saying, "we inform you we're short of this" and the likely timescale." *INT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital* | QA Hospital (INT 3), BNH Hospital (INT 3), RB Hospital (INT 1), BC 1-3 (INT 1) |
| | Blood shortage and usage; email and fax; blood centre→hospital; *ad hoc* | Warning the hospital on low stock levels and appropriate use of blood | Contribution, representation, and subordination of actions | HI+ | Ensured awareness of blood shortage (H); ensured availability of limited blood stock (BC-H); ensured appropriate use of blood (BC-H) | Potential adjustment of operations towards BSA; assurance of BSA | "National blood service [NHSBT] are very good at keeping us up to date with what their stock levels are like and issuing us warnings to be careful of what we're using. "So if you can use something [else] please do because we're low on the stock level of X". So it's a balancing, at sharing information between the two of us, communicating to make sure that we protect the stock that's available and that it goes to the right people. So if we could use something else instead because stock is low then we will. And we'll do that by | BC 1-3 (INT 3), QA Hospital (INT 1), BNH Hospital (INT 1), SHG Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | communicating closely with the national blood service. […] Via email and fax usually. So they send us, like, an emergency warning. "So, we're low on stock of A neg platelets, could you please do, X, Y, and Z", then we will do." *INT – Blood Transfusion Section Manager SHG Hospital* | |
| Emergency | Order information; telephone and OBOS; hospital→blood centre; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Fulfilled need for blood during emergency (H); ensured timely delivery (H) | Adjustment of operations towards BSA; assurance of BSA | "We might have to, if it's really really urgent, we might have to order some by picking up the phone and ordering on OBOS. Because it won't be that quick if it's really really an emergency. So if it's a massive, a major incident for example, then part of our action is to ring the NBS [blood centre], say we are in a major incident. And they'll automatically give us some boxes of blood that they would send to us. So, ya, that wouldn't be dealt with via ITS [VMI]. I mean ITS is working all the time. But because it's only a snapshot every half hour, an hour, that's not quick enough if you've got a major incident going on, you need to get your stock much quicker, so we'd need to ring and use OBOS, we call them." *WT – Transfusion Head Biomedical Scientist and Clinical Transfusion Services Manager RB Hospital* | BNH Hospital (INT 6), QA Hospital (INT 1; WT 1), RB Hospital (WT 2) |
| | Order information; OBOS and telephone; hospital→blood centre; *ad hoc* | Ensuring the order is received and confirmed | Scepticism | RS+ | Ensured awareness of urgent order (BC); confirmed order (H) | Potential adjustment of operations towards BSA; assurance of BSA | "If we get a blue light for example, we'd order on OBOS but we then follow it up with the phone call just to make sure they've seen it, they know it's an urgent request and they are aware of it, in case they are busy doing something else, we tend to follow them up. Or if we are finding a particularly unusual [situation] to us in the lab we'll say "we've ordered this, can you make sure it's ok, gives us a call back if it's not"." *INT – Senior Biomedical Scientist BNH Hospital* | BNH Hospital (INT 3), QA Hospital (WT 3) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | Unexpected event, delivery placement; telephone; blood centre↔hospital; *ad hoc* | Being responsive in addressing changes in delivery placement during emergency | Responsive-ness | CR+ | Ensured awareness of the unexpected event (H); ensured awareness of the changes in delivery placement (BH) | Potential adjustment of operations towards BSA | "The one that we have from Filton, you know we were involved obviously with Filton [flood] and then they kept us up to speed. But the local distribution centres were able to supply our components and but yes we were informed and across the trust […]. We'd also be communicating with the NHSBT to say that "all of the deliveries and the components will be going to one site". And we may well be looking at shipping components temporarily back to them for storage and then bringing them back. […] It tends to be phone because in those sort of circumstances we'll tend to need an immediate response or rapid response and I think relying on email I think is not conducive for speedy action." *INT – Transfusion Operations Manager BNH Hospital* | BNH Hospital (INT 2), QA Hospital (INT 1; WT 1); RB Hospital (INT 1; WT 1), SHG Hospital (INT 2), BC 1-3 (INT 2) |
| | Major incidents; n/a; hospital→blood centre; *ad hoc* | Alerting blood centre on major incidents | Alertness; contribution, representation, and subordination of actions | HI+ | Ensured awareness of major incidents (BC) | Potential adjustment of operations towards BSA | "So an external major incident, such as a motorway pile up or a plane crash, or something like that. Then essentially the hospital would create a major incident, first of all they will be the main source. The hospitals declare major incidents, they then have an obligation to inform each and every supplier that they have, that they are a part of that major incidents supply chain. So if [this hospital] got information to say, "look we've had a plane crash at Eastleigh Airport, we're declaring a major incident", they're obligated to inform us, I am then obligated to instigate the major incident plan in our organisation." *INT – Hospital Services Manager BC 1-3* | RB Hospital (WT 2), BNH Hospital (INT 1), QA Hospital (WT 1), SHG Hospital (INT 1), BC 1-3 (INT 1) |

**Table F-4: Examples of supporting evidence with CIMO logic across the BSC in the MC-1 (strategic view of Central NHSBT)**

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | Lessons learned from blood safety incidents; regional transfusion practitioner meetings; hospital→NHSBT; quarterly | Sharing lessons learned from blood safety incidents in meetings | Precaution | PF+ | Discussed near misses (NHSBT-H) | Potential improvement of BSA | "So w e support regional transfusion practitioner meetings and they may have tw o or three four meetings a year in each region and a lot of those agendas. I've got standing agenda items of lessons learnt or you know things that w ent wrong, kind of thing, and they have, they are very informal and they're not minuted those sort of sections. But they w ill sit and share problems, you know , we will encourage that and support that and facilitate, often w e organise those days for them and get them to talk about things, sort of near misses particularly, have something could have been, gone w rong etc." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 10; DCMT 2; ARTF 1) |
| | Blood safety incidents, near misses; hospital transfusion committee meetings, regional transfusion committee meetings, national committee meetings; hospital↔NHSBT; quarterly | Openly sharing blood safety incidents and near misses | Openness | PF+ | Lessons learned from blood safety incidents (NHSBT-H) | Potential improvement of BSA | "When w e go to the hospitals' transfusion committees, they alw ays have incidents on their agendas and they w ill openly talk about things that have gone w rong or near misses and stuff, and we will sort of talk on the back of w hat we see from other hospitals and if that's any different. So, it's discussed a lot, locally, regionally, nationally." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 2) |
| | Delivery plan during the high tempo; planning questionnaire, telephone, face to face meetings, w eb-based Q and A; NHSBT↔hospital; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured timely delivery and sufficient stock (BC-H) | Assurance of BSA | "Receiving hospitals w ere consulted, and an engagement plan created, to communicate and agree on how NHSBT and hospitals w ould operate together during the [Olympic] games to deliver timely and sufficient supplies. Various channels of communication w ere developed including: planning questionnaires provided to all hospitals involved, telephone and face-to-face meetings w ith laboratory leads and a | NHSBT (INT 11; ARTF 1; AR 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | dedicated web-based question and answer portal." *ARTF – Glasgow et al. (2014:5), Going for gold: blood planning for the London 2012 Olympic Games, Transfusion Medicine, April 2014* | |
| | Alternative for ordered blood; n/a; blood centre→hospital; *ad hoc* | Ensuring that the ordered blood is suitable for patients' conditions | Scepticism | RS+ | Ensured appropriate order (H) | Assurance of BSA | "We then need to make sure we provide to that order something that is suitable to be transfused to the patient. The hospital then has to make sure that what we've given them is suitable and they transfused to the right patient the right way. […] So there's all sorts of checks along the way. So if we were saying "you've asked for item A but we're going to give you item B", we've got to be assured that item B is a safe alternative for A. And the hospital has also got to be certain that item B is a safe alternative for product A." *INT – Head of Hospital Customer Service NHSBT* | NHSBT (INT 19; AR 3; ARTF 2) |
| | Emergency planning; hospital visit; NHSBT↔hospital; *ad hoc* | Using hospital visit as a way to obtain an absolute outcome from information sharing | | | Ensured understanding of the BSC practices in hospitals (BC); ensured understanding of emergency planning (H) | Assurance of BSA | "When I am planning with somebody and I need an absolute outcome, I usually go and visit them and sit with them. A letter might be good enough for certain things that they are very familiar with. But usually when I am going into a blood bank, emergency planning really isn't their thing. So I will go and I will sit down because then they can ask me questions and I've got an advantage over other emergency planners and business continuity people in as much as I used to work in a transfusion laboratory. So I actually understand what their reality is, a bit out of date now, but I do understand a bit of what their reality is. And so when they ask questions, I feel much more able to cope with those, so that's quite helpful. So I am helpful to, sort of, take that with me and I know that's also bringing baggage, but sometimes the | |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | baggage is actually helpful bizarrely in these circumstances. But that w ay I can interact w ith them and I can say w hy things are important and they can understand it. And so that interaction has to happen much much more closely." *INT - Assistant Director Governance and Resilience NHSBT* | |
| | Blood usage; n/a; NHSBT→hospital; *ad hoc* | Reverse marketing the blood products to hospitals and patients | Checks and balances | RS+ | Ensured appropriate use of blood (NHSBT-H) | Assurance of BSA | "We're also looking at different wastage and ordering patterns from hospitals; and talking to them about that. So if they're using a lot of negative blood for example w e would highlight that there's a target w hen you met [my colleague]. Part of her team is looking at people that use more than w e think they should. And w e're talking about the reasons w hy and see if there's anything can be done to reduce their use because it's a more rare, rare is probably the w rong word, but less plentiful supply because it's universal. So you're looking at, making sure you bring in enough supply to meet demand and also looking at w hat you can do to suppress demand and w here that's appropriate and safe to do so." *INT – Head of Hospital Customer Service NHSBT* | NHSBT (INT 25; AR 12) |
| | Blood safety incidents; regional transfusion practitioner meetings; NHSBT→hospital; quarterly | Making hospitals less complacent about the safety of blood transfusion | | | Lessons learned from blood safety incidents (H); reduced complacency tow ards blood transfusion (H) | Potential improvement of BSA | "So, w hen something goes w rong, everyone suddenly goes, "oh my god that could have been me", you know . When everything, the thing about transfusion it is actually really safe, as much as I go on about it, it is very safe compared to a lot of other things that happen to patients. So, people w ill become quite complacent because you can give transfusions for 20 years and never see a reaction and never have a problem and you become like "ya another transfusion, w hatever" so you become really complacent about the checks that you should do. And | |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | you think "ah the blood's safe, there is no point in doing this observation, it's fine". But, if you suddenly have an incident in a trust, somebody dies, it really w akes everybody up. And it's those stories and those lessons that you've learned that are the best w ay of sharing that back, really. […] Very regularly. At the regional meetings, so w e support regional transfusion practitioner meetings and they may have tw o or three four meetings a year in each region, and a lot of those agendas I've got standing agenda items of lessons learned or, you know , things that w ent wrong, kind of thing." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | |
| | Trend in blood usage in hospitals; national O neg group meeting; NHSBT↔hospital; *ad hoc* | Collectively discussing how to solve unusual trend in blood usage problems | Transparency | SO+ | Reduced O neg usage (NHSBT-H) | Adjustment of operations tow ards BSA | "So, w e do at local level, w e'll do it regionally, and w e can do it nationally as w ell. So, w e have an, obviously an issue w ith O neg that is the percentage is climbing. So w e have a national O neg group and w e bring hospitals' staff into that group as w ell as NHSBT staff and w e look at the data together and say "w hat can we do nationally to trying to alter this?" *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 5; AR 1) |
| | Blood usage and w astage; BSMS; hospital↔NHSBT; regularly | Regularly sharing blood usage and w astage | Regularity of interactions | SO+ | Understood trend in blood usage and w astage (NHSBT-H) | Potential improvement of BSA | "There is lots of information shared coming back in from hospitals. They give us information about their w astage right there. Some information about usage. And that's shared. Have you spoken to [my colleague] at all? A lady that [created] this Blood Stocks Management Scheme and she provides a lot of data. Data comes from hospitals. It's analysed [and] given back to hospitals [at] an individual and aggregate level to help them understand their daily use and w astage. So w e're providing, w e process information on | NHSBT (INT 23; AR 17) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | behalf of hospitals and share [back].” *INT – Head of Hospital Customer Service NHSBT* | |
| | Stock levels; VMI; hospital↔blood centre; real time | Having real time information sharing on stock levels | Real time interactions | SO+ | Mapped stock (BC); replenished stock (H) | Realised improvement of BSA; adjustment of operations towards BSA | “So we, through the blood stock management scheme, where we take some information from hospitals throughout the vendor managed inventory project, we're mapping stock and topping up stocks as a sharing of information backways.” *INT – Head of Hospital Customer Service NHSBT* | NHSBT (INT 2) |
| | Blood usage and wastage; BSMS; hospital↔NHSBT; real time | Having real time information sharing on blood usage and wastage for control and benchmarking purposes | | | Lessons learned from trend in blood usage and wastage across hospitals (H) | Potential improvement of BSA | “So the hospitals can look on that [BSMS] at any point, they can compare themselves with other people, they can look at issues for typical trusts like themselves or there are trauma units […]. So they can go on that and look at issues, they are encouraged to go and enter their wastage as well because otherwise we don’t know what they’re wasting. So we will encourage them to put their wastage on there and again they can compare themselves with like hospitals and say do we waste more or less, you know, and they can see what groups they are wasting.” *INT – Head of Hospital Customer Service NHSBT* | |
| | Unusual trend in blood usage; telephone, hospital visit, email; NHSBT→hospital; *ad hoc* | Being responsive in addressing unusual trend in blood usage and changes in practices in hospitals | Ongoing operational adjustments | SO+ | Ensured appropriate use of blood (NHSBT-hospital) | Assurance of BSA | “And every member of my team around the country will look at, every month they’ll look at hospitals in their region and they know who the high users are, they know who the maternity hospitals are, they know who the trauma centres are. So they can sit and track that pattern very easily. And then if they see someone who is out of [kilter] or whose practice appears to have changed, they can ring the hospital up, they can go on a visit, and they can raise it on a one to one, discuss it with them, they can send emails, you know. So they are tracking it and checking all the | NHSBT (INT 8; AR 2; DCMT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | time." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | |
| | Stock levels; BSMS, w ebsite; NHSBT→hospital; real time | Ensuring the resilience of blood supply by sharing stock levels to hospitals | Readiness | CR+ | Assured blood availability across a range of operational situations (H) | Assurance of BSA | "So w hat we tend to do is, w e tend to provide assurance on w here we have got resilience. […] We w ill also share w ith them w hat our blood stocks are. So there is the blood stock management scheme w here we share all of that sort of information and w e tell them w hat our stock is, in fact w e publish it on the Internet to make sure that they understand this. And of course that's remarkably important because it's not just a case of saying "w e've got plenty", actually the resilience of the w hole blood system relies on our stock. And that's w ider than just the English NHS, because of course we've got reciprocal arrangements w ith the other UK blood services. And of course as w e are 85% of the UK, our stock is really quite important. So w e make sure that it's very w idely shared." *INT – Assistant Director Governance and Resilience NHSBT* | NHSBT (INT 3; ARTF 4) |
| | Changes in hospitals' operations; face to face meeting; hospital↔NHSBT; *ad hoc* | Being involved in deciding the future demand for components from hospitals | Collective decision making | DE+ | Forecasted needs for blood (BC-H) | Realised improvement of BSA | "We also get involved w ith, because we're in hospitals a lot of the time speaking to hospitals, w e get involved w ith trying to decide w hat the demand for future components is as w ell. So w e keep [updated] in terms of w hat's happening clinically and if there is a new development coming out or changes in treatments, that kind of thing, then w e bring that intelligence back into the organisation to help plan for w hat sort of components they're gonna need in the future. […] It might be that w e then […] don't issue much […] in the future. So w e know, we will also feed that back into the organisation and help the organisation plan w hat they're gonna need in the future." *INT – National Lead* | NHSBT (INT 5) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | *Patient Blood Management Practitioner Team NHSBT* | |
| | Transfusion risk; patient information leaflet; NHSBT→hospital; *ad hoc* | Making hospitals and patients aware of the harmful effect of transfusion potentially resulting in death | Alertness | HI+ | Ensured awareness on the fatal risk of transfusion (H) | Potential improvement of BSA | "We have put that, and we've just changed the wording, in the patients information leaflets and it's the first time whether actually there was written the word "death" in the patients' information leaflets. Because you have to know in terms of the rules and the law around consent, patient consent, you have to actually, have to say if there is a risk of death you have to say there is and there is a risk of death. So we, but it must be really hard for patients to try to you know understand you know the risks etc. […] because it's risky, you know it's liquid transplant effectively, it's how we would describe it. You wouldn't have a kidney transplant if you didn't need one, so don't have a blood transfusion if you don't need one." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 9; AR 1) |
| | Warning on blood shortage; email, fax, website; NHSBT→hospital; *ad hoc* | Notifying hospitals on the potential shortage of blood supply | Contribution, representation, and subordination of actions | HI+ | Ensured awareness on the potential shortage of blood supply (H) | Potential adjustment of operations towards BSA | "Outside of that we would be communicating with things that are a bit more unusual, so urgent. So we're going to run short of something. Our systems are broken down. That sort of thing. So we do so there's the proactive communication out to hospitals in a more measured way and then a reactive communication to allow them, to help them to be aware of challenges that we're facing so they can help manage the impact on them and we can work together. […] That's generally shared by emailing out, we fax out, which I know is probably old school, but it's a very low tech high resilience solution. We've got a website where we would post and do post information on the website." *INT – Head of Hospital Customer Service NHSBT* | NHSBT (INT 21; AR 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | Changes in the blood components; OBOS, training; NHSBT→hospital; *ad hoc* | Notifying any operational changes in advance to hospitals | | | Ensured awareness of the updated BSA issues (H) | Potential improvement of BSA | "Information we share out to the hospitals where we share a lot of information about our, what changes we are making to our components so they understand how to use components. If we're launching new components, if we're changing our computer system for example, there is an online blood ordering system. So if we're making a change, would give advance notice to give the hospital a chance to use the test system to test to see if there's any process changes they needed to document. And I have the chance to document and train their staff because any changes to, any changes that we make to something has to be replicated and may have to be replicated in a change process in the hospital, and then have to validate that process and sign it off." *INT – Head of Hospital Customer Service NHSBT* | |
| | Blood supply; n/a; hospital→NHSBT; *ad hoc* | Potentially being complacent about blood as a key supply to hospitals | No scepticism | RS- | Potentially complacent about blood supply (H) | No potential improvement of BSA | "Now the NHS has issued guidance to hospitals which says they ought to have business continuity systems in place and therefore for any of their key suppliers they should be communicating with them to make sure that they have got a reasonable resilience around that key supply. My guess is that most them haven't thought about blood as a key supply. And the reason why they probably haven't thought about blood as a key supply is essentially because we are actually quite good at what we do, we don't let them down very often. So I imagine that they've started off looking at those people where the supply is, shall we say, a little more fragile. So the idea is that all of those hospitals as it were, can come to us and say "have you got good business continuity plan, can you continue to provide?" etc. etc. In order to meet that demand, we felt that | NHSBT (AR5; INT 4) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | because what we could have done is we could have just issued them with all of our business continuity plan, that's a folder about [showing the thickness of the folder by hand]. Now not only is it a ridiculous amount of information, actually it's not terrifically helpful information either because it's not the sort of things that they would understand particularly. It's a different mode of operations therefore it would be unfamiliar, it would be difficult for them to assess whether it was appropriate." *INT – Assistant Director Governance and Resilience NHSBT* | |
| | BSA issues; regional transfusion committee meetings; NHSBT→hospital; quarterly | Like being spoon fed - inactivity to find information independently | No checks and balances | RS- | Lack of understand-ing of the updated BSA issues (H) | No potential improvement of BSA | "We shouldn't have to be spoon feeding this [standardised] information because they can go on to the blood stock management scheme and get it for themselves, but they don't. You know they expect us to turn up to their committee and give them a piece of paper […], a nice picture and they can see it, you know. But, so, they could get that information but they like to be spoon fed, they've got so used to us going to them and giving them information that if we don't turn up they just sort of sit there and don't have it quite often. So that's a bit of our own fault as well. But as I say, we need to know from them what they need now and in the future. And they need to understand you know the issues that are going on in the blood service as well. So, it really is two way and it's vital really." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 2) |
| | New blood safety policy to replace testing; national transfusion committee meeting; | Having a feeling of knowing the best and not involving hospitals in the new safety policy | | | Suboptimal solution to blood safety issues (H) | No realised improvement of BSA | "It [information sharing] is vital really, that we cannot work together enough on really. And we, sometimes we don't work early enough on things. So for example, within the organisation not long ago they were thinking | |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | NHSBT↔hospital; *ad hoc* | | | | | | about doing pathogen inactivation and rather than doing testing, they w ere gonna do pathogen activation of platelets w hich was a different process all together. So they started to look at the organisation that w ould be doing that and w hat would be the cost, you know , w hat would be the operational issues around it. And they started to do quite a lot of w ork on that before they even w ent to hospitals and said “w hat do you think, how w ould this affect you, what are your issues around this?” And w hen they did go, the first presentation they did w as at the national blood transfusion committee last year. […] The hospital people on that committee w ere saying “w hy don’t you come to us w hen you’re thinking about this? This is all gonna be a big problem for us, have you thought about this, have you thought about that?” And the guy, poor guy, w ho w as presenting w ent you know [surprised face] like this. He w as like “oh my goodness, how , you know , w e haven’t thought about that, w e haven’t, you know ”. So I think sometimes, I think w e do consult and I think it’s vital that w e consult w ith them and have that tw o w ay information flow . But sometimes w e think w e know best and w e do stuff and don’t involve them early enough actually. But then, then you have the discussion, so okay, if w e went back six months and said “right w e’re going to have a think about, you know , pathogen inactivation, please could tw o or three lab managers just come to Birmingham for a couple of days to do a couple, do a w orkshop on what this might look like”, they are not able to do it, they haven’t got the time, they haven’t got the funding, they can’t get released. So [w e] are trying to involve at the early discussion | |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | stages when we're still just thinking about it, but how can't they afford that time to come out of their trusts to give us that input?" *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | |
| | Blood volume; n/a; blood centre→hospital; *ad hoc* | Not updating information on the blood volume with the new tested one | No real time interactions | SO- | Insufficient blood for transfusion (H) | No adjustment of operations towards BSA | "A neonatal exchange transfusion was required because of maternal red cell antibodies causing haemolytic disease of the fetus and newborn (HDFN). The volume required to undertake the exchange was calculated by the clinical area and this amount was ordered from the transfusion laboratory. Unfortunately, when the unit was re-processed by the Blood Service to provide the correct specification for the procedure, the initial volume was printed on the label, not the new (lower) volume with the result that the neonate received an exchange transfusion with insufficient blood." *Bolton-Maggs and Ball (2016:104), Annual SHOT Report 2016* | NHSBT (AR 1) |
| | Problems with O neg in the hospitals; n/a; NHSBT→hospital; *ad hoc* | Not being responsive in addressing problems with O neg | No ongoing operational adjustments | SO- | Unresolved BSA issues (NHSBT-H) | No realised improvement of BSA | "Going back years ago, you know, resources were much easier to find, people had more money, more time, could get released for committee meetings, that kind of thing, we could afford to pay their train fares, you know they could get backfill you know, it was easier. Now as resources get tighter and tighter, it's much harder to engage with the customers. You know if we say, if we notice they've got a problem on O neg or something like that and we want to go and talk to them, they might say, like, I am just too busy, I can't talk to you. I know I have got an O neg problem, I haven't got time to talk to you. So we can't always have that discussion with them because they're just fire-fighting really." | NHSBT (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | |
| | Wastage; email; NHSBT→hospital; *ad hoc* | Seeing NHSBT as being critical to hospitals | Negative contribution, representation, and subordination of actions | HI- | Unresolved BSA issues (BC-H) | No realised improvement of BSA | "I think sometimes they see us as being a bit critical. So, some of the big trusts that have, say, high wastage, sometimes in order to highlight how much they're wasting, we will turn it into pound signs. So we, you know, we'll look at the blood stock management scheme, information that they've put into the scheme, we'll go and have a look, alright? And then, if they wasted, I don't know 500 units of platelets, we might […], alright, we'll have a look and we might then write to them and say, "do you know you wasted £300,000 this year on chucking platelets in the bin?" And they might be, like you know […], "we know that, we're doing our best", you know. So sometimes they sort of see us being critical of what they do. And all we're trying to do is raise awareness." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 3) |
| High tempo | Delivery planning during high tempo; face to face meeting; NHSBT↔hospital; *ad hoc* | Creating openness climate to discuss delivery plans and problems faced by hospitals during high tempo | Openness | PF+ | Ensured delivery plans during high tempo (BC-H); ensured understand-ing of the BSA problems in hospitals (NHSBT-H) | Assurance of BSA | "I've actually gone in and spoken to laboratory managers, actually planned [the delivery] with them, sat down, discussed the issues, tried to work out what their problems are, that's been quite useful from that point of view. So, but the key for that is to be relatively open within that meeting, but to be clear with them. "Actually we want to box that off, so I am happy to discuss it with you, but remember that actually this is something that the government doesn't want, they don't want the Olympics to be you know super super imposed on some sort of potential terrorist event. They want everybody to enjoy the Olympics and not worry about the terrorist." You know, so it was that sort of discussion. | NHSBT (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | So it w as quite a boxed off discussion, but nevertheless reasonably open within that discussion as to w hat that might be.” *INT – Assistant Director Governance and Resilience NHSBT* | |
| | Product recall; telephone and email; blood centre→hospital; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured timely response to product recall (BC-H) | Assurance of BSA | “On a much low er level, if it w as, if for example say specific components had to be brought back from the hospital because they might, they might have something w rong with them. It's a recall process and that's led, that's directed from one part of our organisation to the customer directly. It might be they w ould be phoned and sent a w ritten instruction you know by an email so they'd have double communication because you've got to be assured of a response. So w e do that to make, for the certainty of safety of components.” *INT – Head of Hospital Customer Service NHSBT* | NHSBT (INT 2) |
| | Product recall; n/a; blood centre→hospital; *ad hoc* | Discussing the potential impact of potentially harmful recalled product on patients | Scepticism | RS+ | Recalled product (BC-H); ensured patient safety due to transfusing recalled product (BC-H) | Assurance of BSA | “If w e say what might happen w e might find out that a unit might have something potentially w rong with it, might have already been dispatched to a hospital. We w ould go, w e go through this recall process, in w hich w e would send to the hospital the unit number and ask, to ask them w hether it's been used or not. If it's not been used w e w ould tell them to either not use it or hold it and send it back. If it's been used w e would then have to w ork with the clinician, w ould speak w ith them to understand w hether there's been any adverse effect on a patient. In the extreme that could be, could be death. More likely it could be that an ill person gets a little iller, you know , because there's been some sort of contamination that hasn't shown up early enough in w hat we've been doing. | NHSBT (INT 4) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | So that sort of recall process is there." *INT – Head of Hospital Customer Service NHSBT* | |
| | Reasons for wastage; hospital visit; NHSBT↔hospital; *ad hoc* | Discussing reasons for wastage | Checks and balances | RS+ | Reduced stock levels (H); potentially reduced wastage (H) | Adjustment of operations towards BSA; potential adjustment of operations towards BSA | "We also talk to lab managers around stock because if they are holding too much stock and the wastages levels are high, we get data around that. So as part of our visit, we would go, and go to lab managers. And it's not so much, if their wastage is suddenly hugely high, it's just if they have a fridge failure or something like that, if they have a real [reasons]. But if it's sort of trending upward or if it's continually higher than other people, other say comparative hospitals, then we will make an appointment, go to lab managers and discuss the reasons for that. There may be genuine reasons, that suddenly they're building a brand new hospital half a mile away, and people are running up and down the road, and you know whatever. There could be reasons for it, or it could be that there is a new lab manager and they're really out of their depth, so they just thought of doubling what they think they're gonna need as a safety net. So you know, or it can be that the lab managers [are] sick and all the junior staff are running around and trying to sort of manage and so there can be reasons for it but then we will discuss with them. So we look at [factors] contributing to wastage, you need to then audit how much you need and we'll help them you know in terms of reducing that stock again." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 1) |
| | Upward trend of wastage; hospital visit; NHSBT↔hospital; *ad hoc* | Continually monitoring wastage across hospitals | Transparency | SO+ | Potentially reduced wastage (H) | Potential adjustment of operations towards BSA | "We also talk to lab managers around stock because if they are holding too much stock and the wastages levels are high; we get data around that. So as part of our visit, we | NHSBT (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | would go. and go to lab managers. And it's not so much, if their wastage is suddenly hugely high, it's just if they have a fridge failure or something like that [...]. But if it's sort of trending upward or if it's continually higher than other people, other say comparative hospitals, then we will make an appointment, go to lab managers and discuss the reasons for that." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | |
| | Decreasing trend of O neg stock; telephone and email; NHSBT→hospital; *ad hoc* | Being responsive in addressing decreasing trend of O neg stock | Ongoing operational adjustments | SO+ | Ensured awareness of blood shortage (H); ensured appropriate order of blood (BC-H) | Potential adjustment of operations towards BSA; assurance of BSA | "O neg red cells, we start to see that coming down, we start to look at ways in which we can help bring that up, so we're sort of, before we get a problem, we're trying to do some work. And on that call there might be someone from marketing who says we're gonna ring the poly[clinic] and [...] we might say, "right, we're gonna write to hospitals and tell them that we got a problem [...]". We're not saying that we've got shortage, but we're just asking to be extra careful and make sure that they only order it when they need it. So we sort of tackle it from both ends. If we're seeing that the stock is drifting in a particular direction." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 8) |
| | Alternative to out of stock order; telephone; blood centre→hospital; *ad hoc* | Being responsive in offering an alternative for out of stock order | Responsive-ness | CR+ | Confirmed product substitution when stockout (BC-H) | Assurance of BSA | "If we had to we would be, we phone customers in certain circumstances. Particularly those customers where [their requirements] might be high, they might have higher need for a particular thing. And if we can't provide it we will need to be communicating with them. And that can be done partly by the customer service team but also the hospital services team which is a fulfilment team, if you like, they pick and pack the order. And if they haven't got what they | NHSBT (INT 6) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | need they w ould be speaking to the hospital directly saying "I can't give you component A but I could give you B. Will you accept B as a substitution?" So you know that w ould happen." *INT – Head of Hospital Customer Service NHSBT* | |
| | Product recall; n/a; blood centre→hospital; *ad hoc* | Discussing w ith clinician the potential impact of potentially harmful blood for patient | Expertise-based decision making | DE+ | Ensured patient safety due to transfusing recalled product (BC-H) | Assurance of BSA | "We might find out that a unit might have something potentially w rong with it, might have already been dispatched to a hospital. We w ould go, w e go through this recall process in w hich we would send to the hospital the unit number and ask, to ask them w hether it's been used or not. If it's not been used w e would tell them to either not use it or hold it and send it back. If it's been used w e w ould then have to w ork with the clinician, w ould speak w ith them to understand w hether there's been any adverse effect on a patient." *INT – Head of Hospital Customer Service NHSBT* | NHSBT (INT 2) |
| | Blood shortage; email and w ebsite; NHSBT→hospital; *ad hoc* | Notifying hospitals of the blood shortage | Alertness | HI+ | Ensured aw areness of blood shortage (H); ensured actions on blood shortage (H) | Potential adjustment of operations tow ards BSA; assurance tow ards BSA | "When w e get to bank holidays w e alw ays w rite them separately. We can, as w ell as the monthly update, w e will email trusts intermittently like w hen w e have a shortage on the Wednesdays of platelets, you know w e write to them, w e'll email them and w e w ill put things on the w ebsite and stuff, and explain w hat's going on, w hat we're gonna do, and w hat we want them to do." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | NHSBT (INT 2) |
| | Affected blood supply due to sport event; n/a; hospital→NHSBT; *ad hoc* | Notifying NHSBT on the possible impact of the event on blood supply | Contribution, representation, and subordination of actions | HI+ | Potentially adjusted delivery (BC-H) | Potential adjustment of operations tow ards BSA | "So, w hen there was a, the cycling race w ent through Yorkshire or something I can't remember now , there was some cycling event in Yorkshire and some of the main roads w ere gonna be shut. It w as I think it w as actually the hospital that told us that some other deliveries w ould be affected. So | NHSBT (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | they also tell us when things are gonna happen that will affect supply. So it is about, we did try to work with them because you know we can't do anything if they don't comply and if we don't listen to them then they're not gonna get what they want either. So, it has to be a two way flow of information. We don't always get it right but we try to do it." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | |
| Emergency | Order procedure and framework; fax; NHSBT→hospitals; *ad hoc* | Using fax as a back-up when OBOS is down due to cyber attack | Redundancy | RS+ | Ensured placement of order during emergency (H) | Assurance of BSA | "For our hospitals in the south east there was some confusion at first [during the cyber attack] – what was the right paperwork to submit orders? The standard approach is to use our Online Blood Ordering System (OBOS) but with hospitals locked out we faxed the right paperwork to all hospitals for reference." *ARTF – Regional Operations Manager – South East, Manufacturing and Logistics NHSBT, Protect and Serve, Connect Magazine June-July 2017, pp. 8-9* | NHSBT (INT 4; ARTF 1) |
| | Emergency conditions; telephone; NHSBT→hospital; *ad hoc* | Having one to one conversation to explain and try to understand the situation from hospitals' and NHSBT points of view | Checks and balances | RS+ | Ensured awareness of BSA issues during emergency (H); understood BSA issues during emergency (NHSBT-H) | Potential adjustment of operations towards BSA | "I think people who involved, who was, two or three of them who were involved down there and one girl was part of my team. And part of what they did initially was for hospitals that were immediately affected that morning. They rang them all up and they sort of said, "look you know we've got this big problem, we just sent you a communication, a standard communication that we're struggling, but we've got this problem, you know, how are you in terms of stocks, what's going on this morning, have you got any you know foreseen, do you think you're gonna need platelets quickly, have you got, you know, anything?" So we had that conversation on a one to one level with about 30 hospitals that morning to explain, try to | NHSBT (INT 3) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | | |
| | | | | | | | understand, explain to them w hat's happening and to understand w hat issues they w ould have." *INT – National Lead Patient Blood Management Practitioner Team NHSBT* | |
| | Supply source alteration; OBOS or telephone; NHSBT→hospital; *ad hoc* | Being responsive in altering the supply source to other blood centres | Responsive-ness | CR+ | Ensured alternative supply sources (H) | Assurance of BSA | "So w e try and manage that like business as usual. But of course there is an aw ful lot of very rapid information interchange. And so some of their strategic emergency response objectives might be shared all the w ay through. Because w e might be saying to them it didn't happen at, occur at Manchester but w e might be saying to them "you've used up all of the w hatever product it is, w e are backfilling you from Liverpool and Birmingham and New castle", for example so that actually they get, they know that there is something coming. And w e would share that information w ith the hospital again relatively openly. […] The very hot stuff, usually it starts w ith the hospital, so that the channel really is almost dictated by the hospital. So that might be OBOS, in w hich case some of those channels w ill be electronic, or it might be a telephone call, in w hich case some of those channels are going to be that immediate, you know , telephony type channel. So some of that very hot stuff is usually dictated by them." *INT – Assistant Director Governance and Resilience NHSBT* | NHSBT (INT 10; ARTF 4) |
| | Delivery status; telephone; NHSBT→hospital; *ad hoc* | Continually informing hospital on the status of delivery during emergency | Alertness | HI+ | Ensured aw areness of delayed delivery and supply risk during emergency (H); Ensured | Potential adjustment of operations tow ards BSA; assurance of BSA | "We can't avoid this." "We're being as quick as w e can and w e'll update as w e can. But there w ill be delays. And your normal routine deliveries w on't happen quite the same w ay." So w e're telling our customers w hat the impacts are so they can try and manage in their organisation. And in that situation w e probably have those calls maybe a couple | NHSBT (INT 2) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | appropriate actions towards BSA during emergency (H) | | times a day and certainly every day. And you'd be looking at whether you're varying your message to hospitals and whether there's any increased risk to supply to customers." *INT – Assistant Director Governance and Resilience NHSBT* | |
| | Status of the unexpected emergency event; letter; NHSBT→hospital; *ad hoc* | Notifying wider hospitals on the status of the unexpected emergency event | Contribution, representation, and subordination of actions | HI+ | Ensured awareness of the unexpected emergency event (H); ensured blood supply during emergency (H) | Potential adjustment of operations towards BSA; assurance of BSA | "Then we will start to tell hospitals in a wider way and that will be a very light touch. […] You know because when they order stuff it should be coming exactly the same as it was coming before. So the fact that we've lost the manufacturing site shouldn't affect them at all. And indeed it didn't, so that was good. So it's only the local hospitals for whom the transport times are going to have an effect because they are being served by different hospital services departments. So that's why they get to know first, because it will actually materially affect them. Everybody else it's a nice little letter, "you might have heard, we've had a flood", you know that sort of, a nice high level sort of thing." *INT – Assistant Director Governance and Resilience NHSBT* | NHSBT (INT 5) |

## Table F-5: Examples of supporting evidence with CIMO logic in EC 2-1

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | Blood donation plan; written proposal; hospital→blood centre; *ad hoc* | Preventing stockout during Ramadhan | Precaution | PF+ | Prevented stockout during high tempo (BC-H) | Assurance of BSA | "[We organise] a big blood donation session in which our staff are the participants. We make a proposal for the blood centre to organise the big donation session in this hospital to fulfil stockout during Ramadhan." *INT – Laboratory Manager PMU Hospital* | PMU Hospital (INT 1), PW Hospital (INT 1), BC 2-1 (DCMT 1) |
| | BSA issues; hospital visit, written report; hospital→blood centre; quarterly | Reporting blood safety and availability issues to blood centre | Failure reporting | PF+ | Understood BSA issues in hospitals (BC) | Potential improvement of BSA | "[The blood centre] comes to this hospital, checking our needs, any wrong blood groups. They even check any reactions to transfusion. We have the data and we send it to them as well." *INT – Laboratory Manager PMU Hospital* | PMU Hospital (INT 6), KI Hospital (INT 2), PW Hospital (INT 1) |
| | Order information; telephone and order form; hospital→blood centre; daily | Using redundant media to share order information | Redundancy | RS+ | Confirmed blood order (H) | Assurance of BSA | "We use an order form to request blood, because we have an agreement with the blood centre, so we specify how much blood we would like to order. We then phone the blood centre, "from this hospital, we would like to order this many blood packs". Our staff will then go to the blood centre with a box and thermometer, take the order from there." *INT – Laboratory Manager PMU Hospital* | BC 2-1 (INT 1; WT 1), PW Hospital (INT 1; WT 1; DCMT 1), PMU Hospital (INT 1), HM Hospital (INT 1) |
| | Order information; telephone; hospital→blood centre; *ad hoc*, weekly | Checking the availability and shelf life of blood products before ordering | Scepticism | RS+ | Ensured blood availability and shelf life before ordering (H) | Assurance of BSA | "So before ordering, we phone the blood centre first to ensure that the ordered blood is available there." *INT – Laboratory Manager HM Hospital*<br><br>"We phone first [before ordering] […] ensuring if the blood is available, and what is the expiry date, we ensure that." *INT – Laboratory Manager KI Hospital* | BC 2-1 (WT 1; DCMT 2), HM Hospital (INT 1), KI Hospital (INT 1), PMU Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | BSA related concerns; hospital blood bank meetings; training, hospital visit; hospital↔blood centre; quarterly | Auditing processes for ensuring blood safety and availability in hospitals | Checks and balances | RS+ | Ensured appropriate BSA practices (H) | Assurance of BSA | "We go there [to the hospitals], regular visit. […] We visit them every three months; usually it's me and [my colleague]. We then have training for the hospitals' blood banks, if there are any problems. Sometimes we have meetings with the hospitals' blood banks. […] What we do is everything, we socialise about [current blood management policy], and then about making a report, transfusion, we check everything, the cross-match there, stock planning, labelling, everything, blood group [compatibility]. [...] there is a report for the blood safety [in the hospitals that is shared with us]." *INT – Blood Donation and Marketing Manager BC 2-1* | BC 2-1 (INT 2), PMU Hospital (INT 2), KI Hospital (INT 1), PW Hospital (INT 1) |
| | Blood quality management conformance; formal letter; blood centre↔hospital; *ad hoc* | Monitoring blood quality management conformance | Transparency | SO+ | Ensured blood quality (H) | Assurance of BSA | "We also do external quality monitoring with the blood centre. So how is their conformity [with quality]. So for the laboratory process in there, we have to know, certification, also calibration, we have to know everything. That is also related to accreditation. Because we work together with a third party [blood centre], we have to know their quality. For example, whether or not their tools have been certified and calibrated. […] We only exchange letters. From that data [on the letter] we can then cross-check whether that is correct. That's called external quality monitoring." *INT – Medical Consultant HM Hospital* | PMU Hospital (INT 2), HM Hospital (INT 1), PW Hospital (WT 1), BC 2-1 (INT 1) |
| | Blood usage; formal report; hospital→blood centre; monthly | Monthly reporting blood usage to blood centre | Regularity of interactions | SO+ | Ensured awareness of the blood usage in the hospital (BC) | Potential improvement of BSA | "Also for patient surgery, how many used for ob-gyn, CKD [chronic kidney disease], the blood groups, it's there. Because every month we make a report to [the blood centre]." *INT – Laboratory Manager PMU Hospital* | PMU Hospital (INT 2), BC 2-1 (INT 2), PW Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | "It's regular [from the hospital] there is a usage [report] every month. This blood is given to w hom, how many for [patient] surgery." *INT – Blood Storage and Distribution Manager BC 2-1* | |
| | Stock levels; w ebsite, new spaper, social media; blood centre→hospital; real time | Sharing real time information on stock levels | Real time interactions | SO+ | Ensured aw areness of stock level status (H) | Potential adjustment of operations tow ards BSA | "[Hospitals can] monitor [our stock levels] […] [through our] w ebsite, [new spaper]. […] There is an update every day. […] Can you open our Insta[gram]? There is Instagram, tw itter, everything is there. […] If you w ant, you can see how much stocks w e have now." *INT – Blood Donation and Marketing Manager, Blood Storage and Distribution Manager, Project Development Manager, Staff of Blood Testing Department, Quality Control Manager BC 2-1* | BC 2-1 (INT 1) |
| | Order information; telephone; hospital→blood centre; daily | Being responsive in addressing changes in stock levels | Ongoing operational adjustments | SO+ | Replenished stock (H) | Adjustment of operations tow ards BSA | "I alw ays monitor blood stock every day. So for example, w e have 10 stocks in one day. Tomorrow morning w hen w e come, w e will check how many stocks w e need. We then immediately call the blood centre, that very morning w e order again. We don't w ant the delay." *INT – Laboratory Manager PMU Hospital* | PMU Hospital (INT 1), BC 2-1 (INT 1 |
| | Potential reaction to transfusion from ordered blood; w ritten letter; blood centre→hospital; *ad hoc* | Alerting hospital on the potential reaction to transfusion from ordered blood | Alertness | HI+ | Ensured aw areness of possible reaction to transfusion (H) | Potential adjustment of operations tow ards BSA | "From the blood centre usually if there is a reaction [to transfusion], there will be a reaction, there w ill be a notification from the blood centre. For example, this blood that is going to be transfused to the patient, there w ill be a reaction or incompatible. […] [They] use a formal letter." *INT – Laboratory Manager HM Hospital* | BC 2-1 (DCMT 5), HM Hospital (INT 3), PMU Hospital (INT 1), PW Hospital (INT 1) |
| High tempo | Clots in blood bag; telephone, hospital→blood centre; *ad hoc* | Reporting blood quality issue to blood centre | Failure reporting | PF+ | Ensured aw areness of BSA issues (BC) | Potential adjustment of operations tow ards BSA | "If for example there is a complaint from the w ard, "w hy are there often clots in the blood?", w e receive the complaint and phone the blood centre, "w hy there are alw ays clots in the blood? It's difficult to transfuse to | KI Hospital (INT 2), PMU Hospital (INT 1), PW Hospital (INT |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | patients".*" INT – Laboratory Manager KI Hospital* | 1), BC 2-1 (INT 1) |
| | Wrong labels; telephone; hospital→blood centre; *ad hoc* | Confirming wrong labels with blood centre | Scepticism | RS+ | Confirmed wrong label (BC-H); recalled product (BC-H) | Assurance of BSA | "There might be wrong labels, so small mistakes in labelling. We cross-checked with the blood centre; there was a small mistake. […] It might be the date, expiry date, the month should be 12, but it was 11. We thought that [the blood] was expired. We confirmed there [with the blood centre] and it was actually not expired yet, only the labelling error. […] [So] we phoned and return the product back for the label to be amended." *INT – Laboratory Manager HM Hospital*<br><br>"Sometimes we found [a wrong] label, it was once, twice. […] [So] for example, we ordered O; we were given A group. We phoned the blood centre "[was it] really [a mistake]?", [they said] "[it was] really [a mistake". If it was really [a mistake], we returned it back, the blood centre would replace the label." *WT – Laboratory Manager PW Hospital* | BC 2-1 (INT 2; DCMT 1), PW Hospital (INT 1; WT 1), HM Hospital (INT 2) |
| | Order information; n/a; hospital→blood centre; *ad hoc* | Being responsive in addressing product stockout | Responsive-ness | CR+ | Ensured placement of order (H) | Assurance of BSA | "If we have stockout, we immediately [share information] with the blood centre, so we don't involve the patient's [family]." *INT – Laboratory Manager PMU Hospital* | PMU Hospital (INT 1) |
| Emergency | Concessionary blood request; formal letter; hospital→blood centre; *ad hoc* | Being responsive in addressing the need for blood | Responsive-ness | CR+ | Fulfilled need for blood during emergency (H) | Adjustment of operations towards BSA | "So actually for emergency orders we have a procedure, that we still have to complete the cross-match process. But in the condition where the patient is bleeding heavily. A while ago there was an anaesthetist who had a [major] road accident […] and required 125 [packs of blood]. So, there was a consent statement from the medical doctor that takes care of this patient [in the hospital] that he/she requires the blood immediately and | BC 2-1 (INT 3), PMU Hospital (INT 3), HM Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | | | | | | | he/she is responsible for the risk, it was signed. So we still had to cross[-match], we ensured that the blood group was compatible. For example, A with A. But, the testing, screening, and cross-match was still going on. If there was anything about the results, we [would] phone [the hospital]." *INT – Project Development Manager BC 2-1* | |

## Table F-6: Examples of supporting evidence with CIMO logic in EC 2-2

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | Order information; telephone and request letter; hospital→blood centre; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Confirmed blood order (H) | Assurance of BSA | "Hospitals only need to phone us, just phone, usually hospitals phone. We have this blood group available. Usually we then follow it up with the name of patient and hospital. We then make a note and they come with a request letter." *INT – Blood Donation Manager BC 2-2* | BC 2-2 (INT 1), SD Hospital (INT 1) |
| | Blood usage; telephone; blood centre↔hospital; *ad hoc* | Confirming the use of blood and therefore reserved order | Scepticism | RS+ | Cancelled order (BC-H) | Assurance of BSA | "When the patient has gone home, there is then a decision that the blood is not used. It can be that the blood centre phone us or we phone the blood centre to cancel the [ordered and reserved] blood, [because] it's not going to be used." *INT – Midwife SD Hospital* | SD Hospital (INT 2), PR Hospital (INT 1) |
| | Policy on using replacement donors; face to face meeting; blood centre→hospital; *ad hoc* | Reminding hospitals not to use replacement donors | Checks and balances | RS+ | Potentially prevented overstock (BC); ensured patient safety (H) | Potential improvement of BSA; assurance of BSA | "We have an obstacle. The hospitals say "please use family donor, use replacement donor, use fresh blood", that's what the hospitals say. We have warned the hospitals about that. If [they] want fresh blood, we have it. What happens then is we have overstock because [the hospitals use] replacement donors. […] I even gathered [them], 90 hospitals were gathered together for that [problem to be resolved]. What I want is the blood quality can be achieved according to standard operating procedures." *INT – Blood Donation Manager BC 2-2* | BC 2-2 (INT 4; DCMT 6) |
| | Shelf life of ordered blood; order form; hospital→blood centre; *ad hoc* | Notifying blood centre of the need for fresher blood | Alertness | HI+ | Ensured supply of fresh blood for specific patients (H) | Assurance of BSA | "We have communicated the issue, but in reality, we still get the short-dated blood. […] We usually, we put a note on the order form that the blood is going to be used for HD [haemodialysis] patients, for example." *INT – Blood Bank Manager AK Hospital* | BC 2-2 (INT 4), AK Hospital (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | Policy on using replacement donors; face to face meeting; blood centre→hospital; *ad hoc* | Reminding hospitals not to use replacement donors | Contribution, representation, and subordination of actions | HI+ | Potentially prevented overstock (BC); ensured patient safety (H) | Potential improvement of BSA; assurance of BSA | "We have an obstacle. The hospitals say "please use family donor, use replacement donor, use fresh blood", that's what the hospitals say. We have warned the hospitals about that. If [they] want fresh blood, we have it. What happens then is we have overstock because [the hospitals use] replacement donors. [...] I even gathered [them], 90 hospitals were gathered together for that [problem to be resolved]. What I want is the blood quality can be achieved according to standard operating procedures." *INT – Blood Donation Manager BC 2-2* | BC 2-2 (INT 3), SD Hospital (INT 2) |
| | Blood usage; written report; hospital→blood centre; monthly | MoU as a mechanism not to share information | No real time interactions | SO- | Potentially unaware of BSA issues (BC-H) | No potential improvement of BSA | "Here we do not share anything, we have MoU already." *INT – Blood Bank Staff BT Hospital* | AK Hospital (INT 2), BT Hospital (INT 1) |
| | Blood usage; written report; hospital→blood centre; monthly | Sharing blood usage for invoicing purposes | Mismatched use of information | SO- | Potentially unused blood usage information (H) | No potential improvement of BSA | "They [the blood centre] will ask for a blood usage report every month, it's for calculating something like budgeting." *INT – Blood Bank Staff BT Hospital* | BT Hospital (INT 1; WT 1), PR Hospital (WT 1), BC 2-2 (INT 1) |
| | Order information; order form; hospital→blood centre; *ad hoc* | Not ensuring the appropriateness of order information to be shared | Negative contribution, representation, and subordination of actions | HI- | Wasted blood (BC); unused reserved blood (BC); unfulfilled blood needs (H) | No realised improvement of BSA | "Our [blood stock] management depends on our customer, depends on hospitals. I ask for 10 [blood packs], they are not always taking all 10 from us. Many hospitals do, "this is the blood request letter", asking for 5 [blood packs] for example, or 2, but eventually they do not take them from us, we find that a lot. From 17,000 demands for blood [from hospitals], they are only fulfilled 60%, the remaining (40%) are not fulfilled. Because that's how the hospitals work. [...] Even if we put the stock back [for other patients], it might not be good as well." *INT – Blood Donation Manager BC 2-2* | BC 2-2 (INT 5), PR Hospital (INT 2; WT 1), AK Hospital (INT 2), BT Hospital (INT 1), SD Hospital (INT 1 |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| High tempo | Blood shortage; social media, newspaper, TV, radio, SMS, website; blood centre→hospital via public media; *ad hoc* | Using redundant information sharing media | Redundancy | RS+ | Ensured awareness on blood shortage (H) | Potential adjustment of operations towards BSA | "The stock levels and blood groups can be accessed [publically]. We use Facebook, twitter, newspaper, […] TV running text, radio every 7 in the morning and 2 in the afternoon every day on [the radio], and [another newspaper], […] SMS, access through website. […] If I am having shortage, I will incessantly [disseminate the information]." *INT – Blood Donation Manager BC 2-2* | BC 2-2 (INT 1), PR Hospital (INT 1) |
| | Updated stock condition during high tempo; n/a; blood centre→hospital; *ad hoc* | Questioning hospitals on the appropriateness of order | Scepticism | RS+ | Ensured appropriate use of blood (BC) | Assurance of BSA | "But here is the fact [when it comes to order during fasting month, the blood centre will question], "is it really going to be used? Because this is fasting month"." *INT – Midwife SD Hospital* | SD Hospital (INT 2), AK Hospital (INT 1), PR Hospital (INT 1), BC 2-2 (INT 1) |
| | Order information; telephone and order form; hospital→blood centre; *ad hoc* | Being responsive in addressing stockout | Responsive-ness | CR+ | Ensured placement of order (H) | Assurance of BSA | "If there is a request […] and we don't have the blood, stockout, we immediately call the blood centre. […] Our staff will then take the box and the request form to the blood centre." *WT – Blood Bank Staff BT Hospital* | AK Hospital (INT 2), BT Hospital (INT 1; WT 1), PR Hospital (INT 1), BC 2-2 (INT 1) |
| Emergency | Order information; telephone; hospital→blood centre; *ad hoc* | Being responsive in addressing the need to order | Responsive-ness | CR+ | Fulfilled need for blood during emergency (H) | Adjustment of operations towards BSA | "So there was a case of an obstetric patient that was heavily bleeding and required 6 packs of blood. I think it was O blood group so it was easier to fulfil. But then several hours later, this patient requires more. […] It was stockout because the need was higher than [expected]. We then immediately placed an emergency order by phoning the blood centre. We could then provide the blood." *INT – Blood Bank Manager AK Hospital* | AK Hospital (INT 1), SD Hospital (INT 1) |

**Table F-7: Examples of supporting evidence with CIMO logic in EC 2-3**

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| Normal | Blood usage; telephone; blood centre→hospital; *ad hoc* | Confirming the use of blood and therefore order | Scepticism | RS+ | Confirmed use of blood (BC) | Assurance of BSA | "But usually the blood centre also calls us, calls the nurse here, "this patient with this name, we still have the blood, do you still want to use it?" If it is not used, it may be used, automatically allocated to other patients so there is no blood wasted." *INT – Blood Administration Manager TR Hospital* | BC 2-3 (INT 6), TR Hospital (INT 1; WT 1), IS Hospital (INT 2), PMA Hospital (INT 2), MD Hospital (INT 1) |
| | Readiness of ordered blood; telephone; blood centre→hospital; *ad hoc* | Notifying hospital that the blood is ready for collection | Alertness | HI+ | Confirmed availability and readiness of ordered blood (H) | Assurance of BSA | "When the testing is finished, we immediately phone the hospital, telling them that the blood is ready. If they want to immediately use it, the patient's family will come here to pick up [the blood], if not we will save it [for them]." *WT – Transfusion Practitioner BC 2-3* | BC 2-3 (WT 2), IS Hospital (INT 1), PMA Hospital (INT 1), TR Hospital (INT 1) |
| | Blood usage; telephone; blood centre→hospital; *ad hoc* | Confirming the use of blood and therefore order | Contribution, representation, and subordination of actions | HI+ | Confirmed use of blood (BC) | Assurance of BSA | "But usually the blood centre also calls us, calls the nurse here, "this patient with this name, we still have the blood, do you still want to use it?" If it is not used, it may be used, automatically allocated to other patients so there is no blood wasted." *INT – Blood Administration Manager TR Hospital* | TR Hospital (INT 1) |
| | Expiry date; blood pack; blood centre→hospital; *ad hoc* | Hiding expiry date information due to being afraid of complaint | No transparency | SO- | Potentially unaware of expired blood (H) | No potential adjustment of operations towards BSA | "For people outside this area, we usually put the expiry date [on the blood pack], but in this area we cannot do that because people will complain. "Why do you give this blood which was taken on this date?" So if we do that, there will be much expired blood. So only we know when the blood was taken from donors and when is the expiry date." *WT – Transfusion Practitioner BC 2-3* | BC 2-3 (WT 2) |
| | Need for blood; n/a; hospital→blood centre; *ad hoc* | Sharing information only when needing blood | No regular interactions | SO- | Potentially unaware of BSA issues (BC-H) | No potential improvement of BSA | "Because here we only communicate with the blood centre when we need [the blood], otherwise there is no communication. If we don't need the blood, there is no communication." *INT – Nurse PM Hospital* | MD Hospital (INT 2), IS Hospital (INT 1), PM Hospital (INT 1), BC 2-3 (INT 1) |

| Contexts | Interventions | Mechanisms | | | Outcomes | | | |
|---|---|---|---|---|---|---|---|---|
| *Operational conditions* | *IOIS behaviour – content; modality; direction; frequency* | *Co-actions* | *Classified co-actions* | *CM principles* | *Impacts on BSA (entities affected)* | *Classified impacts on BSA* | Representative excerpts | Supporting entities (sources of evidences and total number of excerpts) |
| | Readiness of ordered blood; telephone; blood centre→hospital; *ad hoc* | Not answering telephone for blood collection | No ongoing operational adjustments | SO- | Potential delay of transfusion (H) | No adjustment of operations towards BSA | "We phone them [the hospitals], letting them know [when the blood is ready for collection]. It's difficult for the hospitals [to pick up the phone] because nurses are usually not in their ward, so we usually call the patients' family who will then convey the information to nurses. If the nurses ask [the patients' family to take the blood], they will come here. Otherwise, they will not come here." *WT – Transfusion Practitioner BC 2-3* | BC 2-3 (WT 1) |
| High tempo | Blood availability; telephone; hospital→blood centre; *ad hoc* | Reconfirming blood availability when stock out | Scepticism | RS+ | Confirmed blood availability (H) | Assurance of BSA | "So the nurse will re-contact [the blood centre via telephone]. "So the patient requires blood, the patient's family told the nurse that there is no blood there, is it true?", "There is no blood, how can we be of further help", they say. "We have recommended the patient's family to find the replacement donor". If the donor is available, the nurse will ask the patient's family to bring the donor [to the blood centre]." *INT – Senior Nurse MD Hospital* | TR Hospital (INT 1; WT 1), MD Hospital (INT 1), BC 2-3 (INT 1) |
| | Reaction to transfusion; telephone; hospital→blood centre; *ad hoc* | Being responsive in addressing reaction to transfusion | Responsive-ness | CR+ | Consulted on reaction to transfusion (H) | Assurance of BSA | "If there is allergy [reaction to transfusion], [the transfusion] is discontinued, it is stopped. Then it is consulted with the blood centre [via telephone] that the blood causes allergy to the patient." *WT – Hospital General Affairs and Blood Administration Manager TR Hospital* | TR Hospital (INT 1; WT 1), MD Hospital (INT 1), BC 2-3 (INT 1) |
| Emergency | Cross-match result; telephone; blood centre→hospital; *ad hoc* | Being responsive in addressing incompatible cross-match | Responsive-ness | CR+ | Prevented blood safety incident (H) | Assurance of BSA | "During emergency, the cross-match is only phase 1, but the blood is given to the hospital and we continue [the cross-match] up to phase 3. So when the result comes out and is incompatible, we immediately phone the hospital, "the blood is incompatible, return it, the result is incompatible". So phase 1, and when we are in phase 2 and the result shows incompatible, we immediately phone the hospital." *WT – Transfusion Practitioner BC 2-3* | BC 2-3 (WT 1), MD Hospital (INT 1), TR Hospital (INT 1) |