



**ASSESSMENT OF PHARMACEUTICAL SUPPLY CHAIN RISK
MANAGEMENT: THE CASE OF ETHIOPIAN PHARMACEUTICALS
SUPPLY AGENCY**

Manaye Tamrie (BPharm)

**A Thesis Submitted to Addis Ababa University, College of Health Sciences,
School of Pharmacy, Department of Pharmaceutics and Social Pharmacy for
the Partial Fulfilment of the Degree of Master of Science in Health Supply
Chain Management**

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Addis Ababa, Ethiopia

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Addis Ababa University

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Addis Ababa University
School of Graduate Studies

This is to certify that the thesis prepared by Manaye Tamrie, entitled “*Assessment of Pharmaceutical Supply Chain Risk management: The Case of Ethiopian Pharmaceuticals Supply Agency*” is submitted in partial fulfillment of the requirements for the degree of Master of Science in Health Supply Chain Management. It complies with the regulations of the university, and meets the accepted standards with respect to originality and quality.

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Abstract

Assessment of Pharmaceutical Supply Chain Risk Management: The Case of Ethiopian Pharmaceuticals Supply Agency

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Background: Supply chain risk management is the process of identification, assessment, mitigation, and monitoring of risks. Pharmaceutical suppliers and distributors face multiple risks that disrupt the supply of drugs in terms of quantity, quality, and delivery at the right place and time to the right customer. Therefore, caution must be taken as health is critical and pharmaceuticals are unique.

Objective: To analyze the pharmaceutical supply chain risks and assess the risk management practice of the Ethiopian Pharmaceuticals Supply Agency.

Method: An explanatory and descriptive case study design was employed. Totally, 101 samples were involved in the study selected through purposive sampling technique. An interview guide, questionnaires, and risk checklists were used to collect quantitative and qualitative data from respondents. The Excel-derived failure mode and effect analysis template, and SPSS version 23 were used for the data analysis. Thematic analysis of qualitative data was also employed.

Result: Eighty nine risks were identified and categorized into six groups. Among these, supply and demand side risks take the priority in affecting the supply chain operation. Inability to meet customer demand, lead time variability, and poor logistics performance of suppliers are under high risk score categories. Most of the respondents, 45 (44.6%), agreed that the risk management practice at Ethiopian pharmaceuticals supply agency is at its infancy. Risk identification methods being used are found to be risk estimation, previous risk assessment, and brainstorming sessions. The most applicable risk management tools are inventory optimization (29.9%), sales (22.4%), and operation planning tool (27.6%). The overall implementation of risk management strategies are below the average. Supply side ($\beta = -2.171$, $P < 0.020$), process ($\beta = -0.979$, $P < 0.026$), and control ($\beta = -1.694$, $P < 0.004$) risks negatively affect the supply chain performance, while risk management practices ($\beta = 6.440$, $P < 0.002$) affect it positively.

Conclusion: Supply side risks took the primary position during prioritization followed by demand side and operational risks while environmental risks were at the least position. The overall risk management practice of the Ethiopian pharmaceuticals supply agency is weak. The level of implementation of risk management processes are low while the applicability of risk management tools are above the average level in the last 5 years history of the agency. Supply side, process, and control risks affect the supply chain performance negatively. However, supply chain risk management practices have a positive impact on performance.

Recommendation: The Ethiopian pharmaceuticals supply agency should establish a separate team that primarily assess, analyze and control supply chain risks at all hubs. The agency should also be engaged in more scientific methods of risk identification methods like surveys, and risk assessment to identify, control, and minimize impacts of risks.

Key Terms: Risk Management, Supply Chain, Supply Chain Risk Management, Risk Analysis, Risk control.

Acknowledgement

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Abbreviations and Acronyms

AAU	- Addis Ababa University
AHP	- Analytical Hierarchy Process
CQI	- Chartered Quality Institute
EFDA	- Ethiopian Food and Drug Administration
EPSA	- Ethiopian Pharmaceuticals Supply Agency
ERCA	- Ethiopian Revenue and Customs Authority
FMEA	- Failure Mode Effect Analysis
IT	- Information Technology
MOH	- Ministry of Health
MSH	- Management Science for Health
NGO	- Non-Governmental Organizations
PSC	- Pharmaceutical Supply Chain
QMS	- Quality Management System
RPN	- Risk Priority Number
RSV	- Risk Score Value
SCC	- Supply Chain Council
SCM	- Supply Chain Management
SCOR	- Supply Chain Operations Reference
SCR	- Supply Chain Risk
SCRLC	- Supply Chain Risk Leadership Council
SCRM	- Supply Chain Risk Management
USD	- United States Dollar
WEF	- World Economic Forum
WHO	- World Health Organization

CHAPTER ONE

1. INTRODUCTION

This chapter presents the background of the study, which begins by describing supply chain risks in general and supply chain risk management (SCRM) processes in particular, statement of the problem, objectives of the study, research questions, significance and scope of the study. Additionally, this study also highlighted operational definition, and the organization of the paper at the end of the chapter.

1.1. Background of the Study

Access to medicines is a fundamental human right and it is not the responsibility of health workers alone but it has also political, economic, and social dimensions. Failure to properly manage pharmaceutical commodities obscures access which results in wastage and health devastation (Jaberidoost, Nikfar, Abdollahiasl, & Dinarvand, 2013; Management Science for Health [MSH], 2012). To ensure the sustainable supply of quality-assured pharmaceuticals at affordable prices, there is a prime requirement of strengthening the supply chain of health commodities (Ethiopian Pharmaceuticals Supply Agency [EPSA], 2015a).

Supply chain is the collection of processes and resources required to make and deliver a product to meet the final customer demand (Rajgopal, 2016). It is a sequence of decision-making; execution of processes; and flow of material, information and money from the suppliers' supplier to consumers (Vorst, 2014). In this process, there is a very unavoidable counter force called risk throughout the life of organizations (Breen, 2008). Hence, formulating a method to prevent this hindering factor before it occurs or manage after it happened is better to avoid stockout, wastage, reduce cost, improve efficiency and system reliability, increase the security of supply, and reduce liability in the pharmaceutical supply process (Chartered Quality Institute [CQI], 2010).

Pharmaceutical suppliers and distributors face multiple supply chain risks (SCRs) that disrupt the supply of drugs in terms of quantity, quality, and delivery at the right place and time to the right customer. The high expiration rate of pharmaceuticals and cold chain management problems resulted in quality problems and financial burdens. Therefore, it is necessary to examine risks to take proactive action for their management in the supply chain process (MSH, 2012; Moktadir *et*

al., 2017) and to improve the efficiency of the supply chain management (SCM) system by providing an ability to optimize the level of risk (Vikulov & Butrin, 2014).

Supply chain risk management is an extension of SCM that coordinates and collaborates supply chain partners for assessing, measuring, and developing strategies to manage risks (Singhal, Agarwal, & Mittal, 2011; Supply Chain Council [SCC], 2012; Zsidisin, Ellram, Carter, & Cavinato, 2004). An effective risk management process can protect the continuity of product supply and ensure end-users receive products fit for purpose (CQI, 2010) in terms of quality, safety and efficacy (World Health Organization [WHO], 2013). It also allows chain managers to make better decisions, compete for cost-effectiveness and minimize risk exposure (SCC, 2016).

Currently, SCRM is an important practice due to an increase in collaboration and integration, globalization, outsourcing, just-in-time deliveries, lean inventories, the emergence of technology and consolidated operations to achieve economies of scale (Supply Chain Risk Leadership Council [SCRLC], 2011). This makes it possible to control and coordinate extended supply chains but increases the potential and magnitude of risks (Faizal & Palaniappan, 2014).

Even if risks can block the supply chain process in part or totally, EPSA is not engaged in proper management practice and lacks a dedicated unit to optimize the impact of risks. The EPSA planned to manage risks strictly but the implementation and practical activities on the ground are still poor (Ministry of Health [MOH] & EPSA, 2015). There are also no enough studies to develop an effective SCRM system to minimize the massive consequences of risks in Ethiopia (Mengistu, 2016). Therefore, this study was done to analyze risks, assess risk control practices, investigate mitigation strategies, and determine the level of impact of risks on the pharmaceutical supply chain (PSC) performance of Ethiopia.

1.2. Background of the Study Area

The Ethiopian government is supporting the development of the healthcare and pharmaceutical industries through a variety of programs. Growth and transformation plan one (2010 - 2015) has resulted in expanded access to services, increased facility numbers, and improved health indicators. The share of generic medication is certainly increasing, thanks to increased production by manufacturing facilities in Ethiopia and supply from worldwide manufacturers. This increase in market share can be attributed to rising demand (due to an aging population and

an increase in the frequency of non-communicable diseases), as well as the low cost of generic medicines, which favors price-oriented markets (MOH & Ministry of Industry [MOI], 2015).

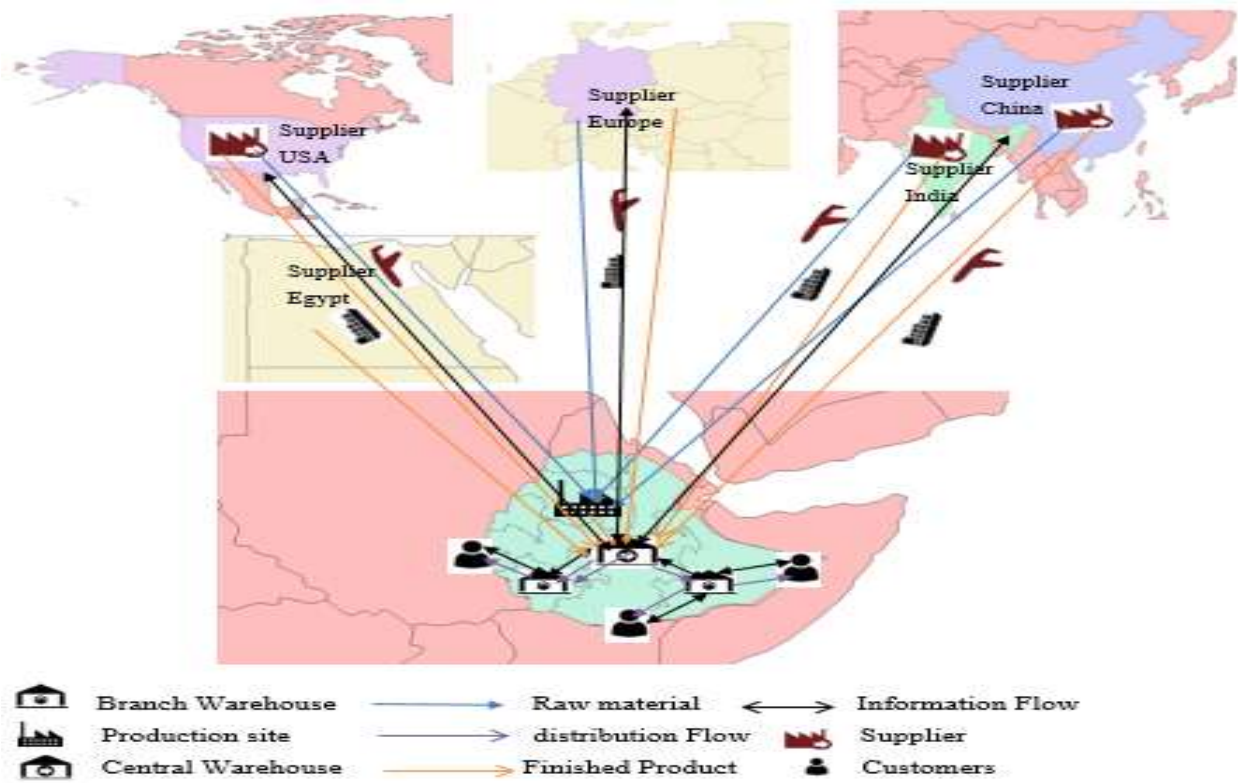
Ethiopia's yearly pharmaceutical market is anticipated to be worth USD 684 million in 2018 and will reach a value of USD 1 billion by 2020, with an annual growth rate of 25%. The African pharmaceutical market, on the other hand, is worth more than USD 25 billion and is growing at a rate of about 13% per year. Ethiopia barely accounted for about 2% of the African pharmaceutical market in 2015. Local manufacturers account for about 20 to 30% of the market. Only about 90 of the 380 critical drugs are produced locally (Kassahun, 2018; MOH & MOI, 2015). The pharmaceutical and medical supply sectors rely heavily on foreign materials. Over 95% of the raw materials required by the sector are imported due to a scarcity of raw materials locally (Embassy of Ethiopia in New Delhi, 2015). In 2015, Ethiopia exported only 0.14% (USD 998 thousand) of the continent's pharmaceutical export (Kassahun, 2018).

The majority of pharmaceuticals consumed in Ethiopia are imported products. The EPSA imports primarily from India, United States, France, Belgium, Republic of Korea, Switzerland, Germany, United Kingdom, China, and Cyprus (Embassy of Ethiopia in New Delhi, 2015) as well as from African nations such as Egypt and South Africa. It has more than 600 local and foreign pharmaceutical and medical product suppliers (EPSA, 2021) (see Figure 1).

Pharmaceuticals are available in Ethiopia from both the public and private sectors. The government is the company's biggest client. The EPSA meets 70 – 75% of the pharmaceutical needs. It's principal business is delivering medications and medical equipment to government-run health care facilities. The public sector buys items mostly based on cost, with generics taking precedence. However, the private sector accounts for around 90% of all branded products. From the 75% of government purchases, revolving drug fund accounts for 30%, while the remaining 70% are program purchases by donor's cash (EPSA, 2020; Kassahun, 2018).

Federal MOH in collaboration with John Snow, Inc. (JSI) launched and working together on digitalizing the health information system, availing quality data, and empowering the workforce in EPSA and other affiliated agencies including health facilities. This collaboration also works to enable EPSA to manage and track its human resource as well as enables it to use information technology for better management of its workforce (Digital Health Activity, 2020).

In Ethiopia's supply chain system, the EPSA is the only public agency (under the MOH) that is responsible for sourcing and distributing pharmaceuticals. It was established by Proclamation 553/2007 to allow health facilities to obtain quality-assured essential pharmaceuticals at affordable prices in a sustainable manner (The drug fund and pharmaceuticals supply agency establishment proclamation, 2007). The agency has 1 central office at Addis Ababa, and 19 hubs at regions to realize access to all public health facilities within 160 - 300 kilometers radius (EPSA, 2015b; USAID, 2009). Currently, the agency organized the 19 hubs into seven clusters based on geographical location for simplicity of management and distribution of products. These are Adama, Central, Northern, Southern, Eastern, Western and Northwestern clusters; consisting of one to four hubs per cluster (see Annex 3). Ethiopia's pharmaceutical supply chain is a complicated, public-sector-dominated system that runs from raw material suppliers in other countries to end consumers in far-flung health-care facilities, with both private and public wings.



Source: Own developed

Figure 1: Supply chain network map of Ethiopia.

1.3. Statement of the Problem

Pharmaceutical SCRs are associated with product discontinuity or shortages, poor performance, and technological problems that incur disruption to the supply system. Thus, risks must be identified and controlled effectively (WHO, 2013). The great concern behind SCR is the lack of coordinated effort in assessing and managing it, so caution must be taken as health is critical and pharmaceuticals are unique products (Savage, Roberts, & Wang, 2006; Breen, 2008).

According to the World Economic Forum (WEF) held in Switzerland, the economic loss in 2010 due to natural disasters were totaled USD 194 billion (WEF, 2012). The study in India also showed that one telecom company lost USD 400 million due to a fire accident at its single raw material supplier in 2004. Such disasters can damage infrastructures, interrupt production and cause complete supply blockage (Faizal & Palaniappan, 2014).

The study in United States of America also revealed that the COVID-19 global pandemic causes high risk of failure in the PSC. The pandemic causes shutdown of manufacturing firms, transportation restriction, professionals in the chain were falling ill and refused to work, and difficulty of delivering the drug for customers without no risk of infection (Strong *et al.*, 2020). A similar study in Namibia showed that the COVID-19 pandemic aggravated the supply chain problems in the country due to border and transportation restrictions (Tirivangani *et al.*, 2021).

The study conducted in Great Britain showed that there were 35 prevalent risks comprised of fragmentation of the chain, lack of visibility, poor stock availability, and inappropriate forecasting among the top 10 identified risks (Breen, 2008). Another study in Ireland stated that risks like component shortages, labor strikes, disasters, and human errors caused disruptions in the supply chain (Deleris & Erhun, 2011). Supply and demand disruptions were the most prevalent and highly detrimental risks that cause a 14% increase in inventories, an 11% increase in cost and a 7% decrease in sales (Hendricks & Singhal, 2005).

A risk event occurring at one point in the supply chain can greatly affect other members (Faizal & Palaniappan, 2014). Hence, different supply chain entities in Ethiopia faced multiple risks from internal and external sources. In Ethiopia's coffee supply chain, 81 risks were identified under financial, technical, managerial, political, resource, security, legal and environmental risk categories. From these, 32 were under the red category by failure mode effect analysis (FMEA)

model (Gebreleul, 2018). The study in Ethio-telecom also showed that the trend of SCRs affecting the performance of supply chains increased from time to time but the level of SCRM practice was at its early stage as compared to international standards. Supply and demand side risks; risks associated with legal, regulatory and bureaucratic environment; infrastructure, and catastrophic risks due to political instability (vehicle damage and difficulty of moving freely) disrupted the flow of supply chain operation (Yoseph, 2017).

Based on the study by Mengistu (2016), the sole public health supply chain agent in Ethiopia, EPSA, faced higher supplier-related risks. It had no dedicated risk management department in its organizational structure and the risk identification and mitigation performance of the agency were weak. The study also showed that EPSA did not participate in identifying risks except for a small-scale risk register activity. This weak risk identification and management trend greatly compromise the effectiveness of the SCM process. The pharmaceutical sector assessment also showed that the availability of essential medicines was 70.7%; conservation of quality was 81.8%; stockout duration was 26.6 days; and wastage rate was greater than 2% that elaborated poor performance of the supply chain network (EPSA & Ethiopian Food and Drug Administration [EFDA], 2017).

The studies conducted in the SCRM practice of Ethiopia are mostly on non-healthcare commodities that have a great difference from pharmaceuticals. The single assessment done on pharmaceuticals by Mengistu (2016) was narrow in scope. It did not include regional hubs, which are the fundamental levels in the supply chain. It also excluded finance, information technology (IT), and human resource directorates from the study. The study did not prioritize identified risk for priority and resource allocation during mitigation planning. It did not also measure and illustrated the association between risks and performance.

Considering the identified gaps and believing in numerous changes that occurred in the setting, process, performance, and structure of EPSA after the previous study, this study was conducted to analyze the main pharmaceutical SCRs and assess existing risk management practices in the public PSC network of Ethiopia.

1.4. Objectives of the Study

1.4.1. General Objective

- ✓ To analyze the pharmaceutical supply chain risks, assess the risk management practice and supply chain performance of EPSA.

1.4.2. Specific Objectives

1. To analyze the pharmaceutical supply chain risks in EPSA.
2. To assess pharmaceutical supply chain risk management practice of EPSA.
3. To analyze supply chain performance from a risk management point of view in EPSA.
4. To determine the association between supply chain risks and perceived supply chain performance of EPSA.
5. To propose risk mitigation strategies for prioritized supply chain risks in EPSA.

1.5. Research Questions

This study primarily focused to answer the following specific research questions:

1. What are the prevalent supply chain risks in the supply chain of EPSA?
2. What are the risk management practices at PFSA?
3. What is the supply chain performance of EPSA from a risk management viewpoint?
4. What is the association between supply chain risks and perceived performance of EPSA?
5. What kind of mitigation strategies are required to manage prioritized SCRs in EPSA?

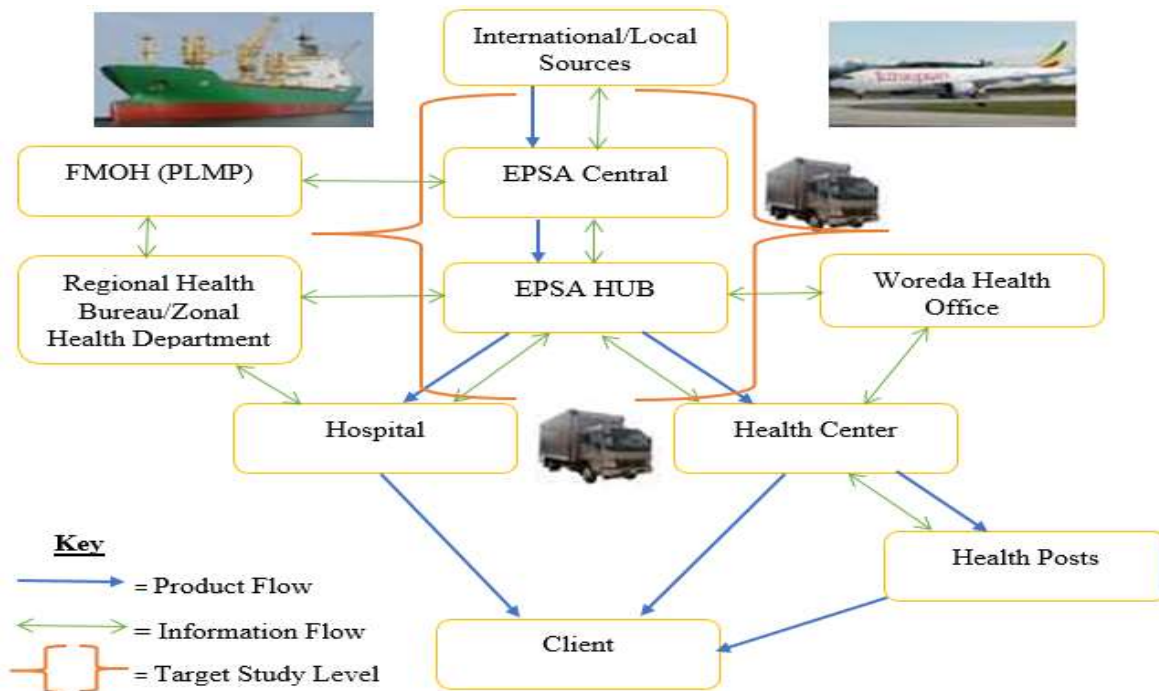
1.6. Significance of the Study

The immediate contribution of the study is to help PSC organizations in Ethiopia in estimating and controlling risks that might disrupt their supply chain activity. On the other hand, the study will assist stakeholders in the pharmaceutical SCM to visualize the risk assessment and risk control practice, to prevent serious risk impacts in supply chain operation, and to improve accessibility of products. The study will also provide baseline information for future studies to fill the gap in investigating the SCRM practice of health and non-healthcare commodities.

1.7. Scope of the Study

This study covered the sourcing, storage and delivery supply chain operations in the public pharmaceutical sector of Ethiopia in the past five years. It included risks associated with core dimensions of supply chain, like forecasting, procurement, transportation, warehousing,

distribution, cold chain management, and inventory management activities in EPSA. Supportive activities like IT, human resource and finance were covered as well. However, no risk assessment was done at supplier and health facility level (see Figure 2).



Source: EPSA (2015b)

Figure 2: Public pharmaceutical supply chain levels in Ethiopia.

1.8. Operational Definitions

Supply chain risk: It is any occurrence or event that could interrupt the movement and distribution of raw materials inside or through an organization's supply chain network (Christopher & Lee, 2004).

Supply chain performance: The perceived performance of the supply chain network of EPSA based on the perception of study participants.

Risk management culture: It is the status of upper management involvement in risk management, firms view and policy towards risk management, and the way the company responded for reported risk information (Gupta *et al.*, 2014).

1.9. Organization of the Study

This study paper was organized into five chapters. Chapter one is composed of the introduction of the study including the background of the study, statement of the problem, objectives of the

study, research questions, significance of the study, and the scope of the study. Similarly, the second chapter deals with the review of related literatures. This chapter has four fundamental components namely theoretical literature review, empirical literature review, the hypothesis of the research, and conceptual framework that shows the overall map of the study.

Chapter three discusses the research methodology details. In this chapter, different parts including a description of the study area, research design, research approaches, source and study population, sampling techniques and sample size determination, data collection methods and instruments, variables of the study and mechanisms of data quality assurance are included. The chapter also discussed the data entry and analysis plan, ethical consideration, and dissemination plan of the final paper to the respective stakeholders.

The results and discussion part of the study are presented in the fourth chapter, whereas, the fifth chapter constitutes the summary of findings, conclusion, recommendation, and limitations of the study including suggestions for future researchers.

Furthermore, this study includes references and annexes (questionnaire, interview protocol, risk checklist, and some analysis results) sections.

CHAPTER TWO

2. RELATED LITERATURE REVIEW

This chapter contains theoretical and empirical literature reviews with the conceptual framework of the study. Theoretical literature review deals with concepts and different aspects of pharmaceutical SCRs, sources of risks and SCRM processes like risk analysis and risk control practices in detail while the empirical literature review discusses how related literature internationally explained SCRM practice. The conceptual framework of the study in the last part of this chapter shows the general roadmap of the whole study.

2.1. Theoretical Literature Review

2.1.1. Supply Chain Risks

Supply chain risk is the negative variance from the anticipated value of those performance metrics, which leads to negative consequences for the focal company that is also equated to the detriment of supply chain disruption (SCC, 2008). It needs careful attention because the effect of SCRs is not limited to financial problems but also causes permanent harm due to delays, defects and poor product or service quality. In the supply chain process, therefore, it is necessary to identify and mitigate risks from raw material sources to end customers (WEF, 2012).

2.1.2. Pharmaceutical Supply Chain Risks

Any risks affecting the PSC can not only waste money but also threaten the lives of patients by impeding access to medicines (Schneider, Wilson, & Rosenbeck, 2010). Risks affecting the PSC may affect health system efficiency and disrupt medicinal supply. Adequate knowledge of risks will help supply chain entities to minimize costs and liability, and reduce waste that lead to an increase in the supply chain performance (Rogachev, 2008). The pharmaceutical sector faces various relevant supply chain issues, like shortage of raw materials, quality problems, short life cycle, delivery problem, information flow issues, customer service disruption, lack of currency, poor skill of workers, regulations, cost of production and products, waste management, sustainable supplier failure, and seasonal demand of products (Jaberidoost, Olfat, Hosseini, Kebriaeezadeh, & Abdollahi, 2015; Moktadir *et al.*, 2017).

2.1.3. Sources of Supply Chain Risks

The modern supply chain is clear, smart, and predictive, making data and processes in supply chain more visible by using cognitive technology, can anticipate and mitigate risks. The probability of risk occurrence is increasing as the supply chain globalizes, becomes networked (multiple partner involvement), and the chain of companies is interconnected or interdependent (SCRLC, 2011).

Supply chain risk sources may be of different forms. It can be an internal or external type. Internal risks have been reported as a result of processes, people, capacity variations, regulations, information delays, organizational factors and mismanagement functions within the company that can be easily mitigated while external risks include market prices, competitor actions, production yields and costs, quality of suppliers and non-company political issues (Jaberidoost *et al.*, 2013).

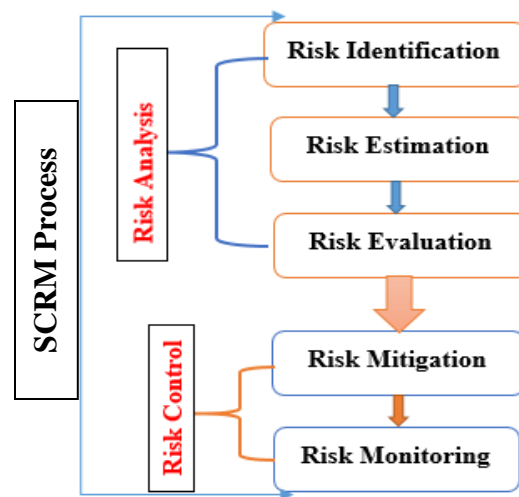
Among the commonly mentioned threats, the WEF (2012) listed risk sources as disruptions in demand and supply, global financial crisis, environmental disturbances and supply chain process threats. Wagner and Bode (2009) also outlined major SCRs as demand-side, supply-side, infrastructural, financial, bureaucratic and catastrophic risks like the classification approach by most scholars as supply, demand, process, control, and environmental risks.

Supply risk is the disturbance to the inward flow of products or information within the network from the upstream chain. It is associated with suppliers or supplier's suppliers being unable to meet demand forecasts but demand risk is related to disturbances to the flow of product, information, and finance within the network between the focal company and the market due to uncertainties in both production volume and mix. Operational risk is a disruption to the processes of value-adding and managerial activities undertaken by the company due to breakdown in core operating capability. Control risk is arising from misapplication of the assumptions, rules, systems, and procedures that govern how an organization exerts control over processes like order quantities, batch sizes, safety stock policies, or others. Environmental risk is associated with external and uncontrollable events that include uncertainties arising from the supply chain and environmental interactions (accidents or natural disasters) while infrastructure risk is associated with human resource, warehouses, IT and transportation infrastructures (CQI, 2010; Moktadir *et al.*, 2017).

Source of risk can also be operational, market orientation factors, strategic decision elements, and logistics management or outsourcing related risks (Zhao & Zhu, 2013). Similarly, complexity, size of the market, and disintegration as well as development factors like globalization, extended supply chains, and supplier consolidation can make supply chains more brittle and risky. Outsourcing related PSC risks like operational (process), financial, technological, information, and relational risks are also few to name (Mokrini, Dafaoui, Berrado, & Mhamedi, 2016).

2.1.4. Supply Chain Risk Management

The SCRM is a natural extension of SCM with the prime objective of identifying the potential sources of risks and suggesting suitable action plans to mitigate them. It is a process of planning, and decision making to solve risks that have high to low impact on supply chain (Singhal *et al.*, 2011). Risk management cannot prevent or control every risk that faces the supply chain but it can make the supply chain actors prepared when a risk occurs (SCRLC, 2011). Sharing of information, collaborative and trusted relationships between supply chain actors (professional bodies, governments, regulators, suppliers, customers, and private actors) is needed to effectively prevent and manage SCRs (Nourbakhshian *et al.*, 2013; Tang, 2006). The SCRM process has two stages namely risk analysis and control. Risk analysis involves identification, estimation, and evaluation of risk while risk control includes risk mitigation and monitoring (see Figure 3).



Source: Faizal and Palaniappan(2014)

Figure 3: Flow of supply chain risk management process.

2.1.4.1. Supply Chain Risk Analysis

Analysis of the risk would include clarifying the nature of the risks, identifying the causes, knowing the likelihood of occurrence and the possible impact of these incidents. It is composed of the measurements of probability and impact. Likelihood measures the probability that the event will occur based on historical data and expert opinion at a specified time horizon while impact measures the consequences on the organization by financial measures or scales (SCC, 2008). Risk assessment is the degree of risk analysis associated with increasing danger to determine which areas and activities are most vulnerable within the supply chain (Breen, 2008). It deals with the identification, estimation and evaluation of risks (Musa, 2012).

A. Risk Identification

Risk identification is a pillar of SCRM. It means maintaining a list of risks that could affect any aspect of supply chain efficiency and allowing an organization to be prepared before risks occur which is more cost-effective than waiting to respond when risks occur. Surveys based on secondary data, expert opinion, Delphi process, supply chain operations reference (SCOR) mapping, and value streams mapping is commonly used risk identification methods. Risk checklists, diagrams of cause and effect, and Gantt charts are also the main methods used in the process (CQI, 2010).

Risk identification has numerous advantages for every supply chain healthy operation like cost reduction, improved responsiveness to risks, accurate prediction, increased knowledge of risks, visibility and increased productivity of supply chain entities (Aghapour *et al.*, 2015).

B. Risk Estimation

This process estimates the likelihood and impact of risks and prioritizes them for risk mitigation. Risk events could be prioritized based on an overall, simplistic qualitative level risk approach. It could be used for the initial phase of risk reporting and offers a simple way to classify perceived risks quickly for priority considerations. Having established top risks, more advanced approaches such as causal and consequence analysis may be used to better understand the essence of the risks, and to assess the probability and effect of inherent risks in the supply chain system (SCRLC, 2011).

For risk assessment processes, different risk analysis tools such as fault tree, event tree, preliminary hazard analysis and FMEA could be used. Fault tree analysis (FTA) is a deductive

approach for determining all of the root causes of assumed harm but narrow in focus. The approach analyses failures one at a time, but defines causal chains by combining several causes of failure. Event tree analysis is a method used to define and analyze the sequence of events in a risk situation after an initiating event occurs. The aim is to assess whether or not the initiating incident can grow into a serious problem, whereas preliminary hazard analysis applies prior experience and knowledge of a hazard or failure to identify future hazards or failures, which is biased and shallow analysis (Faizal & Palaniappan, 2014).

Since it can identify, estimate, and analyze risk incidents, FMEA has the potential to be used as a stand-alone method for assessing risks in a supply chain. However, FTA and analytical hierarchy process (AHP) can complement each other, and combining the two methods results in a less complicated process for assessing SCRs (Musa, 2012).

The FMEA uses evaluation of known possible defects and the likely consequences of outcomes. If such failures have been detected, risk management is implemented to remove, decrease or monitor possible failures. FMEA is the most popular, simple to use and feasible method that relies on understanding the product and processes. It helps to prioritize risks using risk priority number (RPN) and risk score values (RSV). The rating scales for occurrence, severity and detection of each risk can be used as an input for the RPN and RSV calculation (Zsidisin & Ritchie, 2009).

C. Risk Evaluation

Risk evaluation is a comparison of the calculated risks by a quantitative or qualitative scale with a specified risk criterion to determine the importance of the residual risk levels against an appropriate level of risk, i.e. risk tolerance. When the probability and effect of residual risks surpass their risk tolerance, additional risk mitigation measures should be applied to lower the risk level. So, either risk is considered reasonable or risk reduction methods have to be applied such as brainstorming, the Pareto's principle, the frontier graph (plotting probability of events by their consequence), and the risk threshold, showing risk-events on a matrix describing probability and effect rates. The latter approach helps administrators to grasp the relative possibilities and consequences of different risks (SCRLC, 2011).

2.1.4.2. Supply Chain Risk Control

Global supply chains are the backbone of the global economy and, because SCRs can waste resources as well as deteriorate supply chain output, risk management is getting more attention nowadays. Because of economic, social and political uncertainty in developing countries, the supply of medicines faced more uncertainties and vulnerabilities. Proper identification and risk analysis is thus a prior practice in formulating approaches to reduce risks (Jaberidoost *et al.*, 2015) specifically in developing countries.

Risk control is about risk mitigation and monitoring. Risk mitigation contributes to process optimization, increased productivity, risk minimization, and fulfillment of accessibility, consistency, and affordability targets (Jaberidoost *et al.*, 2013), while tracking internal and external risks helps to predict risk events and identify new risks. Active risk mitigation components like technology, versatility, supplier selection, and the likes are becoming more important. Risk control requires supply chain managers to work together to strengthen cooperation, develop a risk reduction strategy, and draw up a network-wide contingency protocol across the chain (SCC, 2016).

A. Risk Mitigation

Risk mitigation approaches geared to cause and effect allow companies to implement SCRM successfully. Juttner, Peck, and Christopher (2003) categorized SCR mitigation strategies as avoidance, control, collaboration and flexibility, but Wagner and Bode (2009) categorized them in two as causal and effect-oriented strategies. Cause-oriented mitigation approaches seek to eliminate any risks by concentrating on possible triggers that involve identified source products, not operating in hazardous geographic areas, collaborating with customers and suppliers, free exchange of information and frequent monitoring of suppliers. Effect-driven mitigation approaches, by contrast, reduce the negative effects of SCRs. There is nothing to call about shifting as much risk as possible to the supplier, using flexible contract options with suppliers, creating a contingency plans, providing late product differentiation and maintaining additional reserves of inventory and power.

There is evidence of a change in risk management that leads from more individualistic and autonomous responses such as insurance, defining supplier service rates to more cooperative responses like exchanging strategic information and forming relationships (Ritchie & Brindley,

2007). Supply chain integration may have both a positive and negative effect on the effectiveness of risk management. It can be used to build competencies in joint risk planning and collaborative risk management capabilities (Chaudhuri, Ghadge, Gaudenzi, & Dani, 2020).

B. Risk Monitoring

After the identification of possible risk areas by an organization, monitoring should be followed in an internal and external environment. This helps to predict the possible occurrence of risky events and identify new risks. Monitoring is a tool for measuring the effectiveness of risk controls and a tool for risk identification. It is measuring the impact of risks on business performance outcomes, and helps in checking sign of risk by seeing relevant metrics (Zsidisin & Ritchie, 2009). Risk monitoring allows organizations to check that risk response strategies have been adopted, assess their ongoing effectiveness, and recognize risk-impacting improvements to organizational information systems and operating environments (National Institute of Standards and Technology, 2011). Risk reduction approaches may be what-if simulations, financial models, expert opinions, or supply chain indicators that explain the impacts of the risks (SCC, 2008).

Supply chain metrics and performance reports will provide real-time information about potential risks and show patterns for decision-makers. Supplier visibility and customer satisfaction metrics improve the ability to track SCRs. Monitoring also includes tracking qualitative information sources such as news or weather forecasts to recognize incidents that are precursors to risks and the environment that is external to the supply chain of the organization. Delivery risk monitoring can be assessed using customer service metrics while supplier visibility metrics can be used to track the source risk monitoring (Faizal & Palaniappan, 2014).

2.1.4.3. Pharmaceutical Supply Chain Risk Control

The availability of medication is an important priority of every healthcare system, a strategic commodity. Pharmaceutical companies, a significant player in the supply chain of drugs, face numerous risks. Therefore, the implications of taking constructive measures for mitigation need to be investigated (Moktadir *et al.*, 2017). Risk management is gaining more coverage in the sense of pharmaceutical companies. Since medicinal products are subjected to profound regulation and are under the authority of public regulators (Connor *et al.*, 2017).

Pharmaceutical sector managers need to develop resilience skills to enhance the efficiency and effectiveness of the PSC program. To improve the resilience capabilities of their supply chains,

they need a clear understanding of the current SCRs in the first place. Risk mitigation approaches including prioritizing the supply and quality of medicines; minimizing losses; adequate storage and handling; working in collaborations between the MOH and the pharmaceutical companies as well as waste minimization approaches are potential strategies for risk mitigation (Jaberidoost *et al.*, 2015; Moktadir *et al.*, 2017).

2.2. Empirical Literature Review

2.2.1. Supply Chain Risk Management Practices

2.2.1.1. Risk Analysis Practice

The supply chain is affected by risks at various stages, from the sourcing of raw materials to the destinations of goods and services, and these risks are not always under control. In the risk evaluation of supply chain firms, there are several aspects to be considered. The size, experience, and a number of clients in the supply chain influence the risk profile of a company. Studies demonstrated that the risk magnitude of a company was influenced by the company's size and year of experience (Florian & Constangioara, 2014; Ouabouch & Paché, 2014) as well as the distance from the supplying firm (Mengistu, 2016).

The WEF held at Davos indicated that SCRM was a greater priority in the supply chain operation. In the report of the forum, natural disasters such as volcano eruptions in 2010, the 2011 Earthquake and Tsunami in Japan, and floods in Thailand were recorded as risks that cause systemic supply chain disruptions. The report also identified environmental catastrophes as the most likely risks (natural disasters (59%), extreme weather (30%), and pandemic (11%)) followed by geopolitical conflict and political unrest (46%); and import/export restrictions (33%) (WEF, 2012).

Through a literature analysis, a study in England discovered nine process-based strategies for finding and assessing SCRs. According to the data, standard risk assessment methods are more widely used than supply chain-specific tools such as the six-sigma method. Risk mitigation strategies were proposed for identified risks by focus group discussion method (Juttner, 2005).

The survey in Germany categorized risks sources as internal (supply-demand coordination risks) and external (regulatory, legal and bureaucratic; infrastructure; and catastrophic). The study identified severe disruptions (caused by regulatory, legal, or bureaucratic barriers, infrastructure

breakdowns, or serious catastrophes), that lead to the release of informal messages, occur less frequently than repeated demand and supply side disruptions (Wagner & Bode, 2009).

The results of the study in Bangladesh identified 16 risks through an extensive review of the literature and by the Delphi method. Supply related risks like fluctuation in imports arrival, lack of information sharing, supplier failure and non-availability of materials were prioritized over operational, financial and demand side risks. The AHP was used to prioritize risks as supply, organizational, financial and demand side respectively (Moktadir *et al.*, 2017).

In Malaysia, most of the responding companies were committed towards the implementation of SCR identification. The results of the study indicated that supply and demand were two highly prioritized areas to implement risk identification while the environmental issues were given the least attention. The supply chain environment that covers natural disasters and political instability was not given concern by respondents (Aghapour *et al.*, 2015) whereas, a study in Iran by expert judgment and multi-standard decision-making methods indicated that due to the policies implemented by the government and its ratified regulations, the most influential and important risk was environmental risk. Supply chain risks were prioritized orderly as environmental, financial, strategic, informative and communicative technology, technology and equipment, and human resource risks (Zandhessami & Savoji, 2011).

Another study in Malaysia also showed that the SCR identification has the highest advantage to increase supply chain visibility (85%), increase knowledge about potential risks (76%), improve risk predication (60%), to reduce potential costs (33%), and to increase responsiveness toward risks (55%). On top of this, 42% of the respondents agreed that there is a relationship between risk identification and productivity (Aghapour *et al.*, 2015).

Two studies were done in Iran regarding SCRs. According to both studies, many risks reported were internal risks due to processes, people and functions mismanagement but only a few of the risks were external ones. According to the study in 2013, 50 main risks were identified, and classified in to seven categories. From these, 40% of risks were related to supply and supplier issues; and regulatory issues were in the next level of importance with 28% frequency. This study didn't show disruption's impact on companies (Jaberidoost *et al.*, 2013) while the study during 2015 identified 86 main pharmaceutical SCRs and the majority of risks described were related to the financial and economic category including political conditions followed by

regulatory issues. Top 20 risks with a high impact on financial, supply, sales, operations, and quality management function, and impact on each function of supply chain were measured (Jaberidoost *et al.*, 2015).

In an expert judgment and survey based risk prioritization study in India, internal risks got 83.33% weight while external risks score 16.67% as per the pairwise comparison by fuzzy AHP calculation. This showed that the likelihood of factors of internal risks was higher than external risks. The analysis also showed that the risk sub-categories disruption, forecast inaccuracies, and delay have higher impact on the supply chain performance (Gupta, Sahu, & Khandelwal, 2014).

The study done in South Africa showed that external disruptions (customer and supply-side) on third-party service providers were found to be the primary sources of SCRs. Based on the finding of this study, SCRs resulted primarily from labor strikes and cyber-attacks while crime and security; and IT risks were identified as the second major concern (Meyer *et al.*, 2019). Risk analysis with risk impact and likelihood as assessment scales and indicator risk monitoring tools were employed to result in a flexible supply chain (Simba, Niemann, Kotze, & Agigi, 2017).

Risk estimation was the most commonly employed risk identification approach in the Kenyan study, followed by previous risk assessments, establishing risk registers, brainstorming sessions, and surveys. Currency fluctuations, quality, taxes, customs procedures, and other laws, as well as physical theft, were identified as the key SCRs in this study. According to the report, SCRs were classified as a supplier, end-to-end supply chain, distribution, and enterprise risks (Aluda, 2015).

A study in Morocco founded that supplier quality problems were the gravest risk factor but supplier failure and increase in risk management price were the most probable risk factors. Unexpected demand fluctuations, delivery chain disruptions, decreasing market prices, unpredictable trade barriers and upstream transportation failure were severe risk factors identified but less likely to occur. The highest probability was observed in supplier failure and increase in raw material prices whereas internal risk factors had the least probability of impact (Ouabouch & Amri, 2013).

Studies were done in Ethiopia regarding the SCRM process and practice over both health and non-health commodities. The study done at Ethio-telecom showed that demand-side risks (unexpected volatile demand and distorted information), supply-side risks (poor logistics

delivery system of suppliers and poor logistic service of third party service providers), quality-related, administrative barriers, capacity risks, and currency problems affected the supply chain operation (Yoseph, 2017).

Another study done in Ethiopia on coffee supply chain showed that 81 risks were identified as financial and economic, technical, managerial, political, resource, safety and security, legal, and environmental risks. These risks were analyzed using the FMEA tool and resulted that 32 risks were in a red zone that required immediate action. Insufficient and incorrect information and lack of technical and managerial skills were the main cause for most risks (Gebreleul, 2018).

Mengistu (2016) concluded that EPSA was weak in the formal and reliable risk register and survey methods of risk identification. Supplier risk (single supplier, lead-time, and unavailability of an item) posed higher threat; and currency fluctuation, adulteration, and quality assurance related risks posed a significant threat in its functioning. Internal risks (rapid staff turnover, forecasting error, strategic risk, lack of funds, obsolete and expired inventories, lack of number of staff, and lack of training and knowledge) also posed a serious problem. Distribution risk, unexpected rise in demand and longer lead-time resulted in a higher threat to the supply chain while environmental disruptions (catastrophic, political, natural and manmade risks) were perceived as a low threat.

2.2.1.2. Risk Control Practice

Lack of visibility and quantification of risks impeded more effective risk management across supply chain. Considering this, companies should struggle to quantify their risks due to a lack of understanding, standardized metrics, and relevant and updated data (Breen, 2008).

The study in Australia elaborated the management of risks in the downstream supply chain through a process of close collaboration, effective communication and building trust within the relationships. Companies did not see the development of performance standards as the imposition of a risk management strategy but rather a collaborative approach that resolved the risks within the chain to the mutual benefit of all partners (Ritchie & Brindley, 2007).

A systematic review done in Germany revealed that one mitigation strategy might alleviate other SCRs and consolidating demand reduces anticipated risks such as inventory and capacity risks. The review identified eight top risk management strategies from literature as visibility and

transparency, partnership, flexibility, backup inventory, collaboration, postponement, multiple sourcing as well as flexible contracts, and joint planning and coordination were supposed crucial by the researchers (Kilubi, 2016).

The study conducted in French companies also concluded that management of organizational relations is important in managing risks. Communication and information exchange with partners, supplier support, forecasting accuracy and industrial relations were the most frequently chosen alternatives whereas the appointment of a SCR manager, cultural proximity and presence of a firm backbone were the least popular means (Lavastre, Gunasekaran, & Spalanzani, 2012).

The study in Iran revealed that since most of the risks facing the pharmaceutical companies were found to be internal risks, supply chain entities should fix it internally. The efficient relationship between MOH and companies was recommended as the best risk review and mitigating strategy for internal risks (Jaberidoost *et al.*, 2015).

According to the study in India, identifying supply chain vulnerability points, contingency planning, adding inventories, increasing capacity, increasing flexibility, responsiveness, managing demand, incentivize customers, cost reduction in operations and capacity, better planning and coordination mitigate risks in supply chain (Gupta *et al.*, 2014). Another study done on the process of quality risk management in WHO approved plants of India also showed that due to high incidence of product recalls and quality implementation problems, assuring personnel with appropriate product-specific knowledge and expertise were recommended for effective planning and completion of quality risk management activities (WHO, 2012).

The study done in Kuwait founded that few functions of the pharmaceutical sector remain vulnerable to corruption. However, the willingness of Kuwait's MOH to adopt assessment study and accept the weaknesses of the sector was selected as a mitigation strategy to achieve a transparent pharmaceutical system soon (Badawi, Alkhamis, Qaddoumi, & Behbehani, 2015).

The findings of the study in South Africa indicated that the four primary approaches employed in collaborative, planning, forecasting and replenishment (CPFR) is an essential mitigation method. Long-term relationships, information systems, clear communication and internal business processes were also identified as the best risk mitigation strategies employed whereas high cost to implement, unwillingness of supply chain partners, not accepting responsibilities and the

presence of uncontrollable factors were constraints in implementing SCRM strategy (Meyer *et al.*, 2019).

Similarly, the study in Moroccan companies showed that supply chain managers should primarily turn their attention on supply and demand side risk sources, and shine activities such as supplier relationship management, demand forecasting as well as cooperative information sharing with customers and suppliers (Ouabouch & Amri, 2013).

The study by Aluda (2015) founded that concerns about rising prices, poor communication across the supply chain, and a lack of necessary resources are all impediments to implementing SCRM processes. According to the study, 46.4% of respondents said SCRM was widely used, and master data management tool was the most commonly used SCRM tool, followed by operations planning and sourcing tools, spend management analysis tool, sales tools and inventory optimization tools.

The study in Zimbabwe showed that SCRM played a major role in successfully managing a company. Since SCRs have multiple sources like process, control, demand, supply, and environment, an immediate SCRM process is mandatory to have a good response. Efficient SCRM was taken as crucial for the success of supply chain since it enables companies to achieve a competitive advantage where risk is identified, estimated, and mitigated (Mndzebele, 2014).

The study in Ethiopia's coffee supply chain identified challenges to implement the SCRM process. Among these, lack of flexibility; less consistent and unethical suppliers; lack of awareness about risks and their management, lack of skilled experts, and lack of technology were some of them. Giving risk management for only one department, lack of flexible collaborative relationship with suppliers, limited variety of insurance coverage, lack of SCRM policy and governance also vastly affected the practice (Yoseph, 2017).

The study done at EPSA central in 2016 showed that EPSA used risk estimation and previous risk assessment as a risk management practice to a small extent. However, lower risk mitigation capability plus a lower risk identification problem added up to difficulty in achieving an effective SCRM as the report of the study. The potential barriers indicated in adopting the SCRM were supplier geographical distance, inadequate technology, lack of SCM knowledge, and weak communication across the supply chain (Mengistu, 2016).

2.2.2. Supply chain performance from a risk management viewpoint

Numerous prior studies monitored the performance of supply chain system. From the perspective of risk management, there are various techniques to assess supply chain performance. According to the findings of the Shahbaz *et al.* (2018) study, a good metric for measuring SCR performance must include indicators for cost, quality, flexibility, customer satisfaction, capacity, time, and consistency. However, Chen, Sohal and Prajogo (2013) recommended order fill capacity, delivery dependability, delivery speed, and customer satisfaction while Ouabouch and Pache (2014) added quality as one measure. Faizal and Palaniappan (2014), and Musa (2012) supported the SCOR metrics of performance measurement and preferred risk analysis as one indicator.

2.2.3. Risks Associated with Supply Chain Performance

Risks in the supply chain can waste resources and degrade supply chain performance (Adam, 2013; Jaberidoost *et al.*, 2013). It is any deviation from a performance value, which has a negative influence on supply chain operation. It has the potential to block the supply chain network completely or in part (Wagner & Bode, 2009b). Firm performance has a big impact on supply chain performance. By linking risk management and performance measurement systems, companies can track how SCRM affects their supply chain's performance goals (Moniruzzaman, 2016; Ryding & Sahlin, 2013).

According to a study conducted in Germany, SCRs have a considerable yet minor impact on supply chain performance. There was a negative link between supply and demand side risks and supply chain performance (Wagner & Bode, 2008). Supply side risks affected outbound logistics and, whereas demand side risks posed critical challenges to the supply chain's ability to serve its customers and, as a result, influenced the supply chain performance (Chen *et al.*, 2013). As a result, logistical performance in terms of meeting deadlines, reactivity when dealing with hazards, and logistical cost reduction could be affected (Ouabouch & Pache, 2014).

H1: The higher the demand side risk, the lower the supply chain performance.

H2: The higher the supply side risk, the lower the supply chain performance.

Operational risks have a detrimental influence on the supply chain and prevent organizations from achieving their objectives. It hinders the firm's capacity to efficiently fulfill customer orders and, as a result, the supply chain's performance. Risks have a substantial impact on product flow

management at the operational level. It resulted in loss of efficiency and an inability to meet performance targets (Chen *et al.*, 2013; Ouabouch & Pache, 2014; Zeng, 2012).

H3: The higher the operational risk, the lower the supply chain performance.

More disruptions and negative repercussions, including quality issues, customer complaints, delays, and supply and demand mismatches, resulted from a higher level of risks. Firms exposed to SCRs are expected to have weaker performance than those who are exposed to lesser levels of risk. The average value of the logistical performance of a company inevitably deteriorates in moving from a low to a high level of risk (Florian & Constangioara, 2014). The studies by Wagner and Bode (2008), and Florian and Constangioara (2014) pointed out that control, infrastructural and environmental risks had affected the supply chain performances of organizations negatively.

H4: The higher the control risk, the lower the supply chain performance.

H5: The higher the infrastructure risk, the lower the supply chain performance.

H6: The higher the environmental risk, the lower the supply chain performance.

The SCRM strategy is linked to SCRs. Firms can begin to mitigate the negative effects of risks by prioritizing the development of appropriate SCRM strategies. The SCRM technique effectively mitigates the negative implications of risks (Florian & Constangioara, 2014). This revealed that by putting more effort into risk management, supply chain performance might be improved. If SCRs can be carefully handled, supply chain effectiveness (lead-time, inventory turnover, and response time) is predicted to be improved (Zeng, 2012).

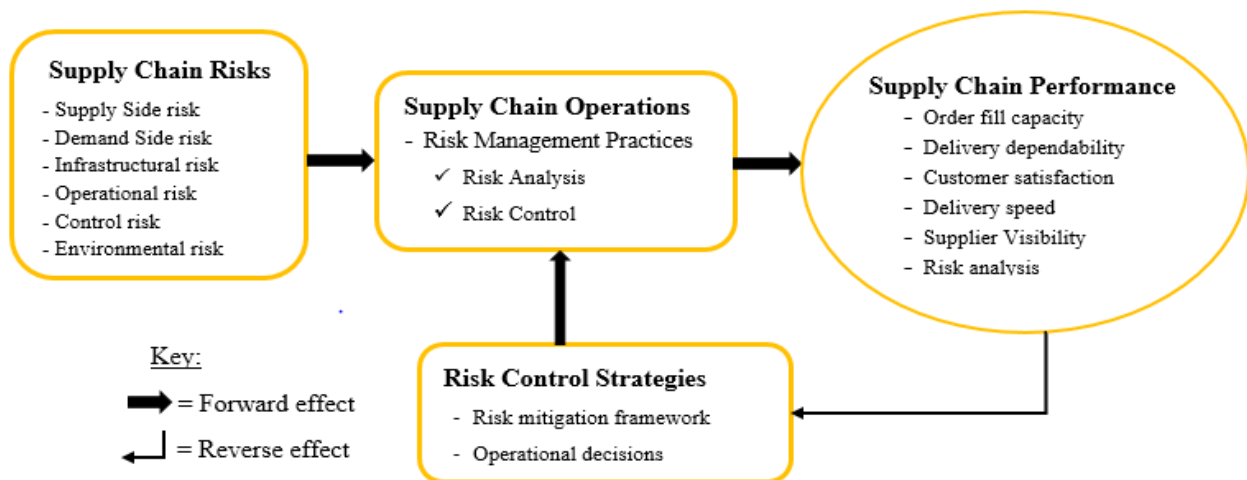
The SCRM procedure improved the performance of the organization positively (Ryding & Sahlin, 2013). Through appropriate plans and strategies, managing SCRs can lead to high performance and reduce supply chain vulnerability and uncertainties. As a result, companies should take a formal, structured approach to identify, quantify, and manage SCRs (Mangla *et al.*, 2016). The use of a structured SCRM approach aids in the development of a resilient supply chain by lowering the risk effect and likelihood (Simba *et al.*, 2017). The study by Florian and Constangioara (2014) documented a positive relationship of SCRM strategy on organizational performances ($\beta = 0.30$, $t = 2.01$). Hamid and Ibrahim (2015) also founded that the supply chain

performance was positively influenced by SCRM practice variables. As a result, risk mitigation techniques and procedures are essential to mitigate the effects of risks.

H7: The higher the SCRM practice, the higher the supply chain performance.

2.3. Conceptual Framework of the Study

Risk management is an extension of SCM (Singhal *et al.*, 2011). Risk analysis helps an organization in the process of preparing for any logistical problem that will occur in the network and improve the efficiency and effectiveness of SCM practice by providing the ability to optimize the level of risk (Vikulov & Butrin, 2014). In this process, SCRs block totally or in part the operation of the network (WEF, 2012). Therefore, risk mitigation strategies are mandatory to reverse the effect of risks (see Figure 4). In moving from a low to a high level of risks, the average value of logistical performance unavoidably deteriorates for companies. Rodrigues, Stank, and Lynch (2004) focused on the downstream supply chain performance to measure this dependent variable and the four performance items including delivery dependability, order fill capacity, delivery speed, and customer satisfaction as well as supplier visibility from the upstream chain. When risk analysis is included as a metric and other monitoring metrics of supply chain performance assessed regularly, there might be a high probability of new risks to be identified (risk monitoring is one form of risk identification). Provided that risk control strategies are going to be re-implemented to accommodate new risks.



Source: Adopted from Musa (2012)

Figure 4: Conceptual framework of the study.

2.4. Summary of Hypotheses

Based on the reviewed prior literature and the objective of this study, the following hypotheses were proposed, and presented as follows.

H1: The higher the supply side risk, the lower the supply chain performance.

H2: The higher the demand side risk, the lower the supply chain performance.

H3: The higher the operational risk, the lower the supply chain performance.

H4: The higher the control risk, the lower the supply chain performance.

H5: The higher the environmental risk, the lower the supply chain performance.

H6: The higher the infrastructure risk, the lower the supply chain performance.

H7: The higher the SCRM practice, the higher the supply chain performance.

CHAPTER THREE

3. METHODOF THE STUDY

This chapter includes study area description, research design, research approach, source and study population, sampling techniques and sample size determination, data collection methods and instruments, variables of the study, data quality assurance, data entry and analysis, and ethical consideration of the final paper.

3.1. Description of the Study Area

The study was conducted at EPSA central and hubs from September 19 - October 18, 2020. The EPSA is the only public agency responsible for sourcing and distributing pharmaceuticals for public and private health facilities in Ethiopia. The study covered all the seven clusters of EPSA namely: Adama, Central, Northern, Southern, Eastern, Western and Northwestern clusters. Each cluster consists of a minimum of one to a maximum of four hubs. Currently, 19 hubs supply products to health facilities (see Annex 3).

3.2. Study Design

An explanatory and descriptive case study research design was employed for the study.

3.3. Research Approach

Both quantitative and qualitative methods were used to collect the required data for the study.

3.4. Population and Sampling Design

The source population for this study were professionals in the managerial positions and senior officers in EPSA including directors and coordinators (team leaders) centrally and at hubs.

Professionals in managerial position working in 14 directorates at central EPSA and 6 teams at the hub level that were directly involved in the core and supportive supply chain activities were included as respondents for the study.

The capacity building and operational research; quantification and market-shaping; distribution and fleet management; general service and property administration; contract management; tender management; warehouse and inventory management; human resource administration and development; management information system; planning, monitoring, and evaluation; finance

(both program and revolving drug fund); and quality control and assurance directorates were selected from the central agency. Branch coordination and director-general office was also included in this study. Six teams namely forecasting and capacity building; transportation and distribution; warehousing and inventory management; planning, monitoring, and evaluation; finance administration; and human resource and general service units were selected from hubs.

All professionals who were in the managerial position at EPSA central and hubs under selected hubs and directorates/teams and available or legally delegated during the data collection and those who were voluntary to participate in the study were included as respondents for the study. Professionals who did not work at least for 6 months at EPSA were excluded from the study.

To make the study more representative and as EPSA hubs are nearly similar in management, operation, and infrastructural structures, seven hubs (one from each cluster) including the central agency were purposively selected and included in the study. The selection of the hubs takes into consideration factors like the number of health facilities served (serving the highest number of facilities from the cluster). Adama hub was included directly since the cluster contains only one hub. Then, Adama, Mekele, Addis Ababa hub 1, Diredawa, Jimma, Hawassa, and Bahir Dar hubs were selected from the 7 clusters (see Annex 3).

Two professionals (the director/team leader and the vice director/team leader) from the 14 directorates at EPSA central and 6 teams from each hub were selected as a study subjects. The director and the coordinators at central EPSA and hubs got a priority to be included in the study but if he/she was not available during the study period, a delegate or a recommended senior officer were included in the study. Given that:

- ✓ The number of sample at hubs = 7 hubs X6 teams X 2 professionals = **84** samples
- ✓ The number of samples centrally = 14 Directorates X 2 professionals = **28** samples
- ✓ The total number of samples in the study = 84 + 28 = **112** professionals

Therefore, the total sample size for the study was 112 managerial level professionals and senior officers having greater than six months of experience for questioner survey. One professional from each directorate and team (56 samples) was considered for the interview survey.

3.5. Data Collection Methods and Instruments

The qualitative data was collected through a face-to-face interview using a structured interview guide while the risk analysis and risk management practice data were collected from respondents using a self-administered questionnaire. During the data collection, the list of risks were divided under core (like procurement, storage, distribution, etc.) and supportive (like IT, finance, human resource, etc.) supply chain areas, and were distributed for respondents for rating accordingly. The respondents from both supply chain areas were rated only risks associated with their activity.

Then, sampled experts rated the occurrence; severity and detection of risks based on the 10-point rating scale of FMEA model in the risk checklist (see Annex 1). The SCRM practice (1 = No extent, 2 = Small extent, 3 = Moderate extent, 4 = Great extent, and 5 = Very great extent), and perceived supply chain performance (1 = Significantly worsened, 2 = Worsened, 3 = No Change, 4 = Improved and 5 = Significantly improved) was rated by a 5-point Likert scale. 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Very often, and 5 = Always rating was used for frequency items.

The data collection instrument was developed by different mechanisms. The principal investigator, based on the objective of the study and reviewing similar literatures, developed the interview guide (see Annex 2) and the risk checklist. Academicians from AAU and professionals at central EPSA capacity building and operational research directorate evaluated the developed risk checklist to rephrase, reclassify, and made addition/deletion of risks on the list. Whereas, the practice assessment tool was customized from previous studies by Aluda (2015), Mengistu (2016), Chen, Sohal, and Prajogo (2013), and Gupta *et al.*, (2014) (see Annex 1).

3.6. Variables of the Study

3.6.1. Dependent Variable

- Supply chain performance

3.6.2. Independent Variable

- Supply side risks
- Operational risks
- Environmental risks
- Supply chain risk management practice
- Demand side risks
- Control risks
- Infrastructural risks

3.7. Data Quality Assurance

The data collection tools were pretested on 12 professionals at Addis Ababa hub 2, one branch of EPSA with a similar setting and management to other hubs. Academicians in AAU and senior professionals from EPSA’s capacity building and operational research directorate made addition and deletion on the tool, and commented on it before the data collection.

Cronbach’s alpha coefficient was calculated to test the reliability of the tool and the filled tools were checked manually for completeness and consistencies. The Cronbach’s alpha coefficient result shows, the alpha coefficient of all the components of the data collection instrument is statistically significant. Based on the study by Taber (2018), the Cronbach’s alpha score of the items in the questionnaire falls under the acceptable range, 0.53 to 0.94. Hence, the reliability of the instrument accounted for an overall Cronbach’s alpha coefficient of 0.870, thus found to be reliable (see Table 1).

Table 1: The Cronbach alpha coefficient of the data collection tool administered in EPSA, Ethiopia, 2020.

	Cronbach α	α if item deleted	Number of items	n
Supply side risks	0.530	0.62	30	15
Demand side risks	0.823		15	48
Operational risks	0.887		19	52
Control risks	0.851		11	11
Environmental risks	0.569	0.633	5	89
Infrastructural risks	0.713		9	45
SCRM practice	0.936		35	100
Supply chain performance	0.780		6	93
Total	0.870		130	101

Note: n – sample size, α - alpha

Source: own survey

3.8. Method of Data Analysis

The quantitative data were analyzed by SPSS version 23. Descriptive (percentage, frequency, interquartile range (IQR), median and mean) and inferential (independent samples test, and regression) statistics were used to analyze and result was presented in tables, and graphs.

The mean score of each risk was taken to create a single variable for each risk type and as well, the mean of each performance and practice score was taken to create a single variable for practice and performance measures. Then, ordinal logistics regression and Kruskal Wallis test was done using these aggregated variables.

The Excel-derived FMEA analysis template was used for risk prioritization and evaluation. The risk priority number (RPN) for each risk was calculated from the filled risk checklist data. This summary risk score was calculated for each risk by multiplying the risk impact score with the probability and detection score, i.e.

$$\mathbf{RSV} = \text{Occurrence} \times \text{Severity}$$

$$\mathbf{RPN} = \text{Occurrence} \times \text{Severity} \times \text{Detection}$$

Then, risks were prioritized by their **RPN** value and the data was tabulated. Top-ranked risks were selected by Pareto's principle (Alecú, 2010) based on the respective RPN score (see Annex 4). Whereas, the qualitative data were analyzed thematically. A concurrent triangulation strategy was followed to amplify the statistical information in four themes, risk analysis, risk control, risk management practice, and challenges of risk management.

3.9. Ethical Consideration

Ethical approval was obtained from the research and ethics review committee of the School of Pharmacy, Addis Ababa University. A letter was also obtained from Addis Ababa University to EPSA central to get their consent for the study to be conducted, and then to the seven hubs from EPSA central.

Participants of the study were asked for consent before being included as respondents for the study. During the consent process, information about the purpose of the study, why and how they were selected, and what is expected from them including the right to leave the study at any point in the interview process was provided. They were also assured that the information obtained in the course of the study will be used only for academic, research, and policy-making purposes. All the data collection and report processes were communicated with each respondent and they were assured that the results of the study will be reported without specific personal identifiers.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

In this chapter, the overall findings of the study are presented in detail. Both self-administered and interview based findings are displayed in word, table, and figure formats. Starting from response rate, demographic characteristics of respondents and EPSA hub information to both descriptive and analytical results of risk identification, risk management practice, and supply chain performance findings are presented. The main findings of the study are compared with related literature. Hypothesis test results are also covered, and at the end of this chapter, important risk mitigation strategies for those top priority risks identified are presented.

4.1. Response Rate

From the total 110 questionnaires distributed to respondents, 108 (98.18%) were received back and 101 (91.82%) were found to be complete. The study covered EPSA central and hub offices and of these, 75 (74.5%) of the respondents were from hub offices while the rest 25% were from central EPSA. The response rate of the qualitative part of the study was 47 (89.93%), which is greater than the acceptable minimum value 60% (Fincham, 2008).

4.2. Demographic Characteristics of Respondents

From the 101 study participants, 84 (83.2%) were males. All participants were first degree and/or above holders, and 26 (25.7%) are pharmacy professionals followed by 18 (17.8%) Logistics and Supply Chain Management professionals. Most participants were from the finance directorate and team, 17 (16.8%), followed by forecasting and capacity building, and distribution and fleet management directorates and/or teams, each representing 16 (15.8%). 46 (45.5%) of the respondents were senior officers, and 29 (28.7%) of the participants were directors or team leaders in their current position. Most of the participants, 80 (79.2%), had more than seven years' work experience in different supply chain levels (see Table 2).

Table 2: The socio demographic characteristics of respondents in EPSA, Ethiopia, 2020.

	Frequency	Percentage	Cumulative %
Sex (n = 101)			
Female	17	16.8	16.8
Male	84	83.2	100.0
Educational Level (n = 101)			
First degree	59	58.4	58.4
Master	42	41.6	100.0
Department or Area of Specialization (n = 101)			
Accounting	12	11.9	11.9
LSCM	18	17.8	29.7
MBA	10	9.9	39.6
Management	12	11.9	51.5
Pharmacy	26	25.7	77.2
PSCM	4	4.0	81.2
Others ^a	19	18.8	100
Directorates or Teams (n = 101)			
Forecasting and capacity building	16	15.8	15.8
Distribution and fleet management	16	15.8	31.6
Finance team	17	16.8	48.4
General Service	6	5.9	54.3
Human resource management	9	8.9	63.2
Monitoring and evaluation	12	11.9	75.1
Warehouse and inventory management	15	14.9	90.0
Others ^b	10	9.9	100
Current Position In the Directorate or Team (n = 101)			
Coordinator or vice team leader	23	22.8	22.8
Director or team leader	29	28.7	51.5
Legal delegate of director/coordinator	3	3.0	54.5
Senior officer	46	45.5	100.0
Work Experience(n = 101)			
1-2 years	1	1.0	1.0
2-5 years	8	7.9	8.9
5-7 years	12	11.9	20.8
>7 years	80	79.2	100.0

Note: LSCM – Logistics and Supply Chain Management, PSCM – Pharmaceutical Supply Chain Management, MBA – Master of Business Administration. a - The category includes biomedical, business administration, business management, computer science, economics, health supply chain management, information and communication technology, nutrition, Public management, public finance management, public health, and statistics. b - The category involves Contract management, Information technology, Quality management, Branch coordination, Quantification, and Tender management.

Source: own survey

4.3. Analysis of Pharmaceutical Supply Chain Risks

In this study, to conduct risk analysis, respondents were asked to rate identified risks that are only related to their assigned department, according to a 10-point FMEA model rating scale (see Annex 1). The RSV (O X S) and RPN (O X S X D) of each risk were calculated by using their respective formulas. Then the risks are ranked based on their RPN score, and cumulative percentage of each risk was calculated from the RPN value (see Annex 4). Top priority risks are then identified based on Pareto's principle of analysis. Based on this analysis, the first category (high-risk zone) includes the first 20% of the total risks that assumed to cover 80% of the disruption (Alecu, 2010). Implied that the cutoff points for RSV and RPN values are 29.37 and 177.35 respectively (the points where 20% of risks are included).

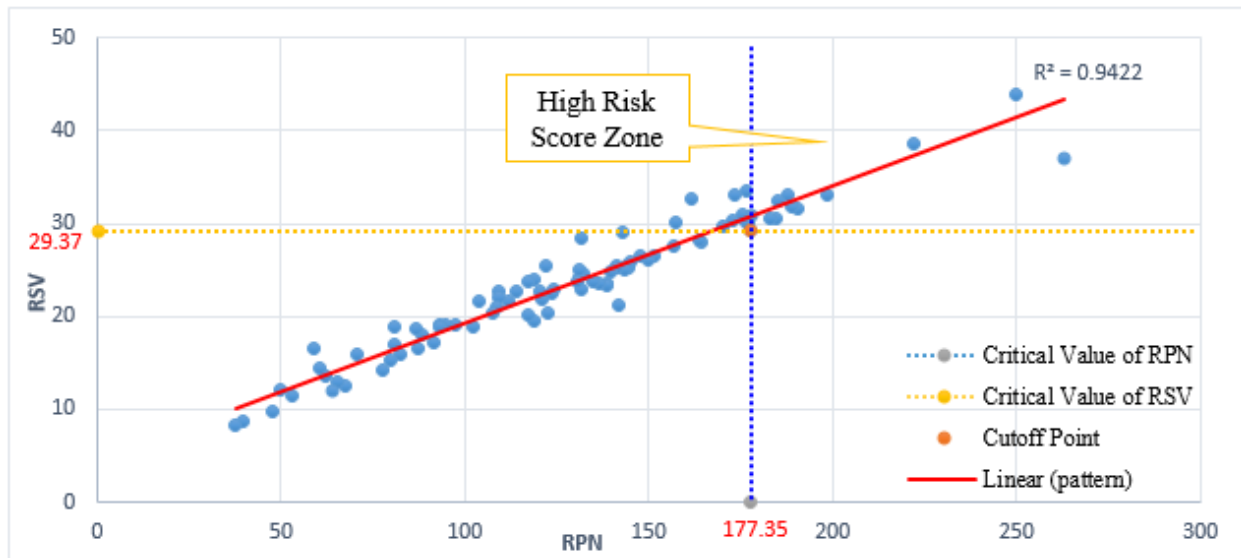
From the overall 89 risks identified in this study (see Annex 4), 12 (20.99%) of them covers 20% of the total risks and are assumed to constitute 80% of the whole supply chain disruption of EPSA, which is categorized under high-risk score category (see Figure 5). The result of this study also shows that supply side risks followed by demand side and operational risks take the priority in disrupting the supply chain operation in EPSA. Among these, inability to meet customer demand, lead time variability, poor logistics performance of suppliers, and forecasting errors are under high risk score categories (see Table 3).

Table 3: The top priority risks identified in EPSA, Ethiopia, 2020 (n = 101).

Risk Types	O	S	D	RSV	RPN	Cum %	Rank	Category
Inability to meet customer demand	5.31	7.00	7.06	37.19	262.64	2.31	1	Supply side
Lead-time variability	6.69	6.56	5.69	43.89	249.61	4.50	2	Supply side
Suppliers' poor logistics performance	5.94	6.50	5.75	38.59	221.91	6.43	3	Supply side
Risks in forecasting	5.53	6.00	5.98	33.18	198.41	8.16	4	Demand side
Poor planning	5.43	5.80	6.04	31.51	190.41	9.81	5	Operational
Customer service disruption	5.77	5.52	5.94	31.84	189.10	11.46	6	Operational
Contract/agreement issues	5.50	6.00	5.69	33.00	187.69	13.10	7	Supply side
Lack of speed of delivery	5.84	5.55	5.72	32.4	185.22	14.70	8	Operational
Poor documentations	5.58	5.46	6.04	30.49	184.32	16.31	9	Operational
Financial risks	5.29	5.76	6.00	30.52	183.11	17.90	10	Demand side
Instability of suppliers	5.38	5.75	5.75	30.91	177.71	19.45	11	Supply side
Unanticipated demand	5.25	5.59	6.04	29.37	177.35	20.99	12	Demand side

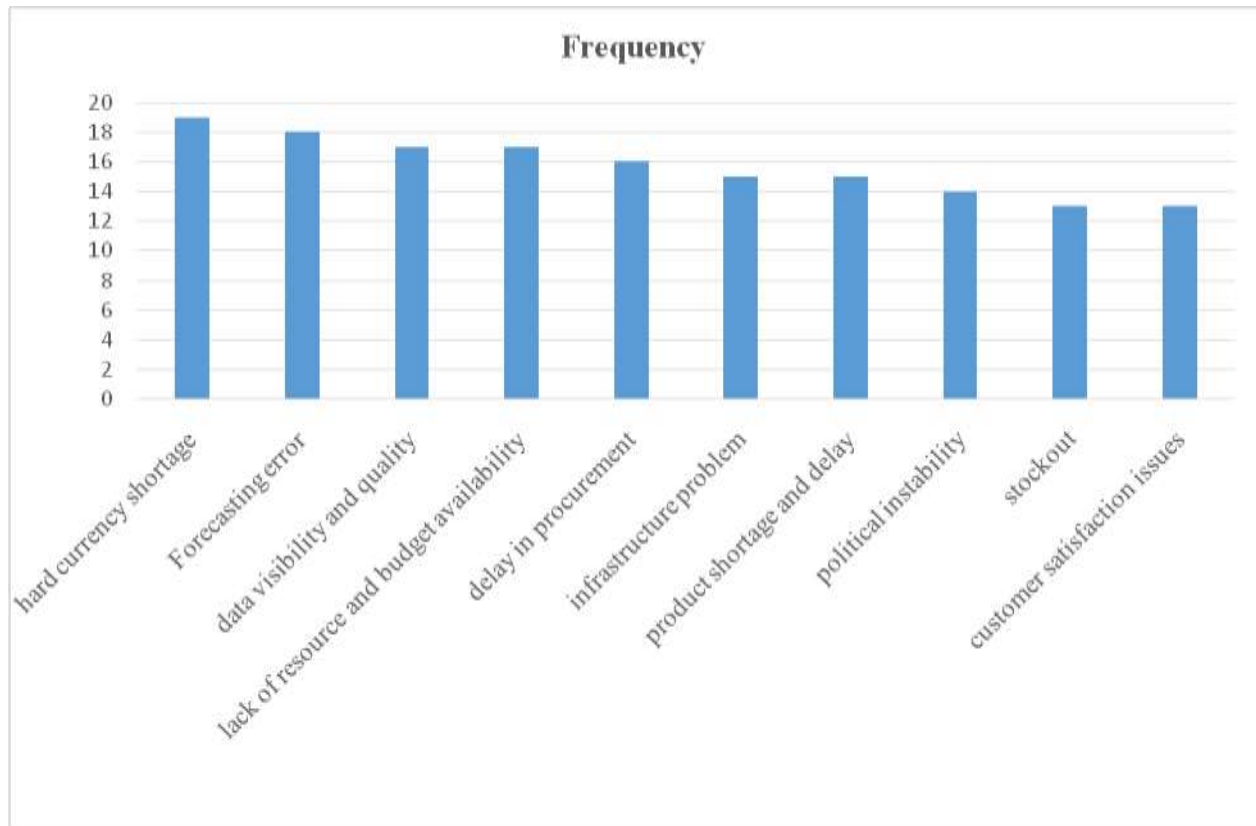
Note: O – Occurrence score, S – Severity Score, D – Detection Score, RSV – Risk Score Value, RPN – Risk priority Number, Cum% - cumulative percentage

Source: own survey



Source: own survey

Figure 5: The scatter diagram of RSV versus RPN values of risks in EPSA, Ethiopia, 2020.



Source: own survey

Figure 6: The most frequently occurring risks in EPSA, Ethiopia, 2020.

Respondents for the qualitative part of the study were also asked to list the most frequently occurring risks in their assigned department, to see the difference in top priority risks from the questionnaire survey. From this, 38 risks are identified from all 47 participants asked. The result shows that supply side, demand side, and operational risks like hard currency shortage, forecasting error, and procurement delay are among the frequently mentioned risks by respondents) (see Figure 6). The result confirmed that these risks are related to those prioritized risks by the questionnaire survey in one or the other way.

The results of this study are similar to the study conducted by Mengistu (2016) that stated supplier risks pose a much higher threat in EPSA's supply chain. The study indicated that potential risk factors like single supplier, lead-time, and unavailability of drugs/or medical supply pose a higher threat than the other potential risk factors. Another study by Yoseph (2017) also showed that demand and supply side risks took the priority in affecting supply chain system followed by regulatory, infrastructural and environmental risks. Whereas, a study by Gebreleul

(2018) revealed that there is a great difference in the top priority risks with the current study. In the former study, environmental, control and operational risks took priority followed by infrastructural risks. Among these, diseases, adverse climatic conditions, corruption, and poor documentation took the rank in the top 10 risk categories. This difference might be due to the difference in product nature and requirement in the supply chain as well as the difference in the direction of flow of products studied in former and current studies.

4.3.1. The difference in Risk Profile between EPSA Hubs

Among the seven hubs included in this study, the mean distance from the central agency to hubs is 370.49 Km (range of 15 - 788 Km), and the average number of catchment facilities served by hubs are 429 (range of 203 - 919). A non-parametric independent samples test (Kruskal Wallis test) was used to assess the difference in risk profile between the seven hubs of EPSA. The result shows that there is a similar risk profile among all risk categories except environmental risks that shows a significant difference among hubs ($\chi^2= 14.014$, $P = 0.029$) at 95% confidence interval. The mean rank score of Jimma hub was 58.50 followed by Dire Dawa hub, 43.21 (see Table 4), showing that Jimma hub encountered the highest environmental risk followed by Dire Dawa hub.

Table 4: The difference in risk profile among the seven EPSA hubs, Ethiopia, 2020 (n = 75).

Hubs	Mean Rank				
	Demand Side Risks	Operational Risks	Control Risks	Environmental Risks	Infrastructure Risks
Addis Ababa	40.40	37.95	44.91	39.14	44.27
Adama	35.56	38.11	35.00	39.09	37.68
Hawassa	41.61	22.50	26.64	26.36	29.59
Jimma	28.71	27.50	45.39	58.50	45.78
Dire Dawa	31.30	30.10	41.63	43.21	39.75
Bahir Dar	25.89	37.11	38.32	32.18	37.82
Mekele	23.45	32.75	34.85	30.05	31.80
Chi-Square	8.047	5.500	5.887	14.014	4.589
P Value	0.235	0.481	0.436	0.029	0.597

Source: own survey

The result of this study is in contrary to the study conducted by (Ouabouch & Paché, 2014) that demonstrated as the size, experience, and number of clients in the supply chain influence the risk profile of a company. Another study in Ethiopia by Mengistu (2016) also showed that supply chain organizations' risk profile was determined by their distance from the source of supply. This might be due to the reason that EPSA hubs have similar management, approach and experience of risk management (lead by one agency), but their difference in environmental risks might be due to the difference in the geographical location of branches.

4.4. Pharmaceutical Supply Chain Risk Management Practices

4.4.1. Implementation of SCRM practices

The SCRM practice consists of activities implemented in risk analysis (identification, estimation and evaluation), risk management capability, risk mitigation, and risk monitoring performance. Respondents were asked to rate the extent to which EPSA currently employed SCRM practices with a 5-point rating scale (1 = no extent, 2 = small extent, 3 = moderate extent, 4 = great extent, and 5 = very great extent). From the total 101 participants, 85 (84.2%) (Median = 2, IQR = 1) of the respondents agree on small or moderate extent implementation of risk management practices.

The results in this study shows that the overall implementation of SCRM practice in EPSA to mitigate the impact of risks is only small extent level. This directly implied that the risk management practice is below the average. The result is supported by the study in England that stated the SCRM practice was at its infancy, which requires ample effort for proper implementation (Juttner, 2005).

4.4.2. Risk Identification

There are several risk identification methods in the risk management process. From these, the participants were asked to rate the applicability of 5 risk identification methods with a 5-point scale (1 = no extent, 2 = small extent, 3 = moderate extent, 4 = great extent, and 5 = very great extent). Among these, risk estimation, previous risk assessment and brainstorming sessions were reported implemented to a smaller extent while developing risk register and survey methods are not used as risk identification methods in the last 5 years history of EPSA (see Table 5). The brainstorming session was reported highly implemented with 42.6% while survey method was reported implemented only in 31.7% of the cases. This result implied that the applicability of risk

identification methods was higher for methods that are more traditional, and more scientific methods (like survey method) were not applicable.

Table 5: The applicability of risk identification methods in EPSA, Ethiopia, 2020 (n = 101).

Risk Identification Methods	Not at All		Small Extent		Moderate Extent		Great extent		Very great extent		Mode	Median (IQR)
	F	%	F	%	F	%	F	%	F	%		
Risk estimation	19	18.8	39	38.6	33	32.7	8	7.9	2	2.0	2	2 (1)
Previous risk assessment	29	28.7	38	37.6	25	24.8	9	8.9	0	0.0	2	2 (2)
Developing risk register	37	36.6	25	24.8	25	24.8	10	9.9	4	4.0	1	2 (2)
Brainstorming session	23	22.8	35	34.7	31	30.7	8	7.9	4	4.0	2	2 (1)
Survey	38	37.6	31	30.7	22	21.8	10	9.9	0	0.0	1	2 (2)

Note: IQR – inter quartile range

Source: own survey

The key informants also agreed that the risk analysis activity in EPSA is at its infancy and needs a revolution to make it come to the real ground at all hubs and directorates in EPSA. One respondent elaborates this idea:

“... It is difficult to say that at this time risk analysis related activities are in place at EPSA. There is no responsible committee to perform such activities. There are no documented strategies to be followed and tools that support risk analysis in place in this hub except some hopeful activities initiated currently by the central office.” (P3, Hub).

Even if they do not follow organized scientific methods, central EPSA, Adama and Hawassa hubs, tried to identify and document the most frequently occurring risks in their respective level. One respondent illustrates this idea:

“... due to the absence of a baseline information/data to start the risk assessment process, we were forced to follow a traditional way of risk identification which is based on the risks that occur previously in this branch.” (P8, Hub).

Another respondent also added that:

“.....Brainstorming, expert consultation, and international documents were used for the risk identification process.” (P21, Central).

Another respondent from central EPSA also responded similarly:

“Currently there is a great move forward in risk management process in EPSA. A risk management team consisting of professionals from different directorates was formed under the quality management system directorate. Moreover, through the initiation of this team, risks from each directorate were identified by directorate level discussion and through review of relevant literatures. Accordingly, the identified risks are documented, a risk mitigation plan was prepared and we are going to develop a risk mitigation framework...” (P17, Central).

The result of this study is similar with study by Juttner (2005) that showed that brainstorming with the highest score of 60%, was used as the most common risk identification method. Whereas, the result is in contrary to the study by Mengistu (2016), which stated that even if the most frequent score was the small extent, the highly implemented risk identification method were risk estimation (52.8%) followed by previous risk assessment (45.8%). Brainstorming as risk identification method was used only in 31.9% of the cases. This difference might be due to the difference in study period, and knowledge and awareness between respondents which implied that not all staffs might have an equal understanding of the risk analysis processes like that of managerial staffs.

4.3.1. Tools Used in Risk Management Process

Six risk management tools were provided for participants to rate how often they are applicable in EPSA (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Very often, and 5 = Always). From these, the most applicable tools were inventory optimization tool 29 (29.3%), sales tool 22 (22.4%), and operation planning tools 27 (27.6%). Out of these tools, 29 (29.6%) (Median = 2, IQR = 3) respondents agreed on the idea that the spend management analysis tool was never used to assess risk management in EPSA (see Table 6). The result also showed that 62.4% of the respondents agreed on the use of the operational planning tool for risk management. It was noted that the operational planning tool is the commonly used tool for managing risks in EPSA currently.

Table 6: The applicability of risk management tools in EPSA, Ethiopia, 2020.

Risk management tools	Never		Rarely		Sometimes		Very often		Always		Mode	Median (IQR)
	F	%	F	%	F	%	F	%	F	%		
Sourcing tool*	25	25.5	25	25.5	31	31.6	12	12.2	5	5.1	3	2 (2)
Inventory optimization tool**	12	12.1	18	18.2	27	27.3	29	29.3	13	13.1	4	3 (2)
Sales tool*	18	18.4	21	21.4	19	19.4	22	22.4	18	18.4	4	3 (2)
Operation planning tool*	10	10.2	25	25.5	25	25.5	27	27.6	11	11.2	4	3 (2)
Master data management tool**	23	23.2	25	25.3	17	17.2	25	25.3	9	9.1	2, 4 ⁺	3 (2)
Spend management analysis tool**	29	29.6	22	22.4	21	21.4	20	20.4	6	6.1	1	2 (3)

Note: * - n is 98, ** - n is 99, IQR – inter quartile range, + - multiple mode

Source: own survey

This result is similar with the study by Juttner (2005) where 40% of the respondents agreed on the implementation of joint operational planning tool, whereas, the study by Aluda (2015) found that master data management tool was the primarily used tool (with average score of 3.791 ± 1.444) followed by operations planning (3.791 ± 1.446), and sourcing tool (3.375 ± 1.582). This difference might be due to the difference in access, awareness and training given for professionals between the former and the current study.

4.3.2. Risk Mitigation Strategies

Risk management strategies were identified from different kinds of literature to assess the risk management practices at EPSA in this study and respondents were asked to rate selected risk management practice elements with a 5-point scale (1 = no extent, 2 = small extent, 3 = moderate extent, 4 = great extent, and 5 = very great extent). The mode value of knowledge about risk and risk analysis practices, supplier capacity assessment and qualification screening, and backup supplier arrangement practice are rated as “to a small extent” while the rest strategies have a mode of “to moderate extent”.

Respondents also agreed that EPSA has adopted knowledge about risk and risk analysis practices, supplier capacity assessment and qualification screening, and backup supplier arrangement practices, to a small extent. Whereas, the rest practices were reported adopted to a moderate extent. Reliable information management system was found adopted to very great extent based on the participants scoring with a frequency of 12 (11.9%) (Median = 3, IQR = 2) followed by transfer of SCRs to insurance companies, 7 (7.2%) (Median =3, IQR = 2) (see Table 7). The result also shows that the overall implementation of risk management practices was adopted to a medium level.

Table 7: The adoption of SCRM practices in EPSA, Ethiopia, 2020.

SCRM Practices	No extent		Small extent		Moderate extent		Great extent		Very Great extent		Mode	Median (IQR)
	F	%	F	%	F	%	F	%	F	%		
Knowledge about risk and risk analysis (n = 101)	8	7.9	41	40.6	38	37.6	13	12.9	1	1.0	2	3 (1)
Supply chain contingency planning (n = 100)	9	9.0	28	28.0	36	36.0	26	26.0	1	1.0	3	3 (2)
Reliable information management system (n = 101)	6	5.9	29	28.7	35	34.7	19	18.8	12	11.9	3	3 (2)
Strategic sourcing or advanced procurement (n = 92)	10	10.9	27	29.3	34	37.0	17	18.5	4	4.3	3	3 (1)
Supplier capacity assessment and qualification screening (n = 90)	11	12.2	35	38.9	21	23.3	19	21.1	4	4.4	2	2 (2)
Building long term relationships with key suppliers (n = 98)	8	9.0	22	24.7	35	39.3	20	22.5	4	4.5	3	3 (2)
Back up supplier arrangement (n = 88)	14	15.9	32	36.4	19	21.6	22	25.0	1	1.1	2	2 (2)
Extra inventory arrangement (n = 96)	11	11.5	26	27.1	37	38.5	18	18.8	4	4.2	3	3 (1)
Transfer of supply chain risks to insurance companies (n = 97)	17	17.5	22	22.7	26	26.8	25	25.8	7	7.2	3	3 (2)

Note: IQR – inter quartile range

Source: own survey

Qualitative respondents also illustrates this practice as follows:

“... We tried to identify and evaluate risks through team discussion and by evaluating risks during report presentation. There are no other specific mechanisms or frameworks to identify and manage risks. According to our hub, we tried to manage risks using strategies/mechanisms like emergency procurement, hub-to-hub distribution, horizontal communication with hubs, information sharing with facilities and central EPSA as well as developing systems that alarm risks in our operation.” (P1, Hub).

Another respondent adds on this by saying:

“Risk identification is not practiced in our hub. When we identify risks during our day-to-day activities, we discuss issues with the responsible body and try to solve the problems that we face. As an alternative strategy we share information on risk and risk mitigation strategies through platforms like M-Brana application and telegram group.” (P3, Hub).

Another respondent from central EPSA also adds on this:

“There was no previously developed risk identification and management framework. There was no risk monitoring done in this agency. Now, risk management strategic framework reaches to the final stage of development. Risks are already identified and prioritized through a risk priority score.” (P21, Central).

Additionally, another respondent from central EPSA also give elaboration on this concept:

“..... There is no agreed process or method for risk identification and management but we identify risks through discussion and from our experience. Often we try to prioritize the identified risks based on their impact. Risk mitigation actions are taken after risk occur. This is mainly because we do not have a prepared mechanism for risk identification and management. The risk management framework development is on the process by quality management system task force.” (P25, Central).

This result is similar with the study conducted by Yoseph (2017) that all the risk management strategies were employed below the moderate level, but the practice of keeping extra inventory was practiced to more than moderate extent. This difference from the current study might be due to the difference in product nature under study, implied that pharmaceuticals have unique nature that makes it difficult to store for a longer period as a backup stock.

4.3.3. Risk Management Capability

There are four categories of SCRM capability measures, each with 3 or 4 sub measures, provided for participants to rate with a 5-point rating scale (1 = no extent, 2 = small extent, 3 = moderate extent, 4 = great extent, and 5 = very great extent). These categories are risk management awareness, culture, process and experience. Almost 50 (50%) of the respondents expressed their agreement on the statement that says EPSA's risk mitigating capability is small or "is to a smaller extent" (Median = 2, IQR = 1).

As shown in Table 8, the overall risk management capability of EPSA is either small (initial) or moderate (repeatable) extent only. Many participants agree on a "small extent" implementation ability of EPSA to recognize risk and predict the impact, 40 (39.6%) (Median = 3, IQR = 1), and moderate extent implementation of the rest awareness measures. Respondents also agree on the moderate extent applicability of view of risk management while the rest culture measures implemented to a smaller extent level. From these, many respondents agree on small extent application of view of risk reporter, 42 (41.6%) (Median = 2, IQR = 1). All process measures have a common mode of small extent level of implementation. From these, the existence of generic or formal processes, and measurement of effectiveness of risk management process have an equal levels of implementation, 43 (42.6%) (Median = 2, IQR = 1). Experience and implementation level of risk management have a moderate extent application while implementation status of risk management tool is only small extent with a respective frequency of 41 (40.6%) (Median = 2, IQR = 1).

Table 8: The supply chain risk management capability of EPSA, Ethiopia, 2020 (n = 101).

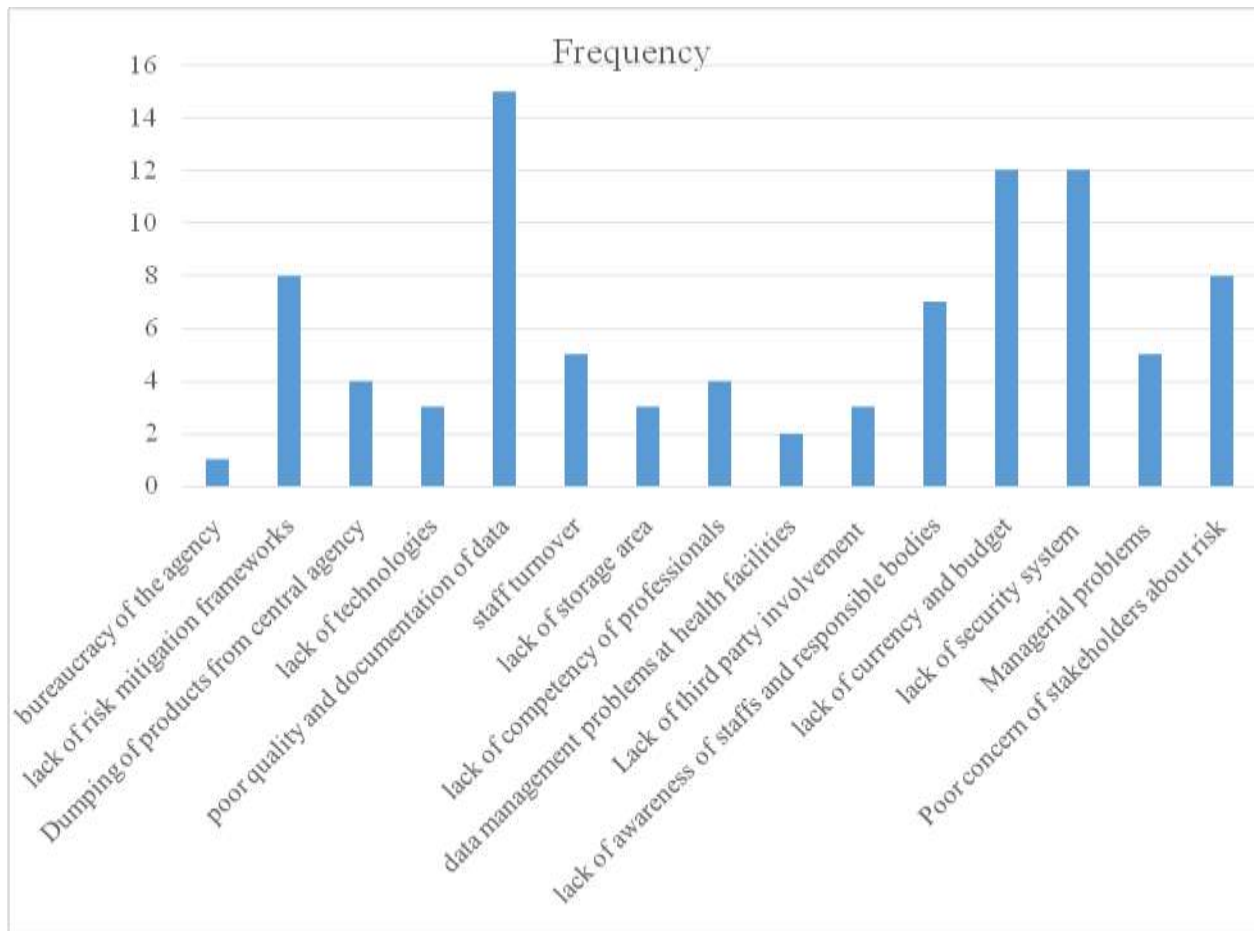
SCRM Capability	No extent		Small extent		Moderate extent		Great extent		Very Great extent		Mode	Median (IQR)
	F	%	F	%	F	%	F	%	F	%		
Risk Management Awareness												
Risk management awareness	7	6.9	29	28.7	38	37.6	23	22.8	4	4.0	3	3 (2)
Attitude towards risk management *	5	5.0	34	34.0	36	36.0	22	22.0	3	3.0	3	3 (1)
Ability to recognize risk and predict impact	9	8.9	40	39.6	34	33.7	14	13.9	4	4.0	2	3 (1)
Cumulative modal Value											2.67	
Risk Management Culture												
Involvement of upper management	13	12.9	33	32.7	30	29.7	23	22.8	2	2.0	2	3 (1)
Firm's view of risk management *	9	9.0	34	34.0	36	36.0	18	18.0	3	3.0	3	3 (1)
Firm's policy towards risk management	16	15.8	33	32.7	30	29.7	19	18.8	3	3.0	2	3 (1)
View of risk reporter	15	14.9	42	41.6	26	25.7	16	15.8	2	2.0	2	2 (1)
Cumulative modal Value											2.25	
Risk Management Processes												
Existence of generic/formal processes	12	11.9	43	42.6	29	28.7	15	14.9	2	2.0	2	2 (1)
Measurement of effectiveness of process*	15	15.0	43	43.0	31	31.0	9	9.0	2	2.0	2	2 (1)
Approach towards risk management	11	10.9	39	38.6	35	34.7	16	15.8	0	0.0	2	3 (1)
Cumulative modal Value											2	
Risk Management Experience												
Experience in risk management	21	20.8	31	30.7	35	34.7	12	11.9	2	2.0	3	2 (1)
Level of implementation*	19	19.0	33	33.0	34	34.0	13	13.0	1	1.0	3	2 (1)
Status of risk management tools	21	20.8	41	40.6	27	26.7	10	9.9	2	2.0	2	2 (1)
Cumulative modal Value											2.67	

Note: * = n is 100, based on Gupta et al. (2014) cumulative score <1.5 is analyzed as adhoc, 1.5 - 2.5 as initial, 2.5 - 3.5 as repeatable, and >3.5 as managed.

Source: own survey

In this study, respondents were asked to identify the EPSA’s effort on SCRM capability along various dimensions. The extent of risk management capability of EPSA ranges from small to a moderate extent (ad hoc to repeatable). The responses showed that the capability of EPSA in risk awareness and risk management experience reached repeatable (moderate extent) while its’ capability in risk management culture and process is at initial (small extent) level only. This result is in agreement with the study conducted in Singapore (Gupta *et al.*, 2014) that showed the risk management capability to mitigate risks in the supply chain of Singaporean firms was at initial to ad hoc level. The study also implied that there was below the average level of capability to combat risks in Singaporean firms. Among all capability measures, risk management process and culture had a better extent of applicability.

4.3.4. Challenges of Risk Management



Source: own survey

Figure 7: The challenges that hinder the smooth process of mitigating SCRs in EPSA, Ethiopia, 2020.

In the management of risks at EPSA, respondents from the qualitative part of the study raise different challenges that hinder the smooth process of mitigating risks. Among these, poor quality and documentation of data, lack of security system, shortage of currency and budget, and lack of risk mitigation frameworks are the most frequently occurring challenges (see Figure 7). The study by Fernandes, Barbosa-povoa, and Relvas (2011) similarly indicated that finance, safety and regulatory issues were challenges in risk mitigation.

4.4. Supply Chain Performance from Risk Management Viewpoint

Different indicators can be used to measure the performance of the supply chain process from risk management point of view. Among these, six indicators were selected for this study. Accordingly, respondents were asked to rate the situation of each indicator with a 5-point rating scale (1 = Significantly worsened, 2 = Worsened, 3 = No Change, 4 = Improved and 5 = Significantly improved). As shown in Table 9, most respondents agreed that all supply chain performance indicators have shown no change in measuring risk management. Respondents agreed that performance indicators like delivery dependability, order fill capacity and risk analysis did not show a significant improvement during the last 5 years. The highest performance level was seen on speed of delivery (53.5%) followed by customer satisfaction (50.5%).

Table 9: The perceived performance level of selected supply chain performance indicators in EPSA, Ethiopia, 2020.

Performance Indicators	Significantly Worsened		Worsened		No Change		Improved		Significantly Improved		Mode	Median (IQR)
	F	%	F	%	F	%	F	%	F	%		
	Delivery dependability*	5	5.0	36	35.6	49	48.5	6	5.9	0		
Order fill capacity*	6	5.9	39	38.6	44	46.3	6	5.9	0	0.0	3	3 (1)
Customer satisfaction**	5	5.0	31	30.7	51	50.5	12	11.9	2	2.0	3	3 (1)
Speed of delivery*	6	5.9	19	18.8	54	53.5	15	14.9	1	1.0	3	3 (1)
Supplier visibility*	4	4.0	32	31.7	50	49.5	5	5.0	2	2.0	3	3 (1)
Risk analysis**	13	12.9	42	41.6	44	43.6	2	2.0	0	0.0	3	2 (1)

Note: * - n is 95, ** - n is 101

Source: own survey

The result of this study implies that the supply chain at EPSA does not show any improvement in its performance due to risk management practice or does not worsened due to risks occurring in the chain in the past 5 years. Different tools can be used to monitor supply chain performances. According to the measures used in this study, performance has neither worsened nor improved. This finding is similar to the studies conducted in Moroccan and Australian manufacturing industries by Ouabouch and Pache (2014) and Chen, Sohal and Prajogo (2013) respectively. These studies showed that a moderate level of improvement was observed in the supply chain performance of the industries.

4.5. Risks Associated with Supply Chain Performance of EPSA

To test the hypotheses of this research, an ordinal logistics regression analysis was employed and five model fit tests were estimated including the goodness of fit, model fitting information, test of parallel lines, and multicollinearity. The result shows that all the model fit tests are significant and the model is acceptable. Model fitting information and goodness of fit are 30.916 ($P < 0.001$) and 127.298 ($P < 0.712$) respectively while the test of parallel lines is significant at a value of 42.186 ($P < 0.914$). Multicollinearity measures are also significant as all variance inflation factor scores are less than 10 and all tolerance values are greater than 0.2 (see Annex 5).

The results of this study show that the model explained 83.8 to 84.9 % of the variability in the supply chain performance. The study in Sudan showed a closely similar result that the SCM practices variables explained 71.09 % of the variance in performance (Hamid & Ibrahim, 2015). Whereas, the study by Wagner and Bode (2008) explained only 6% of the variance in supply chain performance. This implied that the current study better explained the variability in the supply chain performance.

Supply side risks have a negatively significant association with supply chain performance ($\beta = -2.171$, $P < 0.05$) whereas demand side risks have a positive association with performance parameters ($\beta = 2.743$, $P < 0.001$). Process and control risks have also a negatively significant association with performance at a β estimate of -0.979 ($P < 0.026$) and -1.694 ($P < 0.004$) respectively. Environmental and infrastructural risks have no significant association with performance. However, the SCRM practice has a strong positively association with performance ($\beta = 6.440$, $P < 0.002$). This result shows that demand side, environmental and infrastructural risks have no significant impact on the supply chain performance of EPSA (see Table 10).

Table 10: Risks associated with supply chain performance in EPSA, Ethiopia, 2020.

Variables	β estimate	Standard error	P value	95% Confidence Interval		Hypothesis
				Lower bound	Upper bound	
Supply side risk	-2.171	0.936	0.020	-4.005	-0.337	H1 supported
Demand side risk	2.743	0.831	0.001	1.114	4.372	H2 rejected
Operational risk	-0.979	0.441	0.026	-1.843	-0.115	H3 supported
Control risk	-1.694	0.582	0.004	-2.834	-0.553	H4 supported
Environmental risk	1.292	0.127	0.252	-0.917	3.502	H5 rejected
Infrastructural risk	1.555	0.517	0.305	-1.417	4.528	H6 rejected
SCRM practice	6.440	0.075	0.002	2.374	10.507	H7 supported

Note: dependent Variable – Supply Chain Performance, link function - Logit

Source: own survey

In our study, supply side risks have a significant negative impact on supply chain performance of EPSA ($\beta = -2.171$, $P < 0.05$). This result indicates that H1 is supported in the current study. The result is supported by the study by Wagner and Bode (2008) that showed supply side risks have significant association with performance ($\beta = -0.09$, $P < 0.05$). However, in another study, supply risk is not found to have a direct relationship with performance (Chen *et al.*, 2013).

Supply chain process (operational) risks ($\beta = -0.979$, $P < 0.026$) have a negative significant association with performance and this leads to the support of H3. This result is consistent with previous studies by Chen *et al.* (2013) and Zeng (2012) that explained operational risks have a significant negative impact on supply chain performance measures ($\beta = -0.35$, $P < 0.01$, $\beta = -0.2182$, $P < 0.01$ respectively). Whereas, the study by Florian and Constangioara (2014) did not support this hypothesis by indicating that all risks had no significant impact on supply chain performance.

The fourth hypothesis that stated control risks have a negative direct association with supply chain performance is also accepted in the current study ($\beta = -1.694$, $P < 0.05$). This result is not consistent with the study by Wagner and Bode (2008), and Florian and Constangioara (2014) that reveals control risks have no significant association with supply chain performance. The difference might be due to differences in study settings and perspectives of professionals.

The final hypothesis of this study that showed risk management practice variables have a positive association with supply chain performance is supported and the result is statistically significant ($\beta = 6.440$, $P < 0.05$). This result is supported by the results of Florian and Constangioara (2014) ($\beta = 0.30$, $P < 0.05$). This implies that the impact of practice variables on performance in the current study is higher. The study by Hamid and Ibrahim (2015) also showed that there is a positive relationship between SCRM practices and performance measures.

4.6. Risk Mitigation Strategies for Prioritized Supply Chain Risks

Mitigation strategies are proposed for top priority risks identified in this study based on a review of different scholarly risk management literatures. They are not the only solutions but are mandatory to resolve risks in EPSA and can act as a baseline to prepare a SCRM framework (see Annex 6). To solve such types of risks, risk management strategies like prevention, disruption time management, and post disruption mitigation strategies are expected to be applied.

CHAPTER FIVE

5. SUMMARY, CONCLUSION AND RECOMMENDATION

The chapter covers five major sections. These include the summary of the findings, the conclusion of the study, limitations encountered during the study, recommendations, and suggestions for further research in this untouched area.

5.1. Summary of Findings

The findings of this study showed that an overall 89 risks were identified under six categories including: supply side, demand side, operational, control, environmental and infrastructural risks. From these risk types, supply side risks took the first position followed by demand side and operational risks in affecting the supply chain of EPSA. Among these, inability to meet customer demand, lead time variability, poor logistics performance of suppliers, forecasting errors, customer service disruptions, financial risks, speed of delivery, agreement and contract issues and documentation problems are among the primary high score risk categories.

Based on this study, the overall risk management practice of EPSA was found to be unsatisfactory. Scientific methods of risk identification like survey method were applied to less extent than traditional methods of identification like brainstorming. From risk management tools applied in supply chain entities, inventory optimization tools followed by operation planning tools and sales tools were found to be most applicable in the operation of EPSA while spend management analysis tool is the least applicable.

The overall implementation level of risk management strategies is at a medium level. From risk mitigation strategies implemented during supply chain disruptions, reliable information management system is adopted to very great extent followed by transfer of SCRs to insurance companies. Supply chain contingency planning, reliable information management system, strategic sourcing or advanced procurement practices, building long-term relationships with key suppliers, transfer of SCRs to insurance companies and extra inventory arrangement strategies were practiced moderately.

Overall, the ability of EPSA in mitigating supply chain disruptions is low. Among the four SCRM capability measures (risk management awareness, culture, process and experience), the capability of EPSA in implementing risk management awareness and attitude measures is

moderate. View of risk management has also been practiced to a moderate extent from risk culture indicators. The capability of the risk management process of the supply chain practice in EPSA is practiced to small extent, while its findings indicated that EPSA has moderate level risk management experience.

Six indicators were used to measure the performance of supply chain operations in risky situations. These indicators are delivery dependability, order fill capacity, customer satisfaction, speed of delivery, supplier visibility and risk analysis. The performance level of delivery dependability, order fill capacity, and risk analysis fall between significantly worsened to improved level while the rest indicator scores range from significantly worsened to significantly improved level.

Supply side ($\beta = -2.171$, $P < 0.05$), operational ($\beta = -0.979$, $P < 0.05$) and control risks ($\beta = -1.694$, $P < 0.05$) have a negative significant association with supply chain performance, and SCRM practices ($\beta = 6.440$, $P < 0.05$) have a strong positive association with supply chain performance. Whereas, demand side, environmental and infrastructural risks did not negatively impact the supply chain performance of EPSA.

Different reasons were raised as challenges in implementing risk management strategies. Political issues, financial reasons, technological delimitations, infrastructural issues, and poor concern of stakeholders are few to name.

5.2. Conclusion

This study was conducted to assess the SCRM practice of EPSA. In this process, the study aimed to identify and prioritize risks and tried to indicate risk mitigation strategies to be followed to solve supply chain disruptions. Risk management practices in EPSA were also assessed to see their impact on the supply chain performance of the agency.

Totally, 89 risks were identified by literature review, expert consultation and during pretest of the instrument. These risks were categorized into six elements namely supply side, demand side, operational, control, environmental and infrastructural risks. Excel-derived FMEA analysis model was used to analyze the risks and from these risk sources, supply side risks took the primary position during prioritization followed by demand side and operational risks while environmental risks were at the least position. Risks like inability to meet customer demand, lead

time variability, poor logistics performance of suppliers, forecasting errors, customer service disruptions, financial risks, speed of delivery, agreement and contract issues, and documentation problems are among the primary high risk score categories that cover 80% of the supply chain disruption of EPSA.

The overall risk management practice of EPSA was weak. The study showed that EPSA sometimes applied the SCRM process from risk identification to monitoring. Common risk identification methods like risk estimation, previous risk assessment and brainstorming sessions applied to a small extent only while developing risk register and survey methods were not used for risk identification. This showed that EPSA was using traditional risk identification methods to a small extent, while more scientific methods were not given attention.

The overall applicability of risk management tools was above the average level in the last 5 years history of EPSA. From these standardized risk management tools, inventory optimization tools, sales tools and operation planning tools were used by EPSA very often while spend management analysis tool was never applied to solve disruptions in EPSA.

This study concluded that risk management strategies were implemented to moderate extent. From risk management practices recommended by previous articles in supply chain disruptions, knowledge about risk and risk analysis practices, extra inventory arrangement and supply chain contingency planning were adopted at a moderate extent level. Whereas, backup supplier arrangement, and supplier capacity assessment and qualification screening were the least implemented strategies.

The capability of EPSA in preventing and solving supply chain threats was only a small extent. From four indicators of SCRM capability measures creating SCRM awareness and experience were implemented to a moderate extent while risk management culture and process were practiced to a small extent only. From moderately practiced capability measures, factors like the ability to recognize risk and predict the impact as well as the status of risk management tools were adopted at a small extent level. Risk management performance measures showed that the level of supply chain performance was neither improved nor worsened but remained unchanged in the last 5 years at EPSA.

This study also showed that supply side, process and control risks have negative and SCRM practice variables have a positive significant impact on performance of EPSA in the last 5 years. From all variables in this study, SCRM practices and operational risks have a moderate association with performance than other variables that have a weak association.

Numerous internal and external challenges hinder the practice of SCRM. Political issues, financial risks, technological delimitations, infrastructure unavailability, lack of skilled workforce, poor concern of stakeholders, poor policy and regulations, and data management problems are among the primary listed challenges.

5.3. Recommendations

Based on the findings, summary, and conclusion of this study, the following recommendations are proposed. These are:

- EPSA should establish a separate team that primarily assesses, analyze and control SCRs in all hubs and directorates of the central agency to implement formal risk management strategies from identification to monitoring to improve supply chain performance. This approach helps to develop risk-based thinking and predetermination of risk occurrence.
- EPSA should give focus on risk prevention to tackle the occurrence and minimize the impact of risks in the supply chain. Cause-oriented SCRM practices should be given primary focus than effect-oriented practices, and EPSA should be engaged in scientific and regular methods of risk assessment to effectively identify, evaluate, control, and minimize risk impacts.
- The management of EPSA should strengthen its capability in mitigating SCRs and primarily the agency should focus on the development of risk management culture, and risk mitigation process. It should also focus on top priority risks, implement formal risk management tools, develop risk management framework, and regularly monitor its supply chain from risk point of view. This will help to develop a resilient supply chain system and minimize threats.
- The Federal MOH should closely follow the implementation of SCRM practices at EPSA, this will help to avert uncertain supply chain disruptions through settling currency and budget issues, enhancing staff capacitation activities, working on policies, and procedures that affect the performance of the agency.

- The Federal MOH should also focus on capacitating information management systems that allows information exchange throughout the chain, and specifically, at the facility level to improve the supply chain network of EPSA.

5.4. Limitation of the Study

As a limitation, the working dataset was relatively small in this study but similar researches use smaller samples (Antoncic & Scarlat, 2005). This study is also susceptible to respondent bias in which the individuals who participated in the study may not answer the respective questions based on the real practice on ground since they assumed that the failure is due to their managerial inability, and some respondents will answer to advocate the program purposefully. In addition, this study did not include private sector networks, and SCRs and SCRM practices at supplier and customer level. This can negatively influence generalizability of results for the entire SCRM practice. Due to time and resource constraints, this study did not consider the identification of risks based on experts' opinion.

As a strength, this study covers the whole EPSA clusters throughout the country. The sampling procedure tried to minimize the difference in risks and their impact due to geographical distance and catchment facility number. This study focused on perceptions of managers and senior officers as they are very familiar with supply chain disruptions of their department as Wang and Yen (2012) stated the practice of using perceptions of managers in analysis is common in SCM literature.

5.5. Further Research Implications

Supply chain risk management is a very wide and researchable area. This research addressed the entire SCRM practice from risk identification to risk monitoring practices of EPSA. Risks were identified and mitigation strategies were also supposed. The risk analysis and control practice of EPSA and the respective challenges that hinder the SCRM process was also determined. However, future researches should cover the SCRM practice at the supplier, health facility, and individual customer level as well as the practice in private supply chain sector (private manufacturers, importers, wholesalers, facilities) in general. The risks and risk management practice in stakeholders like MOH, EFDA, ERCA, and NGOs should also be considered in future studies.

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Annexes

Annex 1. Questionnaire

I. Consent

Dear Participant,

You have been selected to be part of this study and this is why I would like to interview you. This study is conducted by an MSc student at AAU for the fulfillment of a master's degree in health supply chain management. The aim of the study is only to know the top priority risks and SCRM practice at EPSA then to suppose mitigation strategies.

Confidentiality: The information you provide will not be disclosed to anyone. It will only be used for research and academic purpose. Your name, address, and other personal information will be removed from the instrument, and only code will be used to connect your name and your answers without identifying you.

Voluntary Participation: Your participation is voluntary and you can withdraw after having agreed to participate. You are free to refuse to answer any question asked in the questionnaire/interview guide. If you have any questions about this study, you can ask the principal investigator at the site or AAU School of Pharmacy, department of Health Supply Chain Management.

Name: Manaye Tamrie

Email Address: manayetamire@mtu.edu.et

Consent to participate: Agreed in this consent indicates that you understand what will be expected of you and are willing to participate in this study.

Read by Participant Interviewer

Agreed _____ Refused _____

II. Participant and Hub Information

Please provide your answer by placing a tick in the boxes corresponding to your answer or write a full answer where appropriate.

1. What is your Gender? Male Female
2. The highest academic level you achieved. Diploma and below
Degree Master PhD and above
3. Your department or area of specialization? _____
4. Your work experience? Less than a Year 1 – 2 years
3 - 5 years 5 - 7 years More than 7 years
5. The directorate/ team you work now. _____
6. The position you have in the team/directorate. Director/ team leader
Vice director/vice team leader legal delegate of director/ team leaders
7. The location of the hub is _____ region _____ town.
8. Distance from the central EPSA is _____ KM.
9. The number of catchment facilities supplied by the hub are _____.
10. The number of catchment population served by the hub is _____.

III: Risk Analysis

1. Please, rate the occurrence, severity and detection level of the following Supply Chain risks in the past 5 years in EPSA based on the FMEA model rating scales below.

Occurrence rating scale

Rate	Description	Potential Risk Rate
10	Certain probability	Risk occurs at least once a day or almost every time.
9	Risk is almost inevitable	Risk occurs predictably or every 3 or 4 days.
8 7	Very high probability	Risk occurs frequently, or risk occurs about once per week.
6 5	Moderately high probability	Risk occurs about once per month.
4 3	Moderate probability	Risk occurs occasionally or risk occurs once every 3 months.
2	Low probability	Risk occurs rarely or Risk occurs about once per year.
1	Remote probability	Risk almost never occurs or anyone remembers last risk occurrence.

Severity rating scale

Rate	Description	Definition
10	Certain probability	The risk could cause the loss of a client.
9	Risk is almost inevitable	The risk could cause a major or permanent delay.
8 7	Very high probability	Risk causes minor to moderate delay with a high degree of client dissatisfaction.
6 5	Moderately high probability	Risk causes a minor delay with some client dissatisfaction.
4 3	Moderate probability	Risk causes too minor or no delay but annoys the client.
2	Low probability	Risk causes no delay and the client is unaware.
1	Remote probability	Risk causes no delay and has no impact on the system.

Detection rating scale

Rate	Description	Definition
10	No chance of detection	There is no known mechanism for detecting the risk.
9 8	Very Remote/Unreliable	The risk can be detected only with a thorough inspection and this is not feasible or cannot be readily done.
7 6	Remote	The risk can be detected with manual inspection but no process is in place so that detection is left to chance.
5	Moderate chance of detection	There is a process for double-checks or inspection but it is not automated and/or is applied only to a sample and/or relies on vigilance.
4 3	High	There is a 100% inspection or review of the process but it is not automated.
2	Very High	There is a 100 % inspection of the process and it is automated.
1	Almost certain	There are automatic “shut-offs”/constraints that prevent risk.

No.	Risk Category and Types	Occurrence Score	Severity Score	Detection Score
1	Supply Side Risks			
1.1	Dependency on key suppliers			
1.2	Unplanned shutdown of suppliers (bankruptcy, going out of business, etc.)			
1.3	Key Supplier failures (delay in delivery, quality problems, price, and relationship issues, etc.)			
1.4	Supplier location			
1.5	Single supplier			

1.6	Unavailability of supplier			
1.7	Improper supplier selection			
1.8	Flexibility in product variety and quantities			
1.9	Suppliers' poor logistic performance (delay, not complying with schedules, etc.)			
1.10	Poor performance of 3rd party service providers			
1.11	Partnership/coordination with supplier			
1.12	Fragmentation of supply chain (multiple channels, lack of communication, unilateral decisions, etc.)			
1.13	Supplier quality problems(GMP certificate)			
1.14	Transportation problem (routes, accidents, security, spare parts, fuel, maintenance, etc.)			
1.15	Length/variability of replenishment lead-times			
1.16	Delivery reliability and instability of suppliers			
1.17	Non-availability/shortage of product at suppliers			
1.18	Poor communication with the suppliers			
1.19	Contract and agreement issues			
1.20	Unclear product specifications			
1.21	Accident and injuries in production site (theft, blockage, labor strikes, etc.)			
1.22	Inability to meet customer demand			
1.23	Product development/design changes			
1.24	Lack of visibility of stock			
1.25	Commodity price volatility/ fluctuations			
1.26	Exchange rate fluctuations			
1.27	Market failures (market shortage, fluctuation in commodity price, etc.)			
1.28	Financial distress/problem			
1.29	Insufficient insurance amount and occurrence			
1.30	Technological level and changes/mismatch			
2	Demand Side Risk			
2.1	Unanticipated/volatile demand (seasonal fluctuation, need uncertainty, etc.)			
2.2	Risks in forecasting (lead times, product variety, short life cycles, information distortion, exaggeration of demand, etc.)			
2.3	Transportation problem (spare parts, fuel, maintenance, etc.)			
2.4	Wastage of product (theft, expiry, damage, obsolescence, etc.)			
2.5	Underestimation of quantities/shortages			
2.6	Poor visibility of stock along the pipeline			
2.7	Ordering cycle time			
2.8	Cancelation of firm orders by the clients			
2.9	Distribution channel problems			

2.10	Delivery capacity			
2.11	Delivery reliability			
2.12	Poor communication with customers			
2.13	Customer services disruption			
2.14	Changes in customer need assessment result			
2.15	Financial risks (Lack of funds, late/absence of payment, currency rate, etc.)			
3	Operational Risk			
3.1	Inadequate supply chain actors experience			
3.2	Low harmony between supply chain actors			
3.3	Storage/cold chain management problem			
3.4	Customer services disruption			
3.5	Outsourcing key business processes (delay, risk of intellectual property, etc.)			
3.6	Lack of speed of delivery			
3.7	Risks due to reliability and compliance to delivery schedule			
3.8	Poor planning (short term planning)			
3.9	Lengthy set-up times and inflexible processes			
3.10	Communication barrier with branches (insufficient, poor communications, etc.)			
3.11	Inventory management problem (holding cost, expiry, obsolete and excessive inventory, etc.)			
3.12	Poor documentations			
3.13	Insufficient supervision and late internal approval			
3.14	Picking error (medication, packaging, etc.)			
3.15	Prioritization problem			
3.16	Consolidation problem			
3.17	Poor visibility along the pipeline			
3.18	Operational cost/ financial restriction			
3.19	Failure in resource allocation			
4	Control Risk			
4.1	Nonstandard practice (customized policies per hospital, lack of common codes, local laws, etc.)			
4.2	Inappropriate rules that distort demand (JIT delivery, max/min inventory system, etc.)			
4.3	Regulatory issues (change of standards, drug recalls, quality assurance, etc.)			
4.4	Government/political intervention			
4.5	Inappropriate type of contract (big contract, mistakes in the document, lack of clear understanding, ambiguous clauses, etc.)			
4.6	Lack of collaborative planning and forecasting			
4.7	Export/import restrictions			
4.8	Change in priority/focus by the government			

4.9	Illicit trade and organized crime (contraband, vandalism, corruption, theft, counterfeit, etc.)			
4.10	Unstable policies (pricing, tariffs, etc.)			
4.11	Administrative barriers (mismanagement, wrong decisions, excessive procedures, etc.)			
5	Environmental Risk			
5.1	Natural Disaster (flooding, thunder strike, environmental disaster, etc.)			
5.2	Exceptionally unfavorable/extreme weather			
5.3	Epidemics/disease outbreak			
5.4	Manmade disasters (fire, political/civil unrest, terrorist attack, etc.)			
5.5	Remoteness of site/difficult landscape			
6	Infrastructural risk			
6.1	Infrastructure unavailability (IT, vehicle, road, equipment, etc.).			
6.2	Lack of proper storage area with adequate facilities			
6.3	Technology development and level			
6.4	Lack of maintenance for equipment/machine			
6.5	Machine, equipment, facility failure/malfunction			
6.6	Disruptions in the supply of electricity, water, etc.			
6.7	Local human centered issues (industrial accidents, labour strikes, vandalism, sabotage, availability...)			
6.8	Lack of technical and managerial skill of staff (motivation, knowledge, training, turnover, etc.)			
6.9	IT infrastructure problems (breakdown, system failures, integration disruption, virus, software errors, internet disruption, cyberattacks, etc.)			

IV: Risk Management Practice

1. To what extent EPSA currently employed supply chain risk management process?

No extent (1) Small extent (2) Moderate extent (3)

Great extent (4) Very great extent (5)

2. To what extent EPSA used the following risk identification methods?

Risk Identification methods	Not at all [1]	Small extent [2]	Moderate extent [3]	Great extent [4]	Very great extent [5]
Risk estimation					
Previous risk assessment					
Developing risk register					
Brainstorming session					
Survey					
Others, Specify					

3. How often EPSA used the following potential supply chain risk management tools?

Risk Management Tools	Never [1]	Rarely [2]	Sometimes [3]	Very often [4]	Always [5]
Sourcing tool					
Inventory optimization tool					
Sales tool					
Operation planning tool					
Master data management tool					
Spend management analysis tool					
Others, Specify					

4. Please provide applicable information relating to the extent to which EPSA adopted the below supply chain risk management practices in its day-to-day operations. Where, 1 = No extent, 2 = Small extent, 3 = Moderate extent, 4 = Great extent, and 5 = Very great extent.

SCRM Practices	Description of SCRM practices	1	2	3	4	5
Knowledge about risk and risk analysis practices	Knowing and documenting risks, inclusive risk management process, classifying risks based on severity, developing risk awareness culture, etc.					
Supply chain contingency planning	Including supply chain contingency plans in annual plan, creating contingency plan with suppliers, etc.					
Real-Time supply chain management practices	Frequent meetings with critical suppliers, implement technologies to track containers, detailed incident report, analysis of risk event, create identification and early warning systems, etc.					
Real time base operation management practices	Includes visibility of inventory, centralized distribution, responsive delivery capacity, employee training, develop real time decision report, hold extra work force, etc.					
Reliable information management System	Robust backup systems and well-designed duplication process of all data and transactions.					
Strategic Sourcing or Advanced Procurement Practices	Involves regular screening and monitoring of suppliers, produce detailed plan of disruption awareness, include expected cost of risk, signing long term contract, etc.					
Supplier capacity assessment and qualification screening	Identify potential supplier disruption reports during vendor evaluation, serve geographically scattered customers, undertakes continuous performance measurement, conduct supplier's risk audit, supplier development practice, etc.					
Building long term relationships with key suppliers	Build a long-term collaborative relationship with key suppliers, collaborate in the areas of sharing risks, develop considerable trust, etc.					
Back up supplier	Maintaining backup supplier, having capacity					

arrangement Practice	reservation contract, shift to multiple suppliers, etc.					
Extra inventory arrangement	Maintaining buffer stocks, demand forecasting, balancing capacity and inventory by cost of products, combining inventory with transportation modes, etc.					
Transfer of supply chain risks to insurance companies	Considering insurance as a key means of mitigating risks, spread the risk across more customers, adequate compensation of insurable risks, etc.					

V. EPSA’s SCRM Capability

1. To what extent EPSA is capable of mitigating key supply chain risks it faces right now?

No extent (1) Small extent (2) Moderate extent (3)
 Great extent (4) Very great extent (5)

2. Please provide applicable information relating to the extent of EPSA’s SCRM capability.
 Where, 1 = No extent, 2 = Small extent, 3 = Moderate extent, 4 = Great extent, and 5 = Very great extent.

SCRM Dimensions	Risk Management Capability	1	2	3	4	5
Risk Management Awareness	Risk management awareness					
	Attitude towards risk management					
	Ability to recognize risk and predict the impact					
Risk Management Culture	Involvement of upper management in risk management					
	Firm’s view of risk management					
	Firm’s policy towards risk management					
	View of risk reporter					
Risk Management Processes	Existence of generic or formal processes					
	Measurement of effectiveness of risk management process					
	Approach towards risk management					
Risk Management Experience	Experience in risk management					
	Level of implementation of risk management					
	Status of risk management tools in EPSA					

VI: Risk Management Performance

1. For each element, please tick the box that corresponds to your situation in the last 5 years.

Where, 1 = significantly worsened, 2 = Worsened, 3 = No Change, 4 = Improved and 5 = significantly improved.

Performance Indicator	Description	1	2	3	4	5
Delivery reliability	Proper execution of clients’ order (delay, quantity, etc.)					

Delivery capacity	Satisfaction of the client's demand with existing resources					
Clients' satisfaction	Performance of the offer regarding the clients' expectations					
Speed of delivery	Time elapsed between the reception of the order and the client's delivery.					
Supplier Visibility	Clear information and communication with supplier.					
Risk analysis	Regular monitoring of risk occurrence and identification.					

Annex 2. Interview Guide

1. Does EPSA had a risk management mechanism to safeguard its supply chain practice?
2. What are the most frequently occurring risks/problems that affect the supply chain process of EPSA? What are the risks specific to your directorate or team that hinders the supply chain operation?
3. How EPSA identifies and prioritizes risks?
4. Is there a separate body or team in place to assess and control Supply Chain risks?
5. Is there any risk mitigation framework to control risks? How identified risks are monitored and mitigated?
6. What are the challenges in SCRM practice at EPSA?

Annex 3. Information about the Ethiopian Pharmaceuticals Supply Agency hubs, Ethiopia, 2020.

No.	Name of Hub	Number of Facilities Served	Distance	Catchment Population	Cluster
1	Adama	342	100 Km	7.8 Million	Adama
2	Addis Ababa 2	220	In Addis	-	Central
3	Addis Ababa 1	919	In Addis	11 Million	
4	Kebridahar	60	990 Km	1.1 Million	Eastern
5	Jigjiga	78	619 Km	-	
6	Diredawa	262	515 Km	7 Million	
7	Asossa	77	668 Km	2.3 Million	North Western
8	Gondar	227	738 Km	4.3 Million	
9	Dessie	348	401 Km	-	
10	Bahirdar	399	565 Km	9 Million	
11	Semera	63	587 Km	1.9 Million	Northern
12	Shire	99	1380 Km	1.7 Million	
13	Mekele	203	788 Km	4.8 Million	
14	Arbaminch	225	505 Km	4.9 Million	Southern
15	Negele Borena	229	610 Km	5.6 Million	
16	Hawassa	501	275 Km	15 Million	
17	Gambella	40	714 Km	0.9 Million	Western
18	Nekemte	256	328 Km	6 Million	
19	Jimma	337	358 Km	9.2 Million	
Total		4885			

Note: Addis Ababa 1 = Addis Ababa Hana Mariam hub and Addis Ababa 2 = Addis Ababa Jakrose hub

Annex 4. Estimation, evaluation and prioritization of risks identified in EPSA, Ethiopia, 2020.

No.	Risk Category and Types	O	S	D	RSV	RPN	Rank
1. Supply Side							
1.1	Dependency on key suppliers	3.94	5.81	5.75	22.89	131.60	42
1.2	Unplanned shutdown of suppliers (bankruptcy, going out of business, etc.)	2.38	5.13	5.25	12.17	63.90	81
1.3	Key Supplier failures (delay in delivery, quality problems, price, and relationship issues, etc.)	4.38	5.75	5.75	25.16	144.65	29
1.4	Supplier location	3.69	5.13	4.94	18.9	93.31	68
1.5	Single supplier	4.50	6.75	5.69	30.38	172.76	18
1.6	Unavailability of supplier	4.19	7.19	5.88	30.10	176.82	13
1.7	Improper supplier selection	4.19	6.06	4.81	25.39	122.17	50
1.8	Flexibility in product variety and quantities	3.56	5.25	4.63	18.7	86.50	72
1.9	Suppliers' poor logistic performance (delay, not complying with schedules, etc.)	5.94	6.50	5.75	38.59	221.91	3
1.10	Poor performance of 3rd party service providers	3.06	4.06	5.44	12.44	67.65	79
1.11	Partnership/coordination with supplier	4.67	5.67	5.73	26.44	151.62	25
1.12	Fragmentation of supply chain (multiple channels, lack of communication, unilateral decisions, etc.)	4.75	5.00	5.69	23.75	135.08	40
1.13	Supplier quality problems(GMP certificate)	3.31	5.13	4.75	16.98	80.64	74
1.14	Transportation problem (routes, accidents, security, spare parts, fuel, maintenance, etc.)	5.13	6.44	5.25	32.99	173.21	17
1.15	Length/variability of replenishment lead-times	6.69	6.56	5.69	43.89	249.61	2
1.16	Delivery reliability and instability of suppliers	5.38	5.75	5.75	30.91	177.71	11
1.17	Non-availability/shortage of product at suppliers	5.63	5.81	4.94	32.70	161.43	22
1.18	Poor communication with the suppliers	4.69	4.88	5.44	22.85	124.26	47
1.19	Contract and agreement issues	5.50	6.00	5.69	33.00	187.69	7
1.20	Unclear product specifications	3.13	4.63	4.19	14.45	60.52	83
1.21	Accident and injuries in production site (theft, blockage, labor strikes, etc.)	2.69	4.81	5.06	12.93	65.48	80
1.22	Inability to meet customer demand	5.31	7.00	7.06	37.19	262.64	1
1.23	Product development/design changes	2.31	3.63	4.50	8.383	37.72	89
1.24	Lack of visibility of stock	4.88	4.94	4.94	24.07	118.85	53
1.25	Commodity price volatility/ fluctuations	5.47	5.18	4.65	28.32	131.60	43
1.26	Exchange rate fluctuations	5.47	6.13	5.27	33.53	176.59	14
1.27	Market failures (market shortage,	3.82	4.35	3.53	16.64	58.74	84

	fluctuation in commodity price, etc.)						
1.28	Financial distress/problem	3.71	4.29	5.18	15.91	82.36	73
1.29	Insufficient insurance amount and occurrence	2.69	3.25	4.56	8.734	39.85	88
1.30	Technological level and changes/mismatch	4.73	4.67	4.93	22.09	108.98	60
2. Demand Side							
2.1	Unanticipated/volatile demand (seasonal fluctuation, need uncertainty, etc.)	5.25	5.59	6.04	29.37	177.35	12
2.2	Risks in forecasting (lead times, product variety, short life cycles, information distortion, exaggeration of demand, etc.)	5.53	6.00	5.98	33.18	198.41	4
2.3	Transportation problem (spare parts, fuel, maintenance, etc.)	5.37	5.51	5.75	29.6	170.07	19
2.4	Wastage of product (theft, expiry, damage, obsolescence, etc.)	5.27	5.51	4.92	29.06	143.03	32
2.5	Underestimation of quantities/shortages	5.53	5.43	5.24	30.03	157.23	23
2.6	Poor visibility of stock along the pipeline	4.65	4.84	5.49	22.51	123.56	48
2.7	Ordering cycle time	4.33	4.98	5.18	21.54	111.68	58
2.8	Cancelation of firm orders by the clients	4.69	4.61	4.8	21.59	103.73	63
2.9	Distribution channel problems	4.22	4.84	5.27	20.42	107.69	62
2.10	Delivery capacity	4.96	4.88	5.42	24.2	131.19	44
2.11	Delivery reliability	5.14	5.06	5.76	26.01	149.81	26
2.12	Poor communication with customers	4.75	5.43	5.63	25.77	145.03	28
2.13	Customer services disruption	5.27	5.22	5.71	27.51	156.97	24
2.14	Changes in customer need assessment result	5.49	5.14	5.80	28.23	163.64	21
2.15	Financial risks (Lack of funds, late/absence of payment, currency rate, etc.)	5.29	5.76	6.00	30.52	183.11	10
3. Operational Risks							
3.1	Inadequate supply chain actors experience	3.96	5.16	6.00	20.43	122.55	49
3.2	Low harmony between supply chain actors	4.19	5.21	5.54	21.85	120.97	51
3.3	Storage/cold chain management problem	4.61	5.52	5.66	25.47	144.07	30
3.4	Customer services disruption	5.77	5.52	5.94	31.84	189.10	6
3.5	Outsourcing key business processes (delay, risk of intellectual property, etc.)	3.09	4.93	5.24	15.23	79.84	76
3.6	Lack of speed of delivery	5.84	5.55	5.72	32.40	185.22	8
3.7	Risks due to reliability and compliance to delivery schedule	4.84	5.09	5.37	24.61	132.24	41
3.8	Poor planning (short term planning)	5.43	5.80	6.04	31.51	190.41	5
3.9	Lengthy set-up times and inflexible processes	5.58	5.38	5.86	30.07	176.26	15
3.10	Communication barrier with branches (insufficient, poor communications, etc.)	4.72	5.34	5.60	25.20	141.05	35
3.11	Inventory management problem (holding cost, expiry, obsolete and excessive	5.42	5.71	5.67	30.98	175.58	16

	inventory, etc.)						
3.12	Poor documentations	5.58	5.46	6.04	30.49	184.33	9
3.13	Insufficient supervision and late internal approval	4.77	5.24	5.73	25.02	143.30	31
3.14	Picking error (medication, packaging, etc.)	3.66	5.19	5.37	18.99	102.05	64
3.15	Prioritization problem	4.34	4.85	5.16	21.05	108.67	61
3.16	Consolidation problem	4.63	5.03	5.96	23.27	138.59	38
3.17	Poor visibility along the pipeline	4.91	5.42	5.55	26.60	147.71	27
3.18	Operational cost/ financial restriction	4.00	4.00	4.41	16.00	70.59	78
3.19	Failure in resource allocation	3.18	3.82	4.12	12.15	50.01	86
4. Control Risks							
4.1	Nonstandard practice (customized policies per hospital, lack of common codes, local laws, etc.)	4.54	5.21	5.87	23.63	138.81	37
4.2	Inappropriate rules that distort demand (JIT delivery, max/min inventory system, etc.)	4.72	5.39	5.57	25.41	141.48	34
4.3	Regulatory issues (change of standards, drug recalls, quality assurance, etc.)	3.78	5.31	5.84	20.06	117.09	55
4.4	Government/political intervention	3.6	4.81	5.28	17.29	91.34	69
4.5	Inappropriate type of contract (big contract, mistakes in the document, lack of clear understanding, ambiguous clauses, etc.)	4.49	5.27	5.78	23.64	136.53	39
4.6	Lack of collaborative planning and forecasting	5.31	5.28	5.87	28.02	164.38	20
4.7	Export/import restrictions	4.40	5.17	5.00	22.77	113.85	57
4.8	Change in priority/focus by the government	4.19	4.56	4.94	19.11	94.48	66
4.9	Illicit trade and organized crime (contraband, vandalism, corruption, theft, counterfeit, etc.)	3.25	5.12	5.22	16.66	87.02	71
4.10	Unstable policies (pricing, tariffs, etc.)	3.40	4.20	5.43	14.28	77.59	77
4.11	Administrative barriers (mismanagement, wrong decisions, excessive procedures, etc.)	4.12	5.16	6.67	21.26	141.73	33
5. Environmental Risks							
5.1	Natural Disaster (flooding, thunder strike, environmental disaster, etc.)	2.37	4.16	4.85	9.848	47.79	87
5.2	Exceptionally unfavorable/extreme weather	2.78	4.12	4.65	11.44	53.21	85
5.3	Epidemics/disease outbreak	5.04	4.72	5.49	23.78	130.65	46
5.4	Manmade disasters (fire, political/civil unrest, terrorist attack, etc.)	5.19	4.80	5.61	24.91	139.86	36
5.5	Remoteness of site/difficult landscape	4.75	4.79	5.29	22.75	120.22	52
6. Infrastructural Risks							
6.1	Infrastructure unavailability (IT, vehicle, road, equipment, etc.)	4.82	5.20	5.22	25.06	130.89	45
6.2	Lack of proper storage area with adequate	4.31	4.43	4.88	19.12	93.32	67

	facilities						
6.3	Technology development and level	4.09	4.40	4.90	17.99	88.20	70
6.4	Lack of maintenance for equipment/machine	4.85	4.91	4.92	23.79	117.03	56
6.5	Machine, equipment, facility failure/malfunction	4.78	4.77	4.79	22.78	109.15	59
6.6	Disruptions in the supply of electricity, water, etc.	4.35	4.32	4.28	18.82	80.61	75
6.7	Local human centered issues (industrial accidents, labour strikes, vandalism, sabotage, availability...)	4.43	4.41	6.07	19.53	118.61	54
6.8	Lack of technical and managerial skill of staff (motivation, knowledge, training, turnover, etc.)	3.34	4.08	4.54	13.63	61.83	82
6.9	IT infrastructure problems (breakdown, system failures, integration disruption, virus, software errors, internet disruption, cyberattacks, etc.)	4.26	4.48	5.11	19.08	97.60	65

Note: O - occurrence, S - severity, D - detection

Annex 5. Model fit test results and regression formula

Checked Tests	Value	P Value
Model Fitting Information (Chi-Square)	30.916	0.000
Goodness of fit (Chi-Square)	127.298	0.712
Test of Parallel Lines (Chi-Square)	42.186	0.914
Multicollinearity	VIF	All < 10 (Average = 1.444)
	Tolerance	All > 0.2
Pseudo R ²	Cox and Snell	0.838
	Nagelkerke	0.849

Note: VIF - variance inflation factor, R² – regression coefficient

Regression formula: $\text{Logit [P (Y} \leq \text{j)]} = \alpha_j - \sum \beta_i X_i$

Where, j = number of responses α = intercept

β = beta estimate

P = probability

i = number of independent variables

Annex 6. Proposed mitigation strategies for prioritized risks in EPSA, Ethiopia, 2021.

Prioritized Risks	Mitigation Strategies	Supporting Empirical Evidence
Inability to meet customer demand	<ul style="list-style-type: none"> ✓ Inventory through adding external safety stocks ✓ Vendor managed or co-managed inventory ✓ Increases control of product demand ✓ Flexible transportation, and Internal integration 	Rajesh & Ravi, 2015; Lavastre, Gunasekaran, & Spalanzani, 2012; Tang, 2006; Zhao, Huo, Sun, & Zhao, 2013 ; Kilubi, 2016
Variability of replenishment lead-time	<ul style="list-style-type: none"> ✓ Operational risk minimization plan in the delivery process ✓ Lead time reduction, and Networking and routing 	Simatupang & Sridharan, 2005; Fernandes, Barbosa-povoa, & Relvas, 2011
Suppliers' poor logistic performance	<ul style="list-style-type: none"> ✓ Partnerships in terms of supplier relationship management ✓ Supply alliance network (being member in networked suppliers) 	Vilko & Hallikas, 2012; Tang, 2006; Kilubi, 2016
Risks in forecasting	<ul style="list-style-type: none"> ✓ Vertical and horizontal information sharing ✓ Internal integration between directorates/teams of EPSA ✓ Better planning and coordination of supply and demand ✓ Flexible/multiple approach to get data for forecasting ✓ Increased responsiveness, and Aggregate pool demand 	Lavastre, Ageron, Chaze-magnan, & Alain, 2014; Gupta, Sahu, & Khandelwal, 2014; Tang, 2006; Zhao <i>et al.</i> , 2013; Kilubi, 2016; Namdar, Torabi, Sahebjamnia, & Nilkanth Pradhan, 2021
Poor planning	<ul style="list-style-type: none"> ✓ Coordination with a motivated cross-functional team ✓ Collaborative/joint planning systems 	Speier, Whipple, Closs, & Voss, 2011; Tang, 2006; Kilubi, 2016
Customer services disruption	<ul style="list-style-type: none"> ✓ Development of early warning systems ✓ Increase control of product demand ✓ Strategic stock, and Follow make-and-buy principle 	Wiengarten, Humphreys, Gimenez, & McIvor, 2016; Tang, 2006; Kilubi, 2016; Namdar <i>et al.</i> , 2021

Contract and agreement issues	<ul style="list-style-type: none"> ✓ Multiple sourcing and flexible contracts can be another way to reduce risks by using alternative suppliers ✓ Development of mechanisms for sharing risk and rewards 	Thun & Hoenig, 2011; Singh, Soni, & Badhotiya, 2019; Tang, 2006; Kilubi, 2016
Lack of speed of delivery	<ul style="list-style-type: none"> ✓ Operational risk planning in the delivery process (synchronize shipping & replenishment schedule) ✓ Flexible transportation, and Strategic stock keeping 	Simatupang & Sridharan, 2005; Tang, 2006; Kilubi, 2016
Poor documentations	<ul style="list-style-type: none"> ✓ Visibility and transparency through information sharing ✓ Further devices of information transmission, and Connectivity and technology (e.g. Mobile device). 	Hendricks & Singhal, 2011; Speier <i>et al.</i> , 2011; Tang, 2006; Kilubi, 2016
Financial risks	<ul style="list-style-type: none"> ✓ Make and buy approach ✓ Wealth and support system ✓ Using financial models (tools) ✓ Increase financial budget, and Silent product rollover 	Tang, 2006; Ghadge, Jena, Kamble, Misra, & Tiwari, 2020; Munyuko, 2015; Singh <i>et al.</i> , 2019; Choi, Govindan, Li, & Li, 2017
Instability of suppliers	<ul style="list-style-type: none"> ✓ Multiple sourcing (from multiple suppliers) ✓ Sourcing flexibility (in time, quantity and quality) ✓ Flexible supply base, and Supply alliance network 	Lavastre <i>et al.</i> , 2012; Thun & Hoenig, 2011; Tang, 2006; Kilubi, 2016
Unanticipated or volatile demand	<ul style="list-style-type: none"> ✓ Vertical and horizontal information sharing ✓ Joint risk planning with supply network members ✓ Responsiveness and managing demand ✓ Flexible supply base, and Internal integration 	Lavastre <i>et al.</i> , 2014; Gupta <i>et al.</i> , 2014; Tang, 2006; Zhao <i>et al.</i> , 2013; Kilubi, 2016