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LABORATORIES PREPAREDNESS IN RESPONSE TO COVID 19 PANDEMIC IN QATAR STRATEGIC PLANNING AND EMERGENCY SUPPLY CHAIN MANAGEMENT

BY

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ABSTRACT

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Title: LABORATORIES PREPAREDNESS IN RESPONSE TO COVID 19 PANDEMIC IN QATAR STRATEGIC PLANNING AND EMERGENCY SUPPLY CHAIN MANAGEMENT

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Introduction: the purpose of this study is to investigate the preparedness of laboratories in Qatar on provisions of essential supplies in pandemic through assesses Supply Chain Management capabilities and its resilience in emergency. The COVID-19 pandemic imposes challenges to many countries' medical laboratories around the world. These challenges were caused by partial to complete lockdown of most countries and lead to worldwide supply chain (SCs) interruption. Supply chains SCs control pandemic outbreak by providing streamline flow of medical resources to prevent shortage of essential clinical laboratories supplies required to reduce the mortality rate and mitigate the pandemic effect. Since laboratories depend on continuity and sustainability of essential supplies provide by SCM, this highlights the importance of investments on preparedness of emergency SCs through creating a strategy of future uncertainty for any disruption event.

Methods: The study relied on primary data collection and the utilization of SWOT tool for SCM analysis. A qualitative data was collected through interviews, the capability of SCM to sustain during pandemic and provide essential laboratories supplies was analyzed by SWOT tool to investigating the strength, weakness, opportunities and threats. On the other hand, the collected data was used to fulfil the checklist requirements; the checklist that used was the modified WHO checklist for H1N1 influenza virus in

2009. The analysis of data relied on the WHO scoring system. The checklist included laboratories' supply chain management preparedness protocols on six key components: Governance, financial, IT system, and personnel; Commodities planning; Procurements and sourcing; Stockpiling and warehouse management; Transportation and customs; and finally, Waste management. Each component is considered as a domain and subdivided into several activities.

Results: Laboratories preparedness plan activities in governance, personnel and finance component have 64% of intermediate progress, however, 26% of preparedness planning for pandemic was in progression. The total percentage of activities on the commodities' planning component was received 70% of intermediate progression, however 20% of preparedness plans was in progression. Activities on the procurement and sourcing of component was received 67% of intermediate progression of preparedness plan, and 33% the preparedness plan was completed. Warehouse and storage management received 58% of preparedness for emergency, whereas 21% of the preparedness plan was in progression. The transportation and customs component show 64% of preparedness plan for emergency, on the other hand, 7% in progression, and 29% the preparedness plan was completed. Most of activities on the waste management component received 47% of preparedness plan, whereas 13% of this component was in progress planning, and 40% the preparedness plan was completed.

Conclusion: Laboratories preparedness for emergency considers crucial footsteps for future countries threats, this achieved through coordination between country health sectors on the laboratories field through allocating national laboratories for public health and establishes SCM center that have unified processes and procedures across country health sectors. In addition, opens communication channels between health

sectors to collaborate in preparedness planning in all emergency supply chain management components that emphasis on; securing and provisions of all essential resources needs for contagious disease, looking for planning the critical supplies forecasting and quantification, focusing in applying diversification in sources and suppliers and encourage of domestic suppliers. Also, SCM personnel in laboratories should put into consideration through prepare them for emergency by applying simulation program. Furthermore, corporation with health sectors in planning for sufficient warehouse with higher capacities for emergency and planning for transportation routing across countries, in addition, coordinate with laboratories to prepare a plan for waste management protocols. Finally adopting promising solutions in SCM that increase transparency along supply chain management between health sectors in emergency.

DEDICATION

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1. CHAPTER 1: INTRODUCTION

1.1. Background of the Study

Supply chain management (SCM) is one of the main areas for organizational performance improvement and variability over the world. Supply chains (SCs) prevent shortage of supplies through provisions of streamline flow of medical resources for reducing epidemic duration and lowering the mortality rate (Paul, S. K., et al 2020). Laboratories essential resources are safely delivered through supply chain management cycle, which ensure the continuity and sustainability of laboratories supplies during emergency to ensure public safety. The preparedness of emergency supply chain for future uncertainty requires creating a plan for any disruption event and to be ready for mobilizing and allocation of resources to reduce mortality rate (Queiroz, M. M., et al. 2020).

The United States Agency for International Development USAID 2018 report the Best Practices in Supply Chain Preparedness for Public Health Emergencies at the national and international level, which includes essential components, Governance and organization structure, Commodity planning, Quantity Forecasting, Procurement and sourcing, health commodity Stockpiling, Emergency response warehouse and storage, Transportation and custom (USAID 2018). These components can be applied within individual health entities, including medical laboratories.

1.2. Statement of the Problem

Clinical laboratories play a vital role in pandemic responding (Vearncombe, M., & Astrakianakis. et al. 2020) via facilitating the delivery of rapid and proper public health responses through identify the earliest infected cases, assist in differentiating patients infected with novel virus from other respiratory diseases, and support public health observation by detecting geographical spread of disease (Vearncombe, M., &

Astrakianakis. et al. 2020). In recent years, surveillance and monitoring has seen a steady rising of pandemic disease rate which leads to increasing demands for essential medical supplies in healthcare sectors including clinical laboratories, this in turn can potentially burden hospitals capacity and the health system (Chen, X., et al 2020). Therefore, the pre-pandemic preparedness plan should be considered to ensure continuity of critical supplies in pandemic, and ensure the continuity of laboratories operations, this achieved by availability of robust supply chain management infrastructure to ensure through accurately identifying and forecasting of essential supplies, ensure efficient and timely procurement of said supplies, optimized storage of reagents, ensure availability of enough capacity for stockpiling, and space management for equipment and storage.

1.3. The objective of the study

1.3.1. General objectives

- To investigate challenges faced by laboratories and the implemented preparedness in response to providing COVID-19 diagnostic tests and preventive supplies.
- To explore the gaps in the emergency supply chain components, and to a plan and recommendation can be made based on best practices to overcome future threats in Qatar.

1.3.2. Specific objectives

This study has the following specific objectives.

- To assess the preparedness of HMC laboratories preparedness by creating supply chain emergency teams and training them on disaster or emergency events.
- To assess the preparedness of HMC laboratories on supplies forecasting and quantification.
- To assess preparedness of HMC laboratories on supplies procurement and selection.

- To explore the inventories managements challenges and preparedness of emergency storage in a warehouse for supplies.
- To evaluate the extent of pre-pandemic planning for transportation and its network.
- To identify problems related to laboratory supplies logistics management information system in HMC.

1.4. Research Questions

What are the major laboratory logistics challenges face problems existing in the emergency supply chain management components? How to strengthen the capacities and enhance preparedness of laboratories supply chain management during an emergency in Qatar to prevent critical supplies shortage in the future pandemic?

1.5. Significance of the Study

Clinical Laboratories' preparedness and response are key factors in successful containments of any public health care threats such as pandemic. Hamad medical laboratories play vital roles in health security and safety by confirming human cases during COVID 19 pandemic via performing different tests to diagnose SARS-Cov-2, including Polymerase Chain Reaction PCR tests and serological tests for patients monitoring. Until October 2021, the total test capacity is accomplished 2,756,985 tests since the pandemic started. It is crucial to ensure continuous provision of supplies in laboratories during uncertainty, especially essential supplies that diagnose expected cases and personal protective equipment supplies, which protects laboratory personnel. SCM is the heart of hospitals that ensures continuous flow of health commodities between manufacturers, suppliers, and providers until it reaches end-users. This will ensure continuous provision of resources for different health departments, including Clinical laboratories, which maintain public health and reduce the mortality rate in pandemic. Therefore, interruption in SCM will leading to shortage of essential supplies. This can be prevented through adopting a

comprehensive preparedness plan and strategy that prepare SCM and clinical laboratories before any crises.

The information provided by this study will encourage other health institutions to take holistic measures in preparedness to their supply chain management for future disasters.

1.6. Scope of the Study

The study investigates major components of emergency supply chain management ESCM in laboratories in COVID 19 pandemic. Also, it examines the availability of strategic preparedness plans that ensure the sustainability of resources and continuous provision of laboratories critical supplies for COVID-19 diagnostic through evaluate SCM capabilities during emergency. Diagnostic supplies include reference sampling method, the nasopharyngeal or nasal swap as recommended by WHO, diagnostic assay for real time PCR, the gold standard of COVID 19 detection, and point of care serological assay for patient monitoring (Péré, H., 2020). The preventive resources include personal protective equipment's PPE (N95 mask, medical masks, gloves, gowns, eye protection) and disinfectant products

(Chen, X., et al; Péré, H., et al 2020).

2. CHAPTER 2: LITERETURE REVIEW

2.1. Supply chain management (SCM) in clinical laboratories

Healthcare supply chain management is a complex procedure that includes procurement of healthcare resources, logistics, and warehousing. Similar to other industries, the process starts with the acquisition of raw materials or inventories of laboratory, the formation and packaging, shipment of products to wholesalers, and ultimately reaching to the patients through concerned medical organizations (Pillai,

S.V 2018).

Similarly, supply chain process in healthcare sectors starts with the flow of medical products from manufacturers and ends at healthcare providers through a distribution center. It also depends on the type of product, whether it is delivered directly from the manufacturer to the healthcare sectors, or it needs intermediary distributer to reach providers. As such, SCM enables visibility of information through new approaches and innovative methods to streamline the process of flow of information and products among stakeholders. The fundamental objective of health care supply chain management is to provide requirements in a timely manner to fulfill the end user's needs (Mathew J. et al., 2013). The supply chain of health sectors is highly fragmented and relatively ineffective (Schneller and Smeltzer 2006); each step proceeds independently, which leads to overlooking the goals that prevent supply chain operations as a system and adoption of management practices related to supply chain.

2.2. Laboratories Supply Chain Management stakeholders

Laboratories' Supply Chain Management is a network of interconnected stakeholders with defined roles who are engaged in delivering products or services. For example, manufacturers create medical products, consumables and durable materials, and medicine through research and development, and any obstructions they face results in shortages of these products. Whereas distributors and logistic partners are responsible for delivering all medical products and supplies from manufacturers to the healthcare facilities, the interruption of borders transportation or country infrastructure destruction will impact product delivery. The providers include all health facilities that receive the medical products from distributers and prescribe to patients or use by end-users (doctors, technicians, nurses, and others).

2.3. Types of SCM strategy used in laboratories field

Supply chain strategy includes push and pull strategy. Push strategy is used when the demand is expected, however, quantity or time of need can be uncertain. For this reason, the quantity is estimated relatively to the situation, so it is pushed into the supply chain and is most commonly used in emergency preparedness plans in pandemics or disasters. Conversely, the pull strategy is used when the demand is well understood which means the quantity to be manufactured is more precise, thus it is pulled into the supply chain and is typically used in short-term projects. In recent years, a new strategy under the pull strategy known as Just in Time (JIT) has been adopted in healthcare sectors and laboratories, aiming to reduce inventory holding costs (Kowalski 1986; Wilson 1992; Lynch 1991). It is a strategy in management that aligns orders of raw materials from suppliers directly with production schedules. Hence, providers keep enough stock on hand to fulfill current orders, which reduces inventory cost, and accurate forecasting of demand is required, and improved information and communication are adopted. According to Landry et al., and Bahkoo et al states that a complete stockless system is best for removing stores at the center and liberating space, but it's not ideal during an emergency, which is unpredictable and leads to a shortage in supplies (Landry et al., 2004; Bahkoo, V. et al. 2012).

2.4. Components of routine Supply Chain Management in laboratories

2.4.1. Procurement process in laboratories

Procurement is the process of purchasing goods, services obtained from external sources of the company. It encompasses mutual development and agreement to terms and conditions for acquiring goods and services, often through tendering or a competitive bidding process. It plays a pivotal role in the overall business strategy of a company to obtain resources at the best possible cost. According to the clinical

laboratory procurement manual adopted by WHO, the procurement process is a process of acquiring supplies such as equipment, diagnostic resources, consumable and durable resources, and other laboratory items. Procurement process cycle is a continuous process to obtaining commodities, and it begins from planning, implementing, monitoring and evaluation (WHO 2013). Each step is subdivided into a detailed strategy. The procurement process should engage stakeholders to reach to right decisions (Sloan, P. 2009); they include government entities, private sectors, national entities, and end-users.

The first step in the procurement process cycle in the clinical laboratory is planning. It starts with a needs assessment by evaluating laboratory scope services, existing supply chain infrastructure and function, assessment of laboratory substructure, and personnel. However, it is preferable to do a comprehensive assessment for the laboratory to determine the exact needs on the ground (WHO 2013; WHO 2020).

After the assessment, procurement and supply management begins with selection of supplies in accordance with the products' protocols and standards, as well as registration status in the local regulatory bodies. Developing a standard list of supplies based on the laboratory level and tests performed will assist in selection of supplies and their management. Also, the level and the complexity of laboratories, personnel competency, and laboratory infrastructure, transportation mechanism, and storage conditions should be considered. Moreover, the diagnostic test performance should be measured during the product selection such as shelf life of reagents, sensitivity, reliability, specificity of the reagents, and compatibility of assays with proficiency tests or External Quality Assurance Services EQAS program. The operational characteristics of the test must also be considered, which include the instrument required to perform the assay, such as; specimen type of each equipment, Turnaround

Time, through-put per hour, and staff training. Moreover, other logistic factors should be considered when selecting tests such as; laboratory infrastructure, the required environmental conditions for shipping, and the storage requirements of the reagents. This information's including the contract with suppliers, should ensure that the received items comply with the agreement terms (World Health Organization 2013& USAID 2008).

Once supplies' selection is completed, the laboratory requirement is estimated through quantification and forecasting. Quantification means identifying the number of laboratory equipment required (reagents, equipment, consumables, and durables) as per the scope of usage and their demand, whereas forecasting is a technique that uses historical data to predict the direction of future trends in hospitals. This step is crucial in the procurement process. It depends on the collection of historical information that is based on demographic, logistic and services statistics, or current field data, or future trends by using forecasting model for accurate prediction, which will help in reducing stock-outs or wastage of supplies in the laboratories, importantly, engaging stakeholders in forecasting assists in reaching the right and accurate decisions. Stakeholder engagement adds value to the operations of the organization and allows it to plan for the future, thus assuring enterprises that their priorities and problems will be appropriately addressed and solved. Therefore, the time and effort consumed in their development will contribute in organization improvement (World Health Organization 2013; USAID 2008).

After the planning phase during the procurement process, the implementation phase takes place through product specification, which is a written detailed statement of the laboratory requirements and covers both technical and commercial attributes. Additionally, the product specification must comply with international standards for

manufacturing and post-market surveillance. Afterwards the procurement method is selected, which entails either international competitive bidding or restricted bidding. Since clinical laboratory product is highly specialized in nature, restricted bidding is typically preferred over the other to ensure standard of quality (USAID 2008).

On the other hand, the vendors' sourcing is identified and evaluated to meet the qualification criteria of the procurement process and have the capability for supplying to the term of the bids. The evaluation metrics of suppliers include service quality, equipment and assays' pricing, reputation, and recognition of industries, provision of warranty and guarantee, ability to supply resources at specified temperature during shipment and providing post-services surveillance. This process involves a web search on the Publication of a request for Expressions of Interest (EOI) or communication with technical experts at WHO to source the vendors. Besides, building long-term relationships with suppliers will incur financial savings through ordering of large quantities of equipment at reduced costs, enables the implementation of initiatives for collaboration, and enhances trust between manufacturers and buyers (Oruezabala et al. 2012). Furthermore, sharing knowledge and information with suppliers regarding forecasting, inventory level, consumption plans, technical information, goods flow, commodities costs, and new products and services that will improve procurement and supply chain management sustainability.

After the specification is written and suppliers are evaluated to contribute on the method of solicitation of a bid which is selected relies on the organizational procurement rules, suppliers are requested to submits either request for proposal or request for quotation to compare it with required laboratories specification. Some criteria should be considered in the solicitation of bid such as technical specification, delivery terms, guaranteed shelf life upon delivery, provision of installation, training,

maintenance, available of storage space, the total cost of ownership, and providing of the quality system for manufacture (e.g., ISO 13485; 2003 and diagnostics ISO9001) (WHO 2013). Contract negotiations with selected suppliers occur after all previous terms are accomplished for suppliers and products. Contracting is helpful for organizations; it creates maximum value and enhances providers-suppliers collaboration. This process involves evaluating critical factors with vendors such as contract duration, vendor and buyer responsibilities, payment terms and method, warranties, training requirement, installation for equipment, and corrective and preventive maintenance must be specified within the contract (World Health Organization 2013).

The final step in the procurement process is the monitored and assessment phase. Procurement of items is monitored through a wide range of indicators, which allows for effective evaluation of the procurement process. For example, it is crucial to evaluate suppliers when orders are completed, the product is delivered in acceptable condition, and when they responsibly address any defective piece of equipment. Furthermore, post-market surveillance, which includes activities prepared for implementation by the manufacturer through collecting, recording, and analyzing the information on the quality, performance, and safety of the devices for the product's whole life cycle, is an essential addition to this step (World Health Organization 2013).

2.4.2. Warehouse and Inventory management in laboratories

Warehousing is preparing the infrastructure to manage inventories of laboratories supplies. The numbers and capacities of the warehouse depending on the quantities and volume of required inventories. Since 20% of healthcare cost is dependent on inventory management, therefore, hospitals attempt to reduce on-hand stock and

controls supplies to reduce the cost, and at the same time, prevent stock out or overstock (Kelle, P. et al. 2012). Warehouse operations require highly organized infrastructural mapping that relies on storage materials being used and their capacity to store inventory effectively. “Inventory management means the knowledge and the practices to keep the optimal number of materials in the storage facility, and it corresponds to the warehouse facility management and the physical management of stored inventories. It ensures a continuous supply of laboratory commodities via proper selecting of inventory, design, and proper implementation of suitable inventory control system (Volland, J. et al. 2017)”.

Inventories management requires deep knowledge of both acquisitions (procurement) process and consumption patterns, which depend on accurate forecasting of demand, monitoring of stock level and consumption, and timely ordering of the right amounts of goods. In addition, managing the stockpile contributes to coping with uncertainty, especially in disasters or pandemics. Furthermore, it helps control lead times (the interval time from ordering until receiving the order) and economies of scale, reducing cost by buying large quantities considering storage cost. On the other hand, absents of inventory management will increase holding cost or overstock of supplies that have adverse effects on laboratories, and leads to hospital burden and cost risk. Effective inventory management in laboratories means keeping optimal inventory levels at all times; this can be achieved by effective scheduling of supplies orders with consideration of estimated demands and the lead time to be covered (Volland, J. et al., 2017).

2.4.3. Transportation and distribution

In the past, transportation had a less critical role in supply chain management, but more recently, it has been recognized as a vital component in SCM; hence it has a

vital role in delivering suitable goods with proper condition, the delivered amounts should match the ordered quantities, which delivered to the planned place with effective price and scheduled transportation time, to the right supplier and to providers. In the supply chain, transportation implies to the movement of goods from one point to another that starts at materials manufacturing and make their way to the distribution center and to the warehouse and continues to the final providers.

Developing a transport strategy in laboratories is crucial to ensure all procedures are organized and appropriately done without discrepancies. During planning, some factors must be taken into account while developing a transportation strategy, and these include: identifying the persons who are responsible for shipping and handling the commodities, such as; shipper, which is a person who sends goods from the point of origin, the agent who has contractually designated to act in a variety of functions from handling to processing of documentation, or service providers who are a contracted third party that offers a variety of activities, usually for-profit basis. Another factor to be considered is managing to transport either by self-transporting or by the third party. Also, the capacity of the means of transport, the nature, and the quantity of goods should be planned; it is essential to know that the conditions required for transportation of some products need cold storage during transit, and others should be handled carefully because of its corrosive or flammable. Also, the availability of human resources and vehicles should be considered in transportation planning, finally ensuring the cost and security over the length of the transport route. Additionally, vehicle movement should be planned for routine and emergency situations, the movements managed by the transport office or persons responsible for determining the commodities route, informing the estimated delivery time, and managing the staff involved in the movement.

It is important to maintain transparency and streamline the flow of information between all parties, including in SCM, to ensure the safety and security of commodities arrived at respected time and to solve any identified problems raised during the commodities movement. Notably, movement in national routes can be planned and coordinated more than international movements, which needs service providers working with a comprehensive plan to meet customers' routing and movement time requirements.

2.4.4. Logistic Management Information System (LMISs)

A logistics management information system (LMIS) is an electronic record-keeping and reporting system. It gathers, analyses, validates, and displays data from all levels of the logistics system in order to make logistics decisions and control the supply chain. According to Saeed (2017), LMISs defines as "all organizational and supply chain digital systems consisting of infrastructure, applications, and media that make up the input data and information, processing, and output knowledge used by an organization and its supply chain stakeholders, principally, suppliers and customers." (Saeed, M. A., et al 2017).

LMIS is essential for laboratories and should be modified for use in this field according to the laboratory's supplies nature; LMIS aims to track all inventories and ensure deliver the order in the accurate time, and has a benefit for decision making improvements to ensure continuous provisions of supplies and to detect the gaps in the supply pipeline.

ERP stands for Enterprise Resource Management "the combined process of gathering and organizing business data through an integrated software suite. ERP software contains applications that automate business functions like production, sales quoting, accounting, and more".

"(ERP) is an innovative system used as a solution for supply chain management; it shares inventory data, makes commodities planning, manages the human resources, and manages manufacturing within an organization. It is considered suitable to share information between companies along the supply chain. Organizations adopting digitalized systems at entry-level systems with ERP will considerably lower the costs in a pandemic than those that do not employ it (Choi, Guo, & Luo 2020)".

According to Choi, Guo, & Luo (2020), the firms that employ digitalized systems, with ERP, will have better performance in a pandemic. LMIS is concerned with three essential data to make logistic decisions; stock on hand, quantities consumed a period of time, and finally losses and adjustments to stock for purposes other than use (expiry, damage, wastage, etc.) (Choi, T. M., 2020). The data is then recorded and reported to the higher level for resupply and management purposes, then feedback reports to the lower level for performance improvement of the logistic system. Notably, the software that is used to manage and analyze the clinical laboratory data must be tailored to support the laboratory logistic activities and decisions.

On the other hand, Blockchain is another promising solution for SCM; it is an innovative software tool with high visibility and transparency along the supply chain. "Blockchain allows a limited number of known parties to protect their business operations against malicious actors while supporting better performance" (Gaur & Gaiha, 2020). In recent years, healthcare sectors adopted the blockchain integrated with artificial intelligence to strengthen their operation protocols and create the basis for an effective evidence-based decision. It has a strategic role in safely sharing data between selected persons, and it works by collaborative tools. It can be used to improvise risk management protocols (Fusco, A. et al. 2020).

Furthermore, virtual centralization of the supply chain is an innovative approach that

have important roles in problem solving that related to the time delayed, personnel shortage, and cut-off budget; it controls hospital costs and improves their services. A well-defined example is a united services center (USC) managed and owned by multiple hospitals and healthcare systems; it is collaborated to centralize supply chain management protocols such as; procurement, contracting, distribution, and logistic operations (Mathew, J. et al. 2013).

Radio Frequency Identification (RFID) "is a technology to identify a tagged object by using radio waves passively". It is used in several applications like commercial and industrial, from tracking items along a supply chain to keeping track of items checked out of a library. Radio Frequency Identification "is a technology that can trace the products through programmable tags, which have information about weight, destination, and time stamp. This tag enhances warehouse space management and product tracking, reducing cost, cutting time, and providing accurate information" (Mathew, J. et al., 2013).

Collaborative forecasting replenishment planning CFRP "is an inventory practice that is digitalized for facilitating SC alliance and acts as a roadmap and thus helps in standardizing the production planning and movement". CPFR is a collaborative mechanism in which the organization combines the planning, forecasting and logistic data from within owned company and data points provided by its suppliers and customers (Parsa, P. 2020). It allows for sharing information with suppliers and providers, developing accurate forecasts, and improving product replenishment and operation processes (Hill, 2018; Hotrawaisaya, C., 2020). Vendor Managed Inventory (VMI) means the supplier have the responsibility for customer inventory management and takes decisions regarding refill (Waller et al. 1999).

In this context, digital systems offer a promising solution in supply chain

management, reduce laboratories cost, enhance the inventories management, improve the flow of information and communication along with the SC, and help in planning and forecasting, provide accurate and appropriate data that is used in laboratories decisions to improve the services. However, in the beginning, stages of development, many of these digital systems are not adopted by laboratories, such as Artificial intelligence.

2.5. Challenge faced by clinical laboratories supply chain management during pandemic

The main challenges that were faced in the supply chain cycle and caused interruption; first in the operational aspect, these concern production or supply problems such as lack of raw materials, lack of machine spare parts, and product cycle (expiration date). Regarding commodities, stock-outs and shortages that caused by plants closed and cut-off material production could lead to delays in patients' diagnosis, extended hospitalization, missed opportunities testing and diagnosis of patient. On the strategy aspect, most healthcare builds on Just-In-Time (JIT) strategy, which has benefit to reducing labor cost, time, and space required to stockpiling the medical products; however, this strategy has a significant effect on medical supplies in the pandemic, this caused imbalance between supply and demand relationships, especially in increased demand in uncertainty. Therefore, Sheffi, Y. proposed to have reserves of critical resources in addition to JIT strategy so that they will take advantage of this strategy and at the same time they keep on hand inventories for any kinds of threats (Sheffi, Y. 2020). On the other hand, some hospitals' lack of system mechanism to track the number of ordered products and information transparency along the supply chain to support future preparedness concerns SCM's challenge (Patel, A. et al. 2017).

2.6. Emergency Supply chain management in clinical laboratories

Supply chains control epidemic outbreaks by providing streamlined medical resources to prevent the shortage and mitigate epidemic duration (Paul and Venkateswaran, 2020). However, during the pandemic, supply chains experienced an interruption upstream and downstream and an imbalance of supplies and demands, which got impacted by lockdowns in most countries (Nikolopoulos, K. et al., 2021). Furthermore, according to the International Civil Aviation Organization (ICAO) report in 2020, supply chain practices have been disturbed drastically due to COVID-19. In addition, COVID-19 distribution leads to weakness and breaks many global supplies chain networks that are not resilient to the pandemic (Araz et al. 2020).

COVID19 triggered severe disruption on economies and transportation, which affected supply chain routes and experienced a worldwide shortage in essential resources, primarily supplies used to contain the pandemic, and reduced the mortality rate in all countries (Guiyang Zhu. et al. 2020). In the first wave of a pandemic, the uncertainty of virus nature and its route of transmission, at the same time, the vaccines need time for created and approved by Food and Drug Administration FDA. Also, the shortage of primary assays for virus detection and diagnosis leads to increased mortality rates due to lockdown, closed countries borders, and interruption in supply chain routes. Team and Murray predicted that COVID-19 would cause severe interruption, and hospitals' capacities would be beyond regular demand (Team, et al 2020). Hendricks & Singhal (2003) assumed that disturbed supply chain causes significant challenges and affects institutions' performance (Hendricks, K. B., et al 2003). Therefore, a strategic plan was established at the onset of pandemic in most countries to categorize patients according to their result diagnosis and severity of disease to prevent hospitals and medical staff overwhelming that leads to health

sectors collapse. In this regard, Health care is a front-line institution, and any threat can cause the breakdown of supplies of delivery at any stage of the distribution process (Chikezie N 2015).

Similarly, clinical laboratories played a vital role in patients' diagnosis by standard gold method Real Time PCR; therefore, the availability of laboratories' essential resources should be prioritized. "The disruption supply chain leads to a shortage of materials, and delays in supply delivery occur downstream, resulting in reduced institutional performance in terms of income, decreased service level, and delayed in process productivity (Dolgui, Ivanov,.et al, 2020; Ivanov, 2014)". Ivanov stated that epidemic outbreak has uncertainty and immediate disruption in supplies and demands, also has a long-term effect on supply chain than other risks because it starts small and spreads on a large scale in the geographical area, which interrupts the logistic infrastructure (Ivanov, D., et al 2019).

On the other hand, poor involvement of stakeholders' coordination concerns the main challenges of supply chain management during uncertainty. Ivanov and Dolgui asserts that the supply chain needs greater visibility and communication to reduce the ripple effects (sudden fluctuation of demands) caused by unpredicted events (Ivanov, D., et al 2014). Therefore, there is a need for a proactive strategic plan to improve the impact of the pandemic on supply chain networks and prevent medical laboratories supplies shortage, delayed delivery, enhance performance, and support decision-making. Also, clarifying governance through identifying authority and accountability of stakeholders (medical manufacturer, distributors, and providers) of laboratories SC and identifying potential partners (ministries of public health, private sectors, other governmental organizations), and opening consistent communication channels will reinforce clinical laboratories to mobilize their resources rapidly and effectively in

response to the pandemic. Moreover, understanding countries' disease threats and potential laboratories resources will facilitate identifying types and quantities of supplies to be stockpiled, depending on the types of hazards, geography, and countries' existing capacity. Also, pre-pandemic planning for storage sites and logistic providers allows rapid response to contain the threats.

The 2019 USAID report on Best Practices in Supply Chain Preparedness for Public Health Emergencies outlined critical components of supply chain management and developed guidelines to be implemented at national and international levels; the same principles can be applied on a smaller scale for individual health care systems, including medical laboratories.

The critical components of emergency supply chain management and preparedness are; landscape assessment, Governance and personnel, commodity planning, procurement and sources, warehouse and stockpiling, transportation, and finally, waste management (Figure1-1). This study will focus on these components and used SWOT analysis to analyze supply chain management current situation and preparedness for pandemic, which helps on the checklist construction.

2.7. Key components of emergency supply chain management

2.7.1. Landscape assessment

Landscape assessment means a comprehensive assessment of emergency supply chain management in laboratories from different aspects such as; stakeholders' assessment, Hazards assessment, and current state of ESCM capabilities assessment. Stakeholder's (suppliers, governmental laboratories, national laboratories, laboratories in private sectors) assessment means identifying the persons that will have a role in laboratories SCM in epidemic and determine their capacity to provide physical support or funding and their roles in the outbreak. Evaluation of their

capacities means their ability to provide personnel, warehouse and space, funds, cold chain, and transportation (USAID2018 & Patel, A. et al. 2017). Collaboration between SCM key persons by sharing information and assessing essential demand will accelerate SCM's adaptability to threat, flexibility, and sustainability. Also, working together between country entities will create a community perspective and increase visibility and understanding of the SC strategy that mitigates SC's threats (de Sousa Jabbour, A. et al. 2020). “SCM sustainability achieved by organizing regular meetings and workshops to create common targets and share information and projections that help manage cooperation in SC (de Sousa Jabbour, A. et al. 2020)”.

At the national level, the stakeholders must be a focal point from all laboratories and should have expertise in laboratories supply chain management; this will benefit during an emergency to share their experience for forecasting and planning.

Hazard assessment means identifying the range of potential risks and prioritizing them; this will help prepare and mobilize the resources to face this threat based on its severity (WHO 2020). If the laboratories supply chain management team understands the hazards, this will help identify and prioritize all likely scenarios for proper flow of logistics planning.

2.7.2. Governance and personnel

Governance and personnel, before any potential crisis, it is essential to have a clear laboratories emergency supply chain structure for team, the roles and authorities are predetermined, this will facilitate rapid response and correct decisions on the critical time, also enhances the interaction between hospitals, laboratories, entities, and relevant partners. Therefore, it is essential to create Laboratory Emergency Supply Chain Management (LESCM) team that includes an assigned emergency supply chain (ESC) lead for each task. Training mechanisms should be put in place before

the pandemic, this team is responsible for implementing a preparedness plan during a pandemic and ensuring its sustainability, and they also facilitate response through allocation and mobilization of all resources. A leader who leads the core team has combined leadership and coordination skills with a technical understanding of laboratories supply chain logistics. On the aspect of relationship with another health sector, Flynn, Schroeder, & Sakakibara, "state that leadership is an essential factor of supply chain management, which provides a clear vision for communication strategy and encourage coordination from different disciplines in procedural, financial, and administrative knowledge to manage the supply chain in a pandemic" (Flynn, B. et al 1995). The leader responsible for recruiting the ESC team from different laboratories in the country and opening consistent communication channels will strengthen countries' ability to respond to any disasters quickly. The team members should have experience and knowledge in different fields for an emergency, and they include; technical expertise lead that has a capability in forecasting and specifying laboratories critical supplies for pandemic disease, procurement leads are well-known in procurement contracts and stockpiling guidelines and requirements, they also identify and coordinate with suppliers. These logistic leads are familiar with warehouse planning, transportation mapping and coordination, and, finally, waste management (USAID 2018). On the other hand, a leader must identify roles and accountability for partners who will engage in ESC and work together, respond to threats, and train them for a pandemic. "The development of an emergency supply chain management team requires communication along the supply chain and coordination, which will accomplished by real leaders. (Flynn, Schroeder, & Sakakibara, 1995)".

Personnel training: The leader must train his team on how to respond to an emergency, so effective laboratory SC response relies on having well-trained

personnel and partners to have an understanding of ESC operations and build their skills and capabilities and create a robust basis for them to respond to any types of threats. The most efficient emergency training program is a simulation which is training exercise for ESC stakeholders to identify supply chain weakness areas to be improved. The improvement must incorporate the information from pre-pandemic training and lesson learned in post-pandemic assessment. Simulation is a mimic program for an epidemic scenario and helps laboratory ESC team in forecasting supplies, planning for purchasing, and prepare a plan to increase capacity for storage and mapped transportation routes for commodities in emergency (Ivanov, D. et al 2020).

Paul and his colleague "Claim that simulation is an essential training tool to predict required performance capacity and disruptive scenarios" (Paul et al. 2020 & Ivanov Das 2020). Its beneficiary if the training conducted regularly and cover all ESC plans for all laboratories departments, stakeholders, internal and external parties, and medical suppliers involved in ESC planning. "The training program could use input based on forecasting, simulation methods, epidemiology modeling, supply chain processes, and other quantitative and qualitative methods (Black, S. 2020)". This will increase their knowledge in response to the pandemic and enhance the relationship between different stakeholders, facilitating coordination during a pandemic.

Finance of emergency supply chain: Preparing a budget for ESC and identifying the sources and procedures to access the funds before disaster triggers SCM to respond swiftly to contain any threats by providing. Therefore, preparedness of budget before crisis invests on time and cost an emergency (UNICEF 2015). There are two kinds of budget; preparedness budget, which incorporate into routine SC strategic planning annually, and allocated for warehouse designated for emergency

storage, labor cost, inventory management of emergency supplies costs, and continuous training of personnel before an emergency; the other kind of funds, reserved funds that cover the cost of responding to an epidemic and it should be revised and updated annually, the size of this funds based on country risk assessment of potential threat, supplies planning and supplies forecasting exercise. The main drivers for this kind of funds are; types and quantities of essential laboratories supplies, transportation cost, and capability required for assays storage, especially the cold chain, and SC personnel considering absenteeism during the epidemic (USAID 2018).

2.7.3. Commodities planning

Commodities planning plays a crucial role in ensuring a rapid response in the early phase of a pandemic. However, a pandemic is unpredictable and is characterized by a sudden amplifier in demands with overwhelming supply chain management in emergency and causes instability between supply and demand. Also, difficulty in forecasting the exact quantity of critical supplies to meet patients' needs, therefore, before the outbreak, laboratories ESC core team must identify and list the requirement of critical supplies based on pandemic or epidemic disease and determine types and its specification based on hazard assessment and severity of disease, this will help in the prediction of the quantity needed, specifying suppliers that will provide these commodities and negotiate agreements with them, also, help to develop storage and transport practices, and create inventory, and finally waste management protocol (Callihan, D. R 2021; WHO 2017).

Types of laboratories resources or commodities needed in the COVID-19 outbreak based on WHO hazard assessment are; "Diagnostic resources, such as, reference sampling method such as; nasopharyngeal, buccal swab, and nasal swab as

recommended by WHO, diagnostic assay for Real Time PCR the gold standard of COVID-19 detection, Antigen Detection tests, and Direct Fluorescent antibody (DFA) test for patient monitoring (CDC 2020; Péré, H. et al. 2020)". The preventive resources include; personal protective equipment's PPE Personal protective equipment to protect healthcare workers from a disease transmitted through the respiratory route includes both respiratory protective devices (N95 filtering face-piece respirators or personal powered air-purifying respirators) and surgical masks to place on ill patients to minimize the risk of respiratory transmission, gloves, and gowns used to protect healthcare personnel, goggles for eye protection and disinfectant products (CDC 2020). The ESC is responsible for providing these resources to the laboratories during an emergency, but the requirements vary based on disease types. On the other hand, there are stable resources for any outbreak which includes; PPE's, sampling methods, and other resources that vary according to the nature of the disease and based on risk assessment. Therefore, it is essential to have an updated list of critical supplies for each outbreak disease; this list is approved by the consensus of ECS core teams before an outbreak or disaster occurs and should be updated regularly.

Commodity specifications "are detailed statements of the laboratory requirements involving both technical and commercial characteristics, and they must be written, have sufficient detail, and be concise to ensure transparent procurement that represents the highest quality for the best price. Also, the commodities specification helps identify suppliers and put a contract in place before an outbreak (Okeagu, C. et al. 2020; WHO 2017)".

Quantity forecasting is a crucial step in commodity planning, forecasting means the process of calculating the quantities of critical resources that are essential to

delivering care in case of a public health emergency), forecasting concerns as a tool in supply chain planning during a pandemic and are necessary for better decisions in government in the management of supply chain resources, so the ability to predict excess demand in pre-pandemic leads to significant implication on supply chain improvement (Nikolopoulos, K. et al. 2021). In the laboratories field ESC team coordinate with partners and stakeholders to predict the quantity of critical laboratories resources which needs in each outbreak; this involves comprehensive information gathered to know laboratories requirements in the outbreak that can be obtained from historical data of past epidemic or pandemic, or countries' experience of the past outbreak, or used sophisticated forecasting model, which assist in determining supplies of quantity to reduce the shortage in critical resources, on the other hand, prevent over-purchasing and overstocking that overwhelm supply chain management (USAID 2019; WHO 2017). Furthermore, quantity forecasting allows laboratories' ESC teams to establish supply agreements and logistic protocol to prepare for a future pandemic. Queiroz et al. state that preparedness for future pandemics involves establishing future uncertainty and pre-allocating resources to carry out the plan. The inputs of epidemiology modeling, simulation methods, supply chain processes, forecasting, and other methods are used in the planning process (Queiroz, M. et al 2020).

CDC (centers for disease control and prevention) for preparedness for influenza employed a forecasting tool; this tool can estimate commodities needs in the outbreak under different scenarios. Furthermore, many factors that can affect commodities quantity should be considered, such as; disease stages and cross-region, there is a variation in the supplies amount in the early and transition stage. Also, the demands are changed between regions according to demographic or geographic factors; on the

other hand, increased demands of critical supplies require to restock strategy and transportation mapping (John S, 2017). In addition, WHO adopted the COVID-19-ESFT forecasting tool is to help governments to estimate potential requirements for essential supplies to respond to the pandemic COVID19. “Essential supplies include, personal protective equipment, diagnostics, biomedical equipment for case management, drugs for supportive treatment, and consumable medical supplies. It is designed to proactively support decision-making and enable the rapid procurement of essential supplies (COVID, W 19. 2020)”.

2.7.4. Procurement and sourcing of emergency health commodities

Procurement and sourcing involve obtaining essential supplies from local and international suppliers in preparation for and during emergency response. Therefore, it is essential to know the source of critical commodities and suppliers before the outbreak; due to the broad of laboratory’s products, the long procedures for vendor selection, and suppliers qualification that can meet the of laboratories criteria for procurement agreements, pre-pandemic planning is necessary to identify first-line suppliers and to put the agreement in a place to obtain diagnostic and preventive resources, also ensuring the contract is comprehensive and includes all laboratories requirements, this will reduce lead time and trigger an emergency response at the onset of the outbreak (Okeagu, C. et al. 2020). In addition, supplier management, selection, and certifying concerns as vital steps before establishing agreements for an emergency; this means building a solid relationship with suppliers to improve product obtainability and reduce costs through sharing information with them about quantities prediction for an emergency, inventories levels, plan for the amount of supplies consumption, negotiate the cost, and other management practices. Therefore, WHO recommends evaluating and selecting certified and authorized suppliers (Duque-

Uribe, V., 2019). Furthermore, after suppliers' selection, a list of first-line suppliers and alternative ones should be created. Long-term agreements for emergencies are established as a preparedness plan for any threats to facilitate quick response and mobilize stockpiles from the warehouse or purchase new resources (USAID 2019).

On the other hand, diversification of suppliers is recommended by WHO to prevent a bottleneck that is due to increased demands in pandemic for essential supplies from different countries, also, reduce risks due to spread of infection and closure of some manufacture plants, which needs a long time for the production of reagents or assays and increase lead time. Therefore, it is preferable to move toward (plus-one) diversification, which means diverse investment in more than one country or company (Guiyang Zhu. et al. 2020). According to Black S et al., "researchers realize that robustness is essential in the supply chain" (Black, S., et al 2020). Robustness indicates to a diversification of suppliers rather than depending on one supplier as an alternative plan. Multiple supplies sources will mitigate the risk of commodities shortage that may result in a minor disturbance (Okeagu, C. et al. 2020). Professor Senthil Veeraraghavan of the Wharton School at the University of Pennsylvania asserts that having alternate suppliers improves long-term stability and mitigates the risk in a time of crisis like the COVID-19 pandemic. On the other hand, relying on limited suppliers in cost-effectiveness leads to adverse consequences during catastrophes. Notably, preparation of procurement agreement before pandemic has benefits in prioritizing the country in an emergency with an obligation with suppliers (USAID 2019).

Interestingly, local suppliers rely on local suppliers to provide critical resources, especially when there is a complete lockdown in leading supplies manufacturer countries, which will respond swiftly to essential laboratories supplies during crises.

In this regard, local suppliers can be used in the first phase of the outbreak or the short term, So, it is crucial to support domestic suppliers by governments through reducing obstacles and reducing facilities licensing and product cost also, and ensuring their qualification and the product's compliance to international standards through regular inspection, and maintain continuous evaluation and monitoring (Guiyang Zhu. et al. 2020; Patel, A. et al. 2017). On the other hand, international sources are preferable because they are less likely to experience interruption during the pandemic as they operate on a large scale and often do not face supply shortages. Notably, both local and international suppliers need pre-pandemic preparedness procurement agreements; this will lead to committing the supplier to provide resources according to the agreement (USAID 2019).

Procurement procedure in a pandemic is different from the routine situation since it needs rapid decisions based on the pre-defined suppliers, current supply chain capabilities, and pre-existence of a comprehensive agreement with suppliers, which includes all laboratories terms such as: (specifying transport methods, equipment's technical specification, identify potential risk, commodities shelf life, amount of critical supplies, total cost, installation and maintenance of essential equipment's, emphasis on staff training, availability of enough storage space to overcome increased demand or rent vendor warehouse), this will avoid supply chain bottleneck when the demands are enormous. Furthermore, regularly updating procurement agreements to fit the change.

Notably, most common practices have essential economic orientation such as; product standardization in all levels of laboratories will reduce item variety, which will help to get better prices and inventory reduction. Also, the use of a purchasing group benefits achieving more competitive prices and economies of scale. Moreover

finally, coordination and alliances with other hospitals impact reducing costs (Duque-Uribe et al. 2019).

2.7.5. Stockpiling

Stockpiling is a pre-purchase and store of emergency supplies will help in reserve for a short term in the event of an emergency. Laboratory ESC team should establish preparedness of stockpiling plan to have the essential supplies on hand for the initial phase of the pandemic; this strengthens laboratories capacity and enhances rapid response through access to critical supplies at times of an outbreak. The local stockpiling provides quick access to critical supplies, which needs the right leaders with expertise by monitoring the expiry dates, preventing product shortage, managing inventories, and considering demand (USAID 2019). It is vital to identify the strategic stock locations at the national level according to the geographic scattering of major public health threats (Okeagu, C. et al. 2020).

International stockpiling is cost-effective as they cater to many countries but may have barriers in terms of the travel time and import protocols (USAID 2018).

2.7.6. Emergency response for warehousing and storage

Before facing any kinds of threats, laboratories are prepared for infrastructure storage, to manage inventories of essential commodities through mapping existing storage infrastructure and creating a partnership. Factors that influence the location of warehouses in the country are; population distribution, quantity and volume of critical forecasting commodities, physical characteristics, infrastructure quality, and particular threats the country faced. In addition, the ESC team reviews the current warehouse situation to identify the capacity and removal of wastage, which is expired and undesirable (LOG, 2019). Notably, the ESC team must be trained before outbreak on the specifications of essential commodities such as; shelf life, volume, weight,

temperature, and demands. This will help the team manage and identify critical supplies' types and capacities (USAID 2018).

The country may need a central large warehouse, in addition to another large one in more than one location, and this depends on the position of health care facilities if they are found in rare areas or all in the hub of the country. The central warehouse should follow special criteria to be considered such as; its proximity to sea and airport, had highly skilled employees, had specialized services and information technology, closeness to the transport services (LOG 2019).

Types of the emergency warehouse could be either built or owned by the government as permanent stores, but this requires highly specialized stores of inventories management, highly skilled and trained personnel, identifying and management of physical space, assuming all costs and risk, establishing and complying with warehousing and stock management policies. The other type is commercial rented or leased warehousing space, which has benefited as a short-term solution or remotely managed facilities and can be used in an emergency, because of the permanent structure, equipment, advanced software, trained workers, and security all exist (LOG, 2019).

During a pandemic, if capacity in a warehouse is not sufficient, the government might extend through build or rent additional capacities that contain all laboratories supplies and human specimens (Okeagu, C. et al 2020). It is preferable to establish an agreement before pandemic with private sectors or partners and negotiate with them about the cost and the capacity of their warehouse (USAID 2018).

2.7.7. Transportation

Most of the countries experienced complete or partial lockdown in the pandemic, caused travel and shipment restrictions and closed borders, this led to escalation of

the cost of medical raw materials and goods that transfer from original manufacturers to providers, also, lead to increased transportation costs (Mikic.,et al 2020). Transportation is depending mainly on Pre-planning and liaising with customs officials, transporters, early transportation mapping across borders or inside countries, and identifying transport mechanisms and routes this will avoid wastage of laboratories supplies due to improper handling during delivery, reduce the lead time in an emergency, and minimize portage cost. In addition, environmental factors should be considered during pre-planning, which comprises, weather and road conditions and political factors, which may also primarily affect transport efficiency (Okeagu, C. et al 2020).

Pre-pandemic identifying of suppliers' logistic capabilities will help the ESC team to determine the vendors that can deliver laboratories supplies to the hospital warehouse or they need third parties for transportation. Also, an updated list of logistic providers and types of vehicles that will deliver supplies for each region in the countries is crucial in mobilizing these vehicles in the emergency. Therefore, establishing pre-pandemic contracts for transportation and determining the routes of delivery is an important step in emergency preparedness. Furthermore, it is better to use national and international joint transportation services as a strategy in emergencies, which is based on a collaborative approach. It aims to take advantage of centralized coordination as sharing assets will reduce transportation complexity during the nature of an emergency.

2.7.8. Logistic Management Information System (LMISs)

Digitalization is a part of formal organizational culture for problem-solving. It's a comprehensive wide of supply chain effort that needs planning and executing regularly and over time (Black. S, .2020). Sharing information in supply chain

networks is one of the proactive ways to mitigate pandemic risk and disruption, it also provides forecasting and order response for short term product life cycles to prevent stock-outs, and similarly, LMISs prevent overstock or accumulation of inventories due to uncertainty through better visibility along the supply chain (Tang, 2006; Lee et al., 1997). Improve communication between parties involved in SCM leads to standardization of medical regulations and reduces the time taken to register vital supplies (Okeagu, C. et al 2020). To get benefit and swift response in emergency, data visibility system must reach the following purpose; monitor stock levels at national, regional, and subnational levels, regulate the push time to downstream and control the amount to re-order the commodities (USAID 2018). LMIS is a promising solution for supply chain management, and have beneficial effects in outbreak through quick response to the shortage, but it needs comprehensive preparation before the pandemic since it needs long procedures to be adopted. There are many considerations LESC team should follow for planning before an emergency; they should ensure all the quantity, specification, and suppliers' information of the critical resources were uploaded on the system, ensure lead time for each supplier is also in the system, ensure the information system is connected to all warehouses in the country, the concerned employee is trained well on the LMIS. These protocols will facilitate the timely response for emergencies and track any shortage of resources, and allow replenishment of the stock of these supplies (USAID 2018).

2.7.9. Waste management

Waste management requires establishing plans for disposing off contaminated resources in a safe way during an epidemic or pandemic, these needs creating specific protocols to be categorized for the resources according to their hazards and the disposal process for each type. The safe disposal of laboratories waste is one of the

main pillars of infection control, and it is vital for pandemic containment. Waste management aims to convert all medical hazards to non-infectious. It's important to provide laboratories and SCM staff extensive training on how to deal with waste, because it's extremely risky, and needs wearing PPE, it also requires disposal facilities and specific equipment to ensure the safety of the public and its staff. The waste generated by healthcare activities amounts to 85% as general non-hazardous waste whereas the remaining 15% is hazardous waste.

Under the COVID-19 pandemic, detailed knowledge and precautions, and management practices are needed at the national level. As a result, proper waste management in healthcare must be based on the 3R principles (Reduce, Reuse, and Recycle). According to the waste management hierarchy, the better practice of healthcare waste management initially should aim to avoid or recover as much of the waste as possible, rather than disposing of it by burning or burial.

"Collaboration and interaction at all levels are needed for successful healthcare waste management. An effective healthcare waste management system requires the establishment of a national policy and legal structure, as well as staff training, public awareness-raising through e-workshops, symposiums, and conferences, and funding for local entrepreneurs to come up with creative ideas (USAID 2018)".

Industrial waste, on the other hand, was dramatically reduced during the pandemic, especially in developing countries. According to NASA satellite images, "there was a positive decrease in air pollution as a result of the quarantine orders. As a result, there are benefits and drawbacks, but countries should strive to reduce their negative effects on environmental protection in any case".

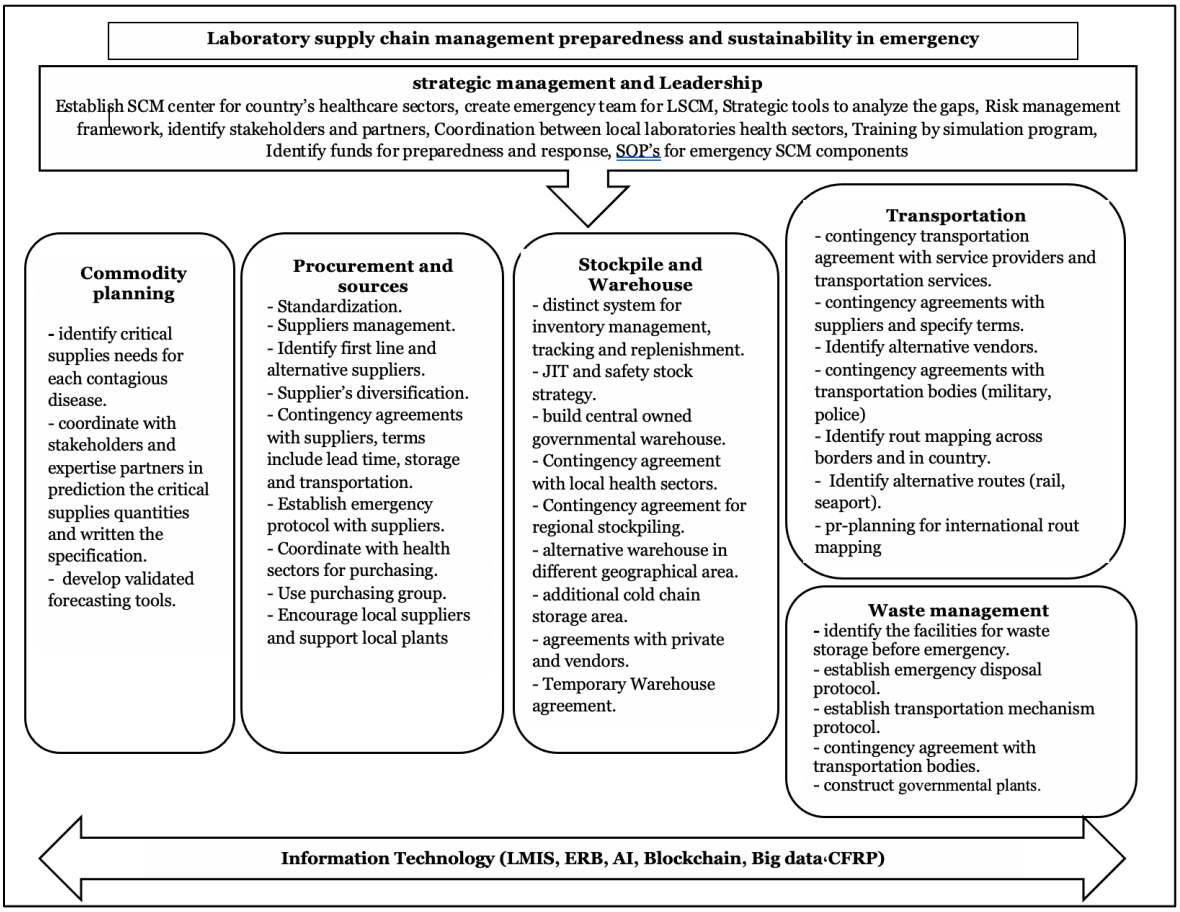


Figure 1: laboratory supply chain management preparedness in emergency
Sourced by Author

2.8. Role of medical laboratories in HMC (Department of Laboratory Medicine and Pathology (DLMP) in Qatar

DLMP is a semi-governmental nonprofit laboratory; its vision is to achieve the highest levels of laboratory medicine in Quality, Advances, Teamwork, Accomplishment, and Research. Their mission is to be the leader in laboratory medicine. Their strength, they are the reference laboratory in Qatar; all samples from government and semi-government health sectors are referral to DLMP. It includes 11 satellite rapid response laboratories distributed in all Qatar geographical areas and covers the rural area. The central hub of DLMP has a complete services laboratory, which offers a collection service and comprehensive test menu in chemistry,

hematology virology, blood pathology, and other specialist services. In addition, they have Rapid Response Laboratories (RRL) that operate in acute care hospitals and provide collection services for inpatients and outpatients and limited on-site laboratory testing; the non-urgent and specialized specimens are transferred to the nearest hub for testing. They have a robust infrastructure that includes highly sophisticated equipment, and state of the art clinical laboratory specialties, standardization and harmonization of policies and procedures along laboratories in all geographical areas give their strength, they sharing information by evolved IT, and consultation on the manager level, they integrate into all administrative activities and supply chain management in policies and procedures. Hence, they work as one huge institution. DLMP is under the umbrella of the leading supply chain department, so all laboratories' commodities are managed through this department. SCM of HMC has a robust infrastructure, high transparency between HMC departments and suppliers. This enhances the communication between them and has flexibility with all HMCs departments; this helped them quickly respond in the first pandemic phase, therefore resilience and rapid recovery to any threats. Also, SCM has a core committee of key members including; administrative lead, procurement lead, forecasting lead, warehouse management lead, laboratory lead, and medical lead; all the information is shared between this committee, then the decisions are released to be executed by SCM sections. SCM has robust business continuity plans to ensure all services remain operational in the threats.

2.9. Role of Supply chain management (SCM) in HMC laboratories in response to COVID 19 in Qatar

Qatar's government responded to COVID 19 pandemic in a timely and powerful way by mobilizing healthcare resources to prevent shortages across the country and lower

mortality rates. However, during the first phase of the pandemic, the rapid spread of virus and increased infections cases in Qatar, SCM of HMC experienced a shortage in critical demands in the first phase of the epidemic, which includes preventive resources, which used to protect personnel in laboratories against COVID19 like PPE's and N95 mask, nasopharyngeal swab was also in short supply, and a major problem was the availability of testing kit used to diagnose the expected cases such as; rapid test, and reagents for RT-PCR and its consumables that under manufacture research and evolving because of virus nature uncertainty.

The routine supply chain management was temporarily disturbed as consequences of complete countries borders lockdown, and restriction of movement through airport and seaport such as; Germany, US, China and UK that export these essential supplies to the worlds, and massive compressed to some countries to increase their productivity to meet increased in demands and export to the countries, like China (The Economic Times, 2020b).which overloaded the healthcare system in the country within few weeks.

After hazards assessment, SCM has a business continuity plan by mobilizing all laboratories' resources, including man power, supplies, equipment, funds, spaces, and transportation, to overcome this surge in laboratories capacity and prioritizing COVID 19 supplies to prevent the increase in mortality rate. Also, the SCM alert and communicate with all suppliers to prioritize Qatar HMC laboratories on the world list to provide critical resources. On the other hand, SCM responds to increased demands by opening new channels with different countries to feed critical diagnostic and preventive laboratory resources (China, Turkey). In addition, a combination of efforts of all governmental health sectors to provide and mobilize all critical resources to contain the virus and ensure public safety, including HMC hospital, Military Clinic,

Police Clinic, Primary Health Care Center, led to a swift recovery in the first phase of pandemic facilitate quick recovery from the country epidemic with low mortality rate.

On the other hand, SCM has a strategy of Just in Time and safety stock that assists in keeping on hand stock for 3 months this helped DLMP use this stock in the short moment until replenishment from suppliers.

Based on WHO modelling approximately 89 million of medical masks are required per month for fighting COVID-19. The number goes up to 76 million for examination gloves, while external demand for goggles is 1.6 million a month (WHO, 2020) (64). With the development of pandemics over time, SCM has gradually recovered. On the second wave, and by the end of the year, overall SCM in HMC capabilities reached 90% compared to the onset of the pandemic. Since August 2021 routine healthcare services and SCM were officially resumed in HMC.

2.10. Challenges faced SCM and medical Laboratories in response to COVID19 in Qatar

The HMC laboratories faced some obstacles during a pandemic. First, for the diagnosed COVID19 population, DLMP employed the in-house method recommended by WHO to replace PCR reagents because there is increased countries' demand for COVID19 diagnostic tests, and manufacturers prioritized high-risk countries to acquire these assays. However, in house method is a lengthy procedure and needs effort and time. Also, it tests small numbers of the population since the cases were increased in the first phase. Hence, they searched for a more appropriate method, and they found the USA semi-automated method for the short term, also it is limited to the USA population as they have the highest mortality rate in the world and experienced supplies shortage. Therefore, this method is discontinued in Qatar.

Finally, they reached PCR assays that can test many populations that transfer to Qatar through corporation and good relationship with Qatar petroleum and Qatar airways. Therefore, they facilitated the transfer and delivery of supplies to HMC supply chain management and laboratories.

On the other hand, DLMP is highly evolved and has sophisticated equipment and facilities. However, it is not proportioned to increase demand for population test in disasters, because it's small facilities and allocated only for patients, So DLMP has limited infrastructure for increased country capacities. They experienced high COVID19 diagnosis, especially for construction groups who came to Qatar to build stadiums and other facilities that help to encage significant events in Qatar. DLMP overcame these issues by allocating three laboratories to meet increased tests demand COVID19 (CDC laboratory, HGH laboratory, and Alkhore laboratory), So DLMP put an alternative plan for business continuity and surge their capacity through using another facility in an emergency. Interestingly, MOPH planned to have a vast reference national laboratory in Qatar concerned with public health, and it is under construction; this laboratory is concerned with public health and will serve Qatar in any emergency and significant events.

Finally, in addition to previous barriers, the absenteeism caused by staff sickness and quarantine caused a severe shortage of trained expert staff, especially for COVID19 diagnosis and prevention.

3. CHAPTER THREE: METHODOLOGY

3.1. Description of the Study Area

Hamad General Hospital was authorized in 1982, and since then, it has gained an international reputation as a teaching and referral center. It is certified by the American Hospital Association and provides medical and surgical sub-specialties to a population of more than 600,000 people. The facility has a capacity of approximately 660 beds and utilizes the most state-of-the-art medical and surgical equipment to keep current with the rapid new development in medicine.

Hamad Medical Corporation's Department of Laboratory Medicine and Pathology (DLMP) is certified by the College of American and Pathology CAP accreditation and has performed over 20 million tests in 2019, providing a comprehensive range of specialized laboratory services for the people in Qatar. Department of Laboratory Medicine and Pathology DLMP serves the patients of HMC and provides referral services to several other entities across Qatar, including the military, police, embassies, private hospitals, and Primary Health Care Corporation (PHCC).

3.2. Research Approach

The qualitative research approach was applied. The data was gathered through observation and interviews with key persons.

3.3. Research Design

A descriptive study design was used to assess the preparedness of the supply chain management department in Hamad Medical Corporation in an emergency, which is considered the leading supplier of all laboratory's commodities in HMC.

Starting from 2nd of February 2021 until 18 April 2021, a comprehensive interview was conducted with key persons in different sections of the SCM department, the executive assistant manager, SCM division manager, warehouse and transportation

officer, inventory management manager, and laboratories SCM coordinator, Vice Chairman of operation for Department of Laboratory Medicine and Pathology (DLMP) and Director to the Quality Management. These persons are responsible for managing the logistic system and providing supplies for all HMC laboratories. The information was collected through guided discussions which aimed to elicit information's exchanges between the evaluator and critical persons to review the laboratories supply chain preparedness protocols and procedures and to assess the functionality of the Supply Chain Management SCM in an emergency in health systems focusing on the laboratories and their resilience to threat and future pandemic. The collected information's was assisted in analyzing the current situation of SCM for its capability to provisions of laboratories resources by used SWOT analysis (APPENDIX 3), which is a strategic tool to investigate the strength, weakness, opportunity, and threats, the analysis was conducted during interviews with key persons.

On the other hand, the collected data was used in the interview to fulfil the requirements of the modified WHO checklist for H1N1influenza virus in 2009 (WHO 2009), this checklist also employed in COVID19 pandemic. According to the importance of SCM in laboratories, country's policies, standards and practices, and COVID19 risk assessment in Qatar, the checklist was modified accordingly. This checklist is revised and approved by MOPH and QU teams, which includes; Associated Professor in Biomedical Sciences in Qatar University, Professionals from Health Protection and Communicable Disease Department in Ministry of Public Health in Qatar, and a member from General Directorate of Emergency and Epidemic Controlled from Federal Ministry of Health in Sudan.

The checklist demonstrates laboratories' supply chain management preparedness

protocols and procedures on six key components: 1. Governance, financial, IT system, and personnel, 2. Commodities planning, 3. Procurements and sourcing, 4. Stockpiling and warehouse management, 5. Transportation and customs, and finally 6. Waste Management. Each component considers as a domain and subdivided into several objectives or activities.

3.4. Population and Sample

Population: the source of the population of this study was the critical preventive and diagnostic resources used in virology laboratory, a section from DLMP in HMC, which is considered the reference clinical laboratories in Qatar, whereas samples from government and semi-government health sectors are referral to this laboratory, it is a central hub for COVID 19 diagnosis. In addition, to this laboratory, the resources used in the Communicable Disease Center (CDC) laboratories and other laboratories, such as, Alwakra, Alkhor, and Cuban hospital, that serves as supply backup for the leading laboratory during surge capacity and to ensure the continuity of work during an emergency. Therefore, the total number of tested people from the onset of the pandemic to 17 of October 2021 is 2,756,985. This number is relevant to the number of reagents (diagnostic resources) and the supply chain department's consumables during the pandemic.

3.5. Data Sources and Types

The study relied on both primary and secondary data. Qualitative data is collected through modified WHO 2009 and WHO 2020 checklists. The Key personnel interview of laboratory logistics coordinator, laboratory professional, and supply chain department key persons served as a primary source of data were covered in the checklist assessment covered qualitative data. Using other documents provided by the laboratory logistic coordinator and published relevant articles were considered

secondary sources of data.

3.5.1. Qualitative Data

A one-to-one interview was guided to fulfill the checklist and collect qualitative data. First, the interviews were communicated and arranged at a convenient place and time for the interview. During the interview, the aims and purpose of the study were described and explained, and the questions were clarified. Before the interview was initiated, they were informed of the recording and getting their consent.

3.6. Ethical Consideration

The HMC board review approved the research as a quality improvement study appendix 1. There is a high degree of confidentiality during data collection, and no name of any participants was added in the result instead of the collected result.

3.7. Data Analysis

The checklist uses color-coded rating to assess the activities in each component, which is similarly used by WHO 2020 readiness checklist. The analysis of data relied on the WHO scoring system (World Health Organization, 2009; WHO 2020). The scores were rated as 0 to 3.

(Score 0, Not started) mean the component have not started or do not exist; (score 1, in progress) mean the component are planed but not functioning (Score 2, Intermediate progress) the components planned but with inadequate evidence of functionality; (Score 3, Completed) evidence of fully functional activities and readiness for the pandemic. Each component's readiness and completion were assessed on the level of planning existence, functioning, and evidence of its implementation (planning measures, updated documentation, and process improvement). See Appendix 2

4. CHAPTER FOUR: RESULTS

This chapter presents the result analysis as per data collected from interviews with key persons in SCM department and HMC laboratory department. The first objective of the study is investigating the laboratory preparedness for the emergency, in the supply chain management aspect, through assessed six components of emergency supply chain management, which includes; governance, personnel, and finance; commodity planning; procurement and sources; stockpile and warehouse, transportation and custom, and finally waste management. These components assessed the capability and preparedness of laboratories and SCM for disasters through the extent of predicting and provisions essential resources in an emergency, managing purchasing and suppliers, maintaining enough on-hand stock, preparing warehouse for supplies storage, route mapping for transportation of supplies, waste handling and disposing of, and preparation of robust information technology infrastructure. Each component in emergency supply chain management was breakdown into activities and practices that should be prepared, planned, implemented, and reviewed before country's faced any threats. It is evaluated according to the accomplishment of these activities to assess the preparedness extent for an emergency. The components and activities were organized in the established checklist (Appendix 2) created by the author and reviewed by the MOPH team and project supervisor. It is obtained and modified from the WHO checklist for H1N1 and WHO checklist for COVID 19 readiness.

4.1. Domain 1: Governance, personnel, and financial

It is the first component of emergency supply chain management. It concerns a financial reserving for an emergency and the coordination between SCM in the local, regional, and international levels to assist in personnel, physical and financial resources, and personnel management in the emergency.

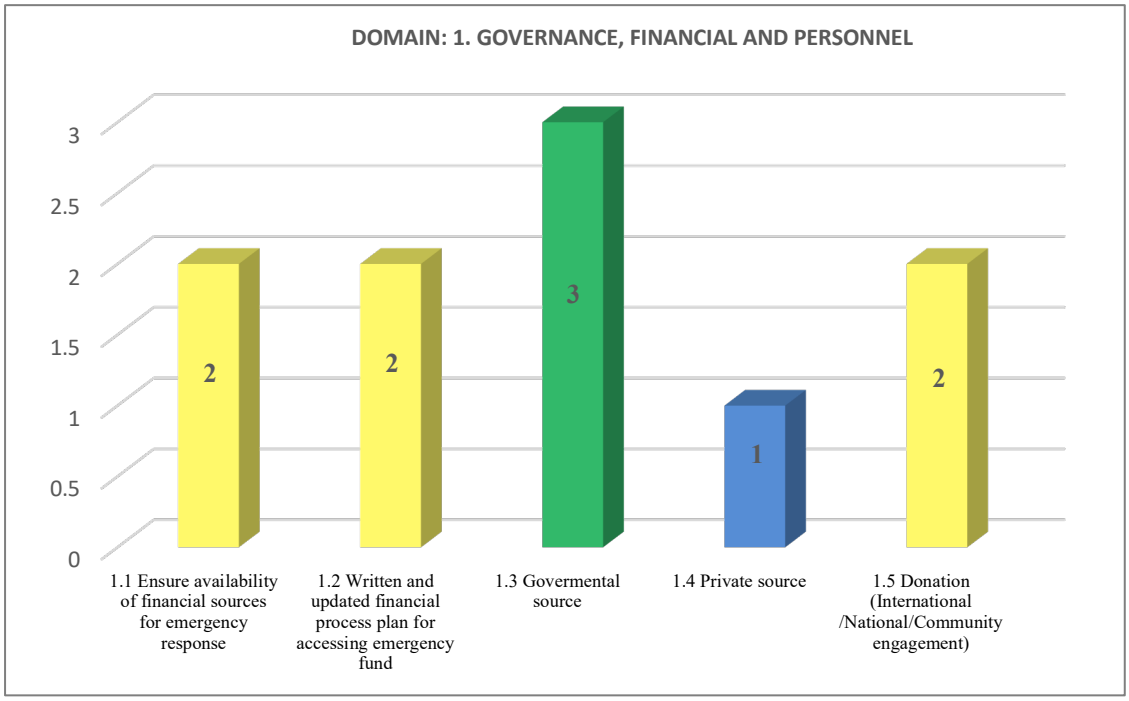


Figure 2: preparedness plan for financial types and sources

Figure 2 shows a preparedness plan for reserving funds in emergencies, this activity had received score of 2, which means that most of this fund is from the preparedness budget that incorporated with routine supply chain funds. As shown in figure 2, the major resource of funds was from the government source. Also, Financial processes and procedures was documented, but they require to be updated regularly.

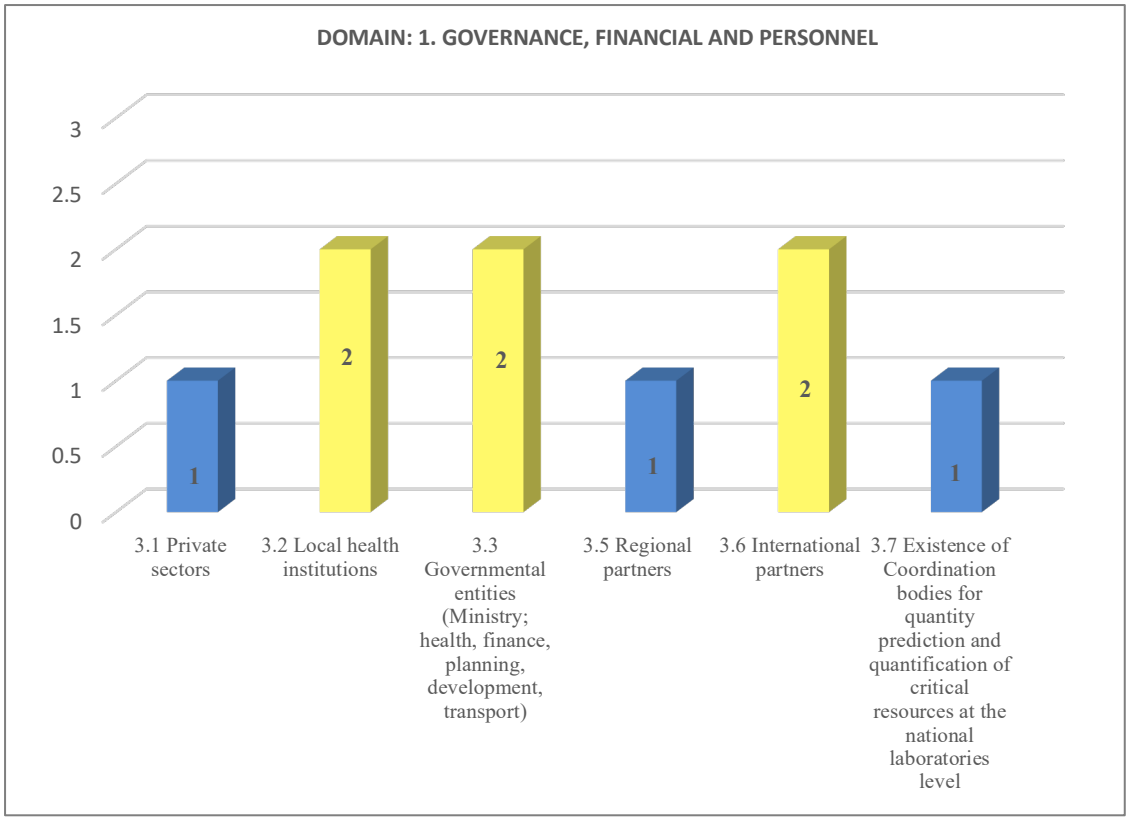


Figure 3: Coordination of SCM regional and long-term contingency agreement.

Figure 3 shows the coordination approaches and long-term contingency agreement between all health sectors locally, regionally, and internationally regarding providing supplies during an emergency when there is a shortage in critical resources. Coordination between governmental entities had a score of 2 which means there is planning and preparation for coordination in emergency. It will be effective and fully functioning through establishing a long-term agreement for emergencies and enhanced through simulation training between all health sectors. On the other hand, the coordination between private, regional (GCC), and international suppliers as international partners or WHO had the lowest score of 1, which means it needs to be considered an improvement. Also, it shows the lowest activity in the commodity planning component, which concerns the existence of coordination bodies for quantity prediction and quantification of critical resources at the national laboratories level.

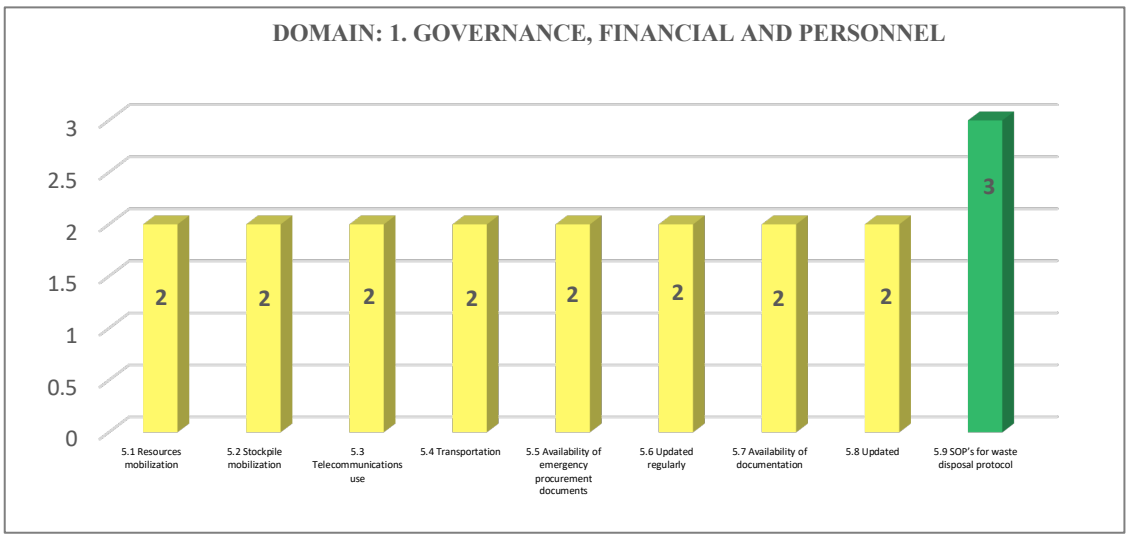


Figure 4 :SOP's for emergency SCM components.

Figure 4 shows the availability of written documents for all logistic components, including (stockpile mobilization, telecommunications use, transportation, resources mobilization, security management), and ensures that it has been reviewed and implemented. This activity had a score of 2, which means all the documents were available and implemented, but it needs to be updated regularly and employee training on these activities.

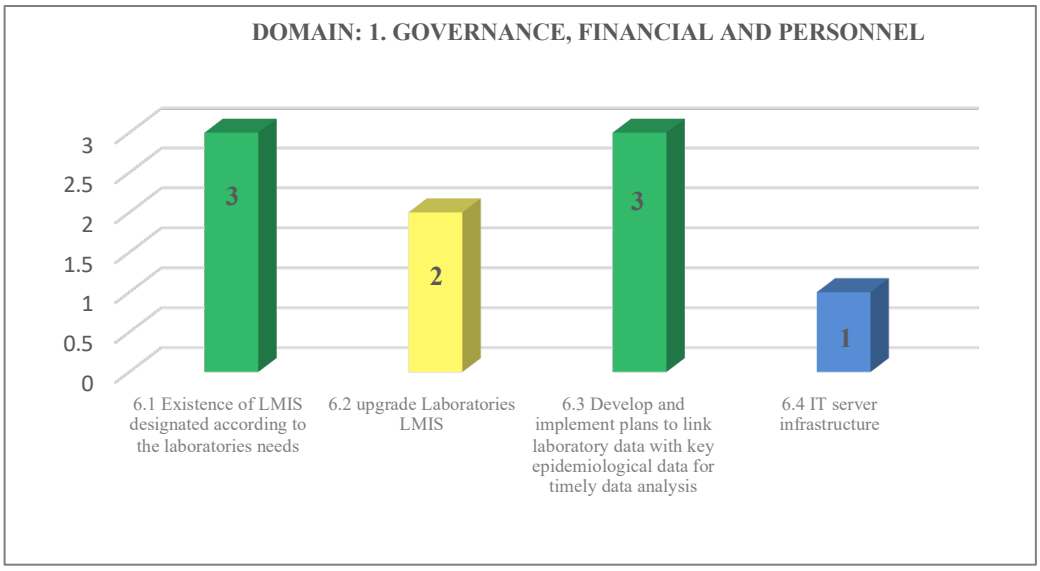


Figure 5: Existence of laboratories SC Information technology and IT infrastructure

Information technology activity in **Figure 5** has a score of 3, which means SCM has a logistic Management Information System (LMIS) that manages all kinds of resources in laboratories in routine and emergency. However, this system needs to be upgraded to fulfill suppliers' management and communicate all health sectors to main supply chain center that facilitates transparency along the supply chain in health sectors. On the other hand, the activity that received the lowest score was the established robust infrastructure (big data, blockchain, Artificial Intelligence) connecting all health sectors and adopting promising future solutions.

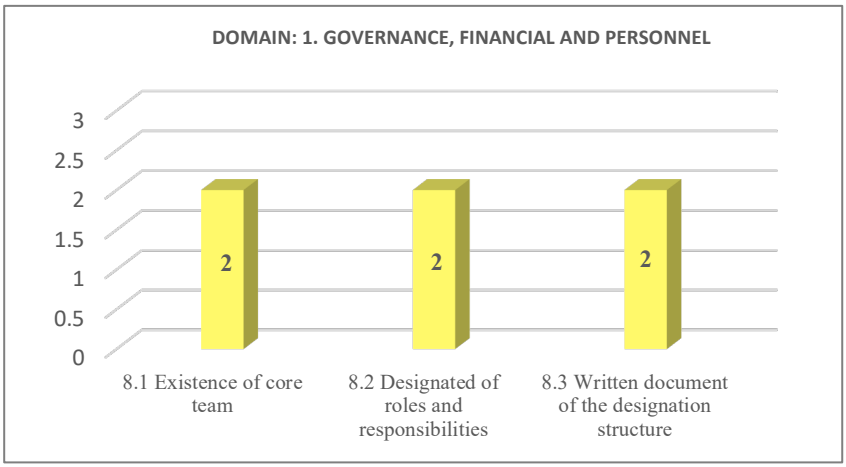


Figure 6: Designation of SCM core team

Activities in **Figure 6** concern the existence of emergency team specified for carrying all supply chain practices in laboratories, including different disciplines from different health sectors; their roles and responsibilities should be identified and written. This activity had a score of 2, which means there is a defined team for supply chain of laboratories; the study assesses the existence of a designated emergency team before the disaster and should be prepared and equipped with all kinds of scenarios to facilitate rapid response in an emergency.

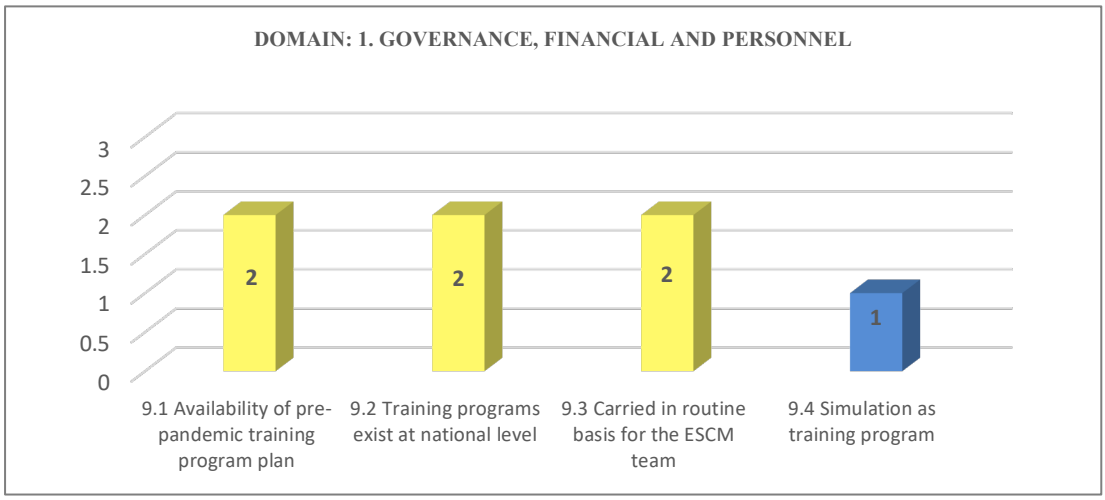


Figure 7: Preparedness plan for developing and training Core team and stakeholders

Figure 7 shows an emergency training program (simulation) should be conducted annually and includes all key stakeholders and partners in SCM in the country's health sectors, the program is essential in disaster readiness, this activity received a score of 2, and the lowest score was simulation program, which needs to be considered in future threats preparedness.

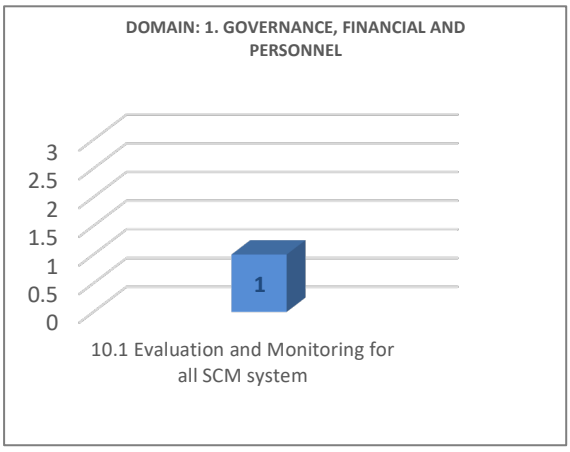


Figure 8: Monitoring and evaluation system for planned measured

Figure 8 shows the establishment of Key Performance Indicators (KPIs) for annual monitoring and evaluating the SCM system plan. Also, assessing KPIs' analysis and incorporating the findings in the conclusion report, the gaps are documented and lessons learned for ongoing response and intervention. These activities received the lowest score of 1 and need improvement for future threats.

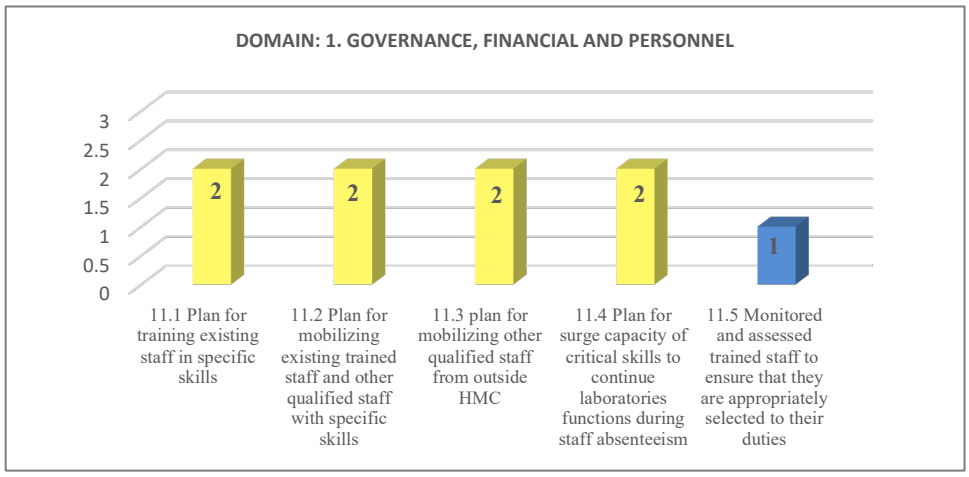


Figure 9: Human resources management

Figure 9 shows the preparedness plan for laboratories' human resource management in an emergency to ensure adequate staff capacity and continuity of operations. It includes; the availability of trained staff to perform lab tests and a plan to mobilize trained staff from HMC and the country's health sectors. These activities had a score of 2, and the lowest rate was in monitoring and assessing trained staff to ensure that they were appropriately selected for their duties.

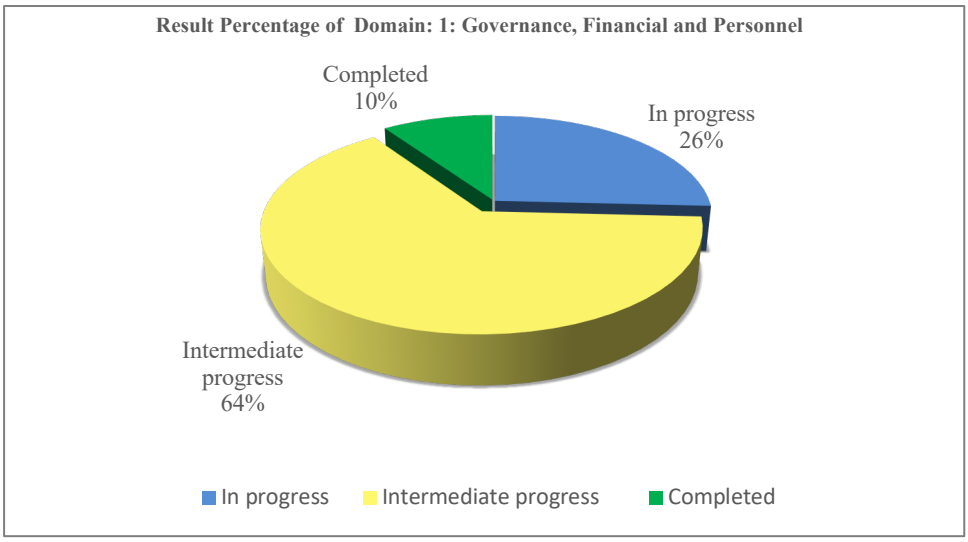


Figure 10: Result Percentage of Domain: 1: Governance, Financial and Personnel

Summary of Governance, personnel and Finance domain 1:

activities in domain 1 have 64% intermediate progress that received score 2, which means there was preparedness plan for financial resources, and continuity plan for personnel management, availability of logistic documents, existence of logistic information system, on the other hand, there is a need of progression on the coordination activities, emergency training programs (simulation), establishes KPI's indicators for planning assessments, and construct robust IT infrastructure to connect all health sectors, these activities have 26% of progression in preparedness planning and needs improvements.

4.2. Domain 2: Commodities planning

This component concerns identifying the type of laboratory critical resources by creating a comprehensive list of supplies and their consumables, quantifying the estimated

amount through forecasting methods, and writing the specification of each contagious disease supply, which should be updated regularly.

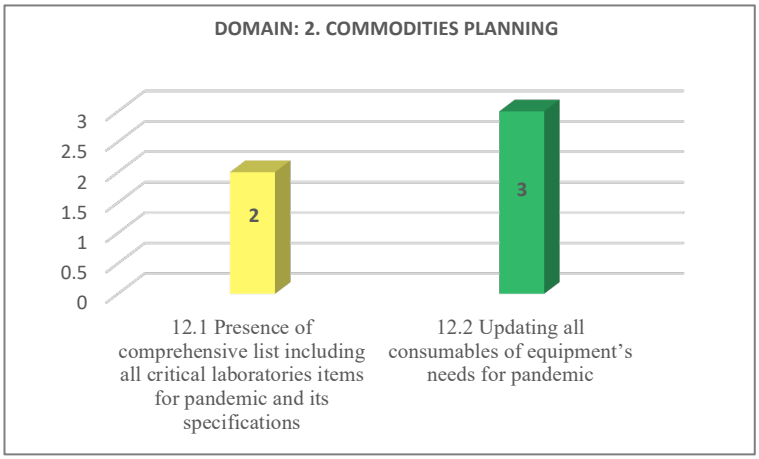


Figure 11: Commodities identification

The activity received a score of 2 in **Figure 11**, which means that laboratories have identified all supplies requirements, but the list needs to identify each contagious disease resource. The highest rating was updating all equipment's list and its consumables used in the pandemic.

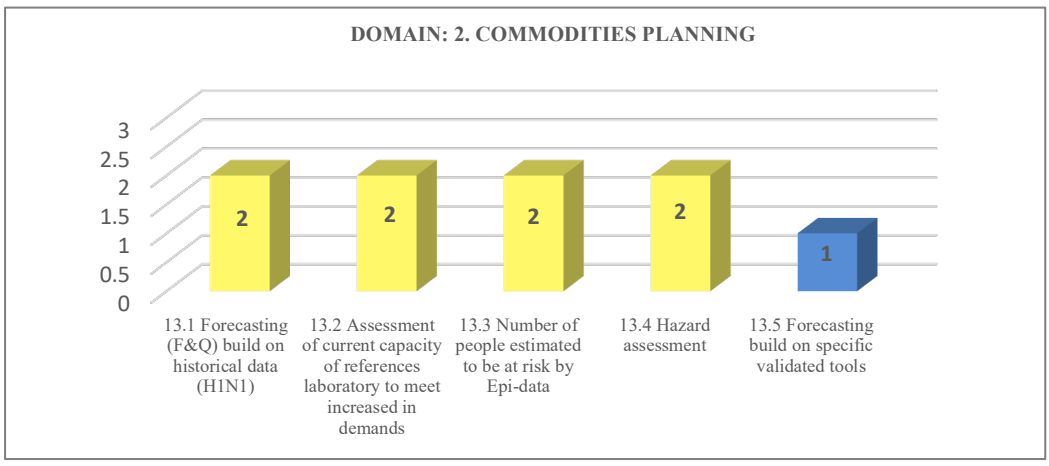


Figure 12: Kinds of methods for Quantity forecasting

Figure 12 shows a kind of forecasting method that predicts the number of critical supplies in an emergency, and this activity should be achieved before a pandemic to facilitate the procurement process in an emergency. Most activities in this graph had a score of 2, which means the laboratories has business continuity plan for commodities planning through used forecasting methods in supply chain management relied on the history date for three months, hazards assessment, epidemiological data, and reference laboratory capacity. The lowest score practice was the forecasting methods or tools used to predict the precise quantities, which is more effective.

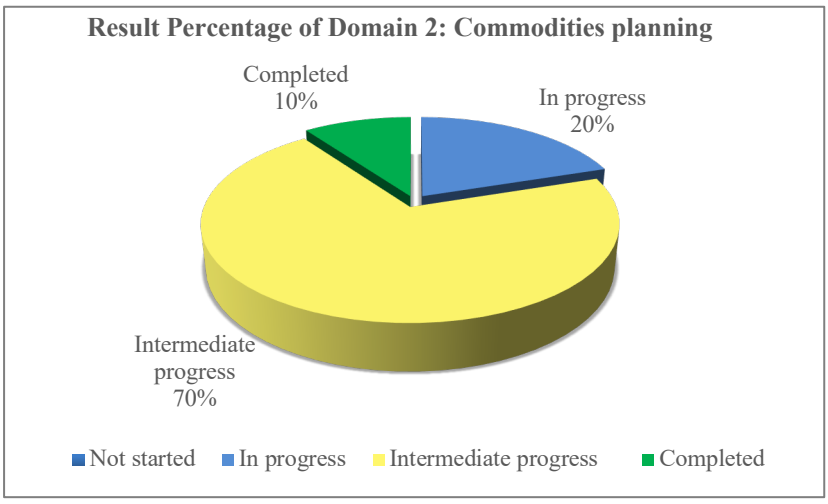


Figure 13: Result Percentage of Domain: 2: Commodities planning

Summary of commodity planning domain 2:

Figure 13 shows the total percentage of commodities planning on the domain 2, that most of activities on domain 2 have intermediate progression 70%, this means that there was business continuity plan through preparing list for all laboratories commodities and equipment's, most of quantities prediction was relied on the history data for 3 months

and epidemiological data at first phase of pandemic. However, having list of critical resources specified for each contagious disease and estimate the quantities for these supplies by using validated forecasting methods considers point for lesson learned and it's under progression that has 20% of preparedness.

4.3. Domain 3: Procurement and sourcing

This component is looking to prepare a list of evaluated suppliers that will provide critical laboratories supplies in an emergency, establish long-term contingency procurement agreements with suppliers, and the availability of written and review agreement. The contract terms should include timing, storage, transport, and payment. Finally, emergency response protocol should be written and reviewed.

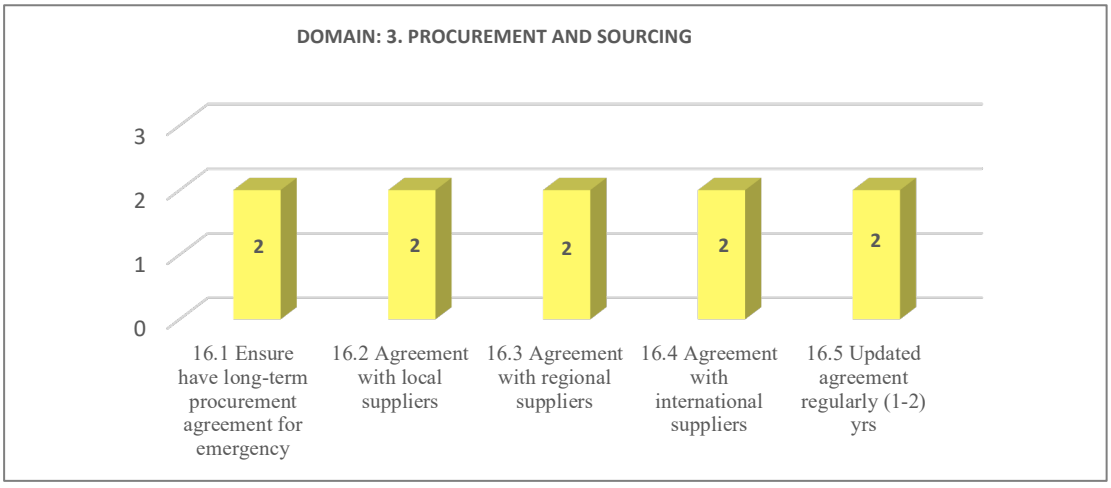


Figure 14: Pre-pandemic agreement with suppliers

The activities in **Figure 14** show the establishment of the long-term contingency agreement with regional and international suppliers for laboratory commodities acquisitions and identifies all terms of emergency, these activities have score of 2, which

indicates a partially achieved activity, while creating an emergency contract with suppliers rather than an ordinary one. In addition, the activity that received the lowest scores was establishing agreements with regional suppliers. Therefore, this activity should be considered in the preparedness plan for a future pandemic. Also, focusing on local suppliers will assist in rapid response to any new threats.

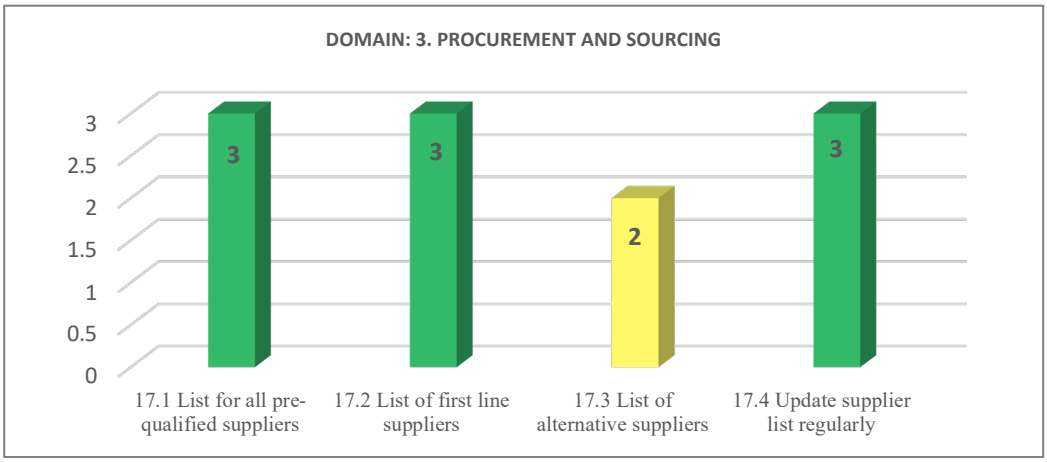


Figure 15: Pre-pandemic identifying a Pre-qualification Suppliers

Figure 15 shows a Pre-pandemic plan to identify a list of pre-qualified suppliers that will provide laboratories commodities in an emergency, receiving the highest score in this component. The activity that needs a future plan is to broaden the sources of essential supplies through diversification of suppliers rather than depending on one supplier as an alternative plan.

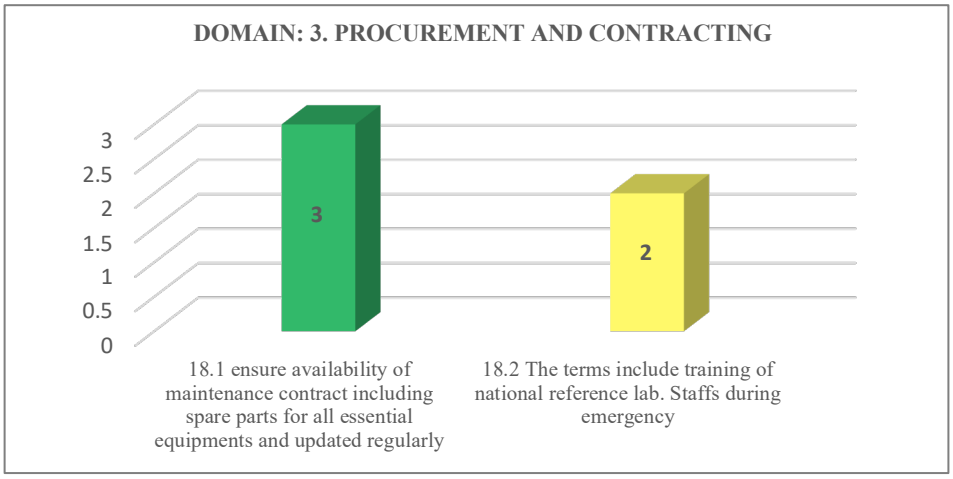


Figure 16: equipment's maintenance contract

Figure 16 shows the highest rate in laboratory equipment preparation activities with a score of 3, through put on long-term agreement of maintenance contract that ensures high equipment's performance in an emergency. However, training and preparation of all reference laboratories staff on these equipment's a preparedness plan that should be consider in future.

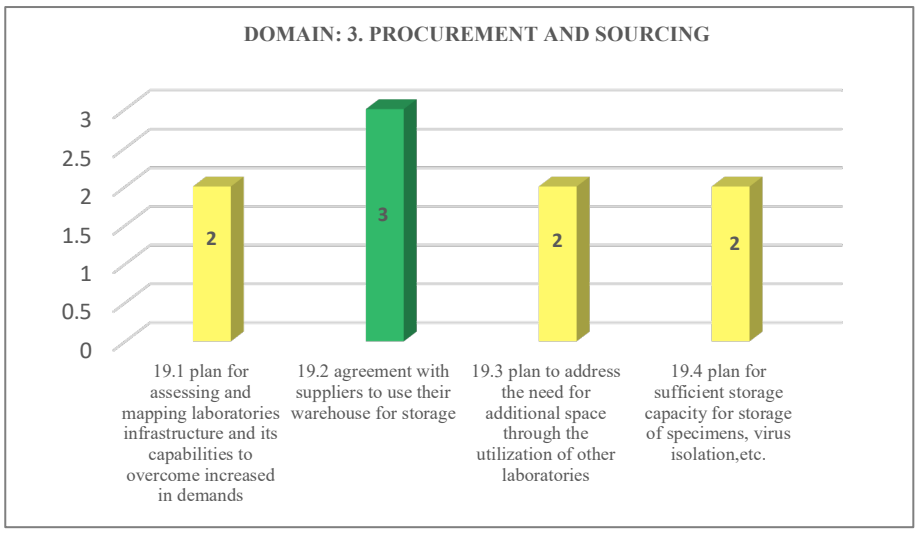


Figure 17: Assessing physical and environmental infrastructure before procuring supplies

The activities in **Figure 17** concern assessing facilities' infrastructure before procuring commodities proceed or negotiating with suppliers to utilize their facilities in an emergency. The highest rating was for cooperation with suppliers to use their warehouse for laboratories supplies storage. On the other hand, infrastructure evaluation and putting plans for additional spaces, plan for sufficient storage capacity before procurement, and the availability of emergency procurement documents, these activities had received scores of 2, which means they need to be prepared in plan and implemented for a future pandemic.

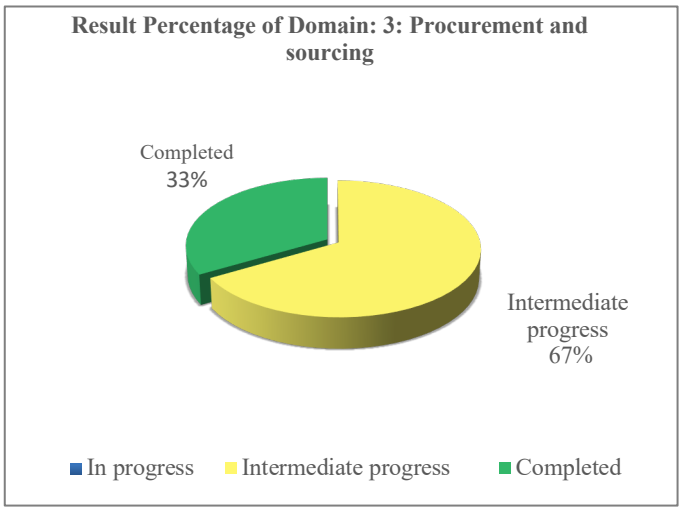


Figure 18: Result Percentage of Domain: 3: Procurement and contracting

Summary of procurement and sourcing domain 3:

Most of activities on this domain received 67% of preparedness plan, this percentage demonstrates contingency agreements with suppliers to ensure their commitments in commodities provisions and storage during surge in capacities, also this percentage

express the preparedness plan for equipment's maintenance contracts, and identifying the first line, alternative, and local suppliers through prepare lists before pandemic and evaluate their capabilities to provisions of resources in emergency, furthermore assessing laboratories infrastructure before procurement includes in this percentage. On the other hand, these activities need improvement to ensure complete functioning of the plan.

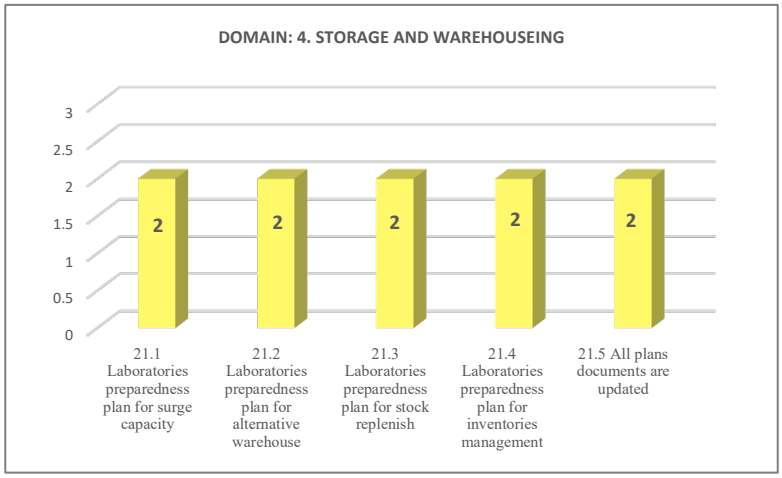


Figure 19: Pre-pandemic plan for laboratories warehouse management

The activities in **Figure 19** received the same score, which is 2. This means there is preparedness in warehouse management for laboratories through applied business continuity plan in inventory management by replenishing the stock at the onset of a pandemic and using an alternative warehouse in an extended HMC branch. From these findings, the inventory management needs to increase safety stock to 6 months to prevent shortages when the demands increase. On the other hand, finding a warehouse with huge capacity and alternative to the main HMC warehouse, considered an essential improvement in future planning.

4.4. Domain 4: Storage and Warehouse

The component attentions with the establish of laboratories warehouses contingency plan and strategy for warehouse management during pandemic, this component divided into activities includes; surge warehouse capacity, inventory management, alternative warehouses, agreements for emergency.

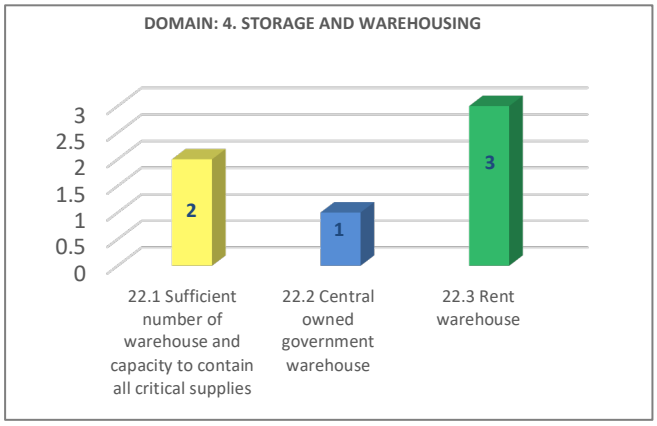


Figure 20: Numbers and kinds of warehouse for pandemic

The highest rate in **Figure 20** was for the activity of rent warehouse than a governmental warehouse. However, the lowest rate was for owned governmental warehouses. Therefore, building or owning government warehouses as permanent stores coordinating the country's health sectors will be crucial steps for future preparedness. Although, on the other hand, there is a need to increase warehouse numbers to ensure its sufficient during a considerable surge in demands and meet the forecasting of essential commodities quantities, this activity had a score of 2 in rating.

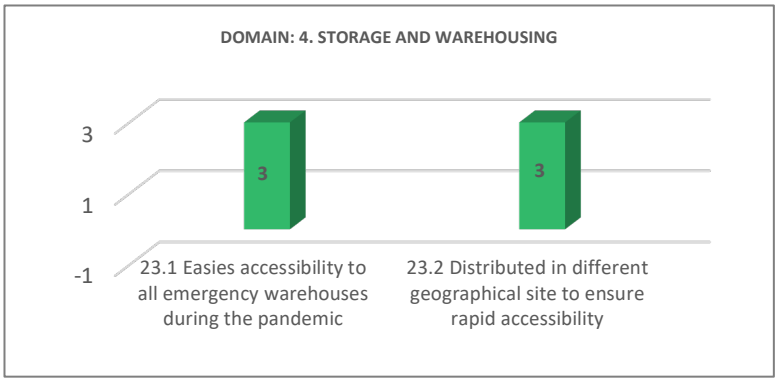


Figure 21: Warehouse location

Figure 21 shows the completion of activities, which concerns the existence of an alternative warehouse and its distribution to the different geographical areas and access to the laboratories' staff.

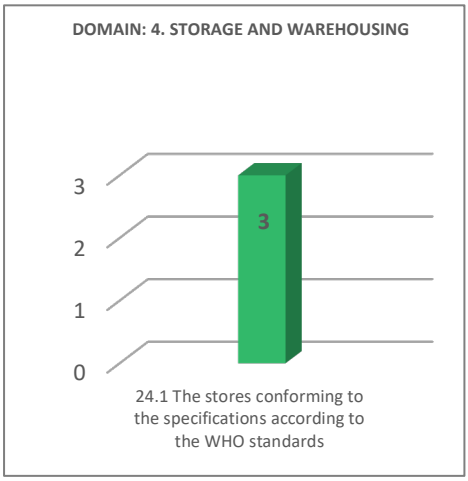


Figure 22: Warehouse environmental condition

Figure 22 shows warehouse environmental conditions conforming to the international standards (accessibility, security, ambient temperature, ventilation, light exposure,

humidity), and it is suitable for critical commodities storage; this activity received a score of 3.

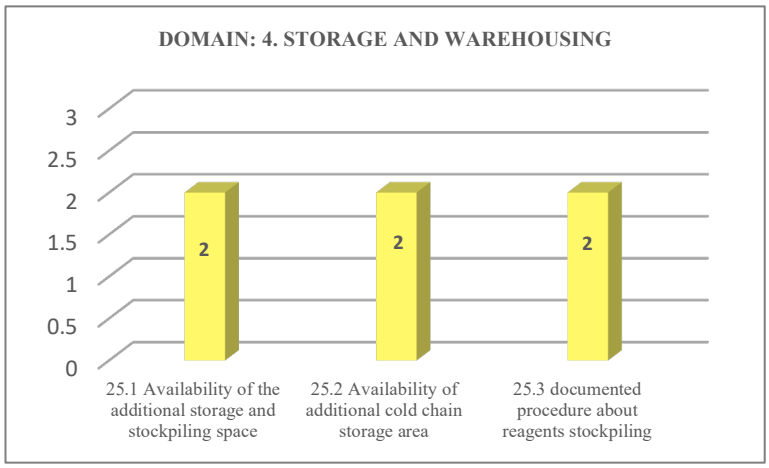


Figure 23: Additional storage Within National laboratory and hospital

Figure 23 identify physical space within the reference laboratory and hospital for storage and stockpiling of additional supplies, and this should consider additional stockpiling space and cold chain storage near laboratories that diagnose contagious disease. Again, the activities had a score of 2, which means increasing numbers and capacity for storage considered vital steps for future planning.

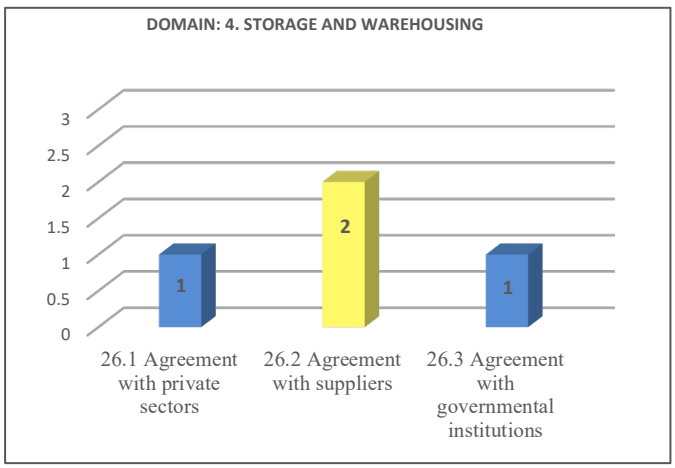


Figure 24: Temporary Warehouse agreement

The activity on **Figure 24** searches for establishing agreements with private sectors, suppliers, and governmental institutions for temporary local warehouses in pandemic. This activity received the lowest score, this means coordination and put on agreement should be considered as the first step in future planning for an emergency.

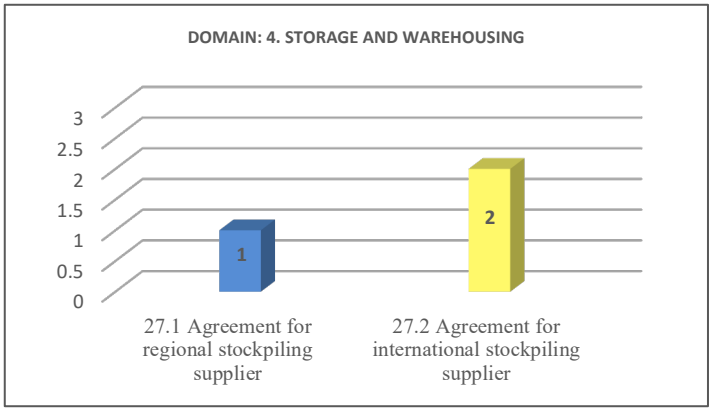


Figure 25: Agreement for stockpiling and restock

Figure 25 shows agreement activity with regional and international partners for stockpiling; this needs improvement to overcome critical supplies shortages during supply chain disruption.

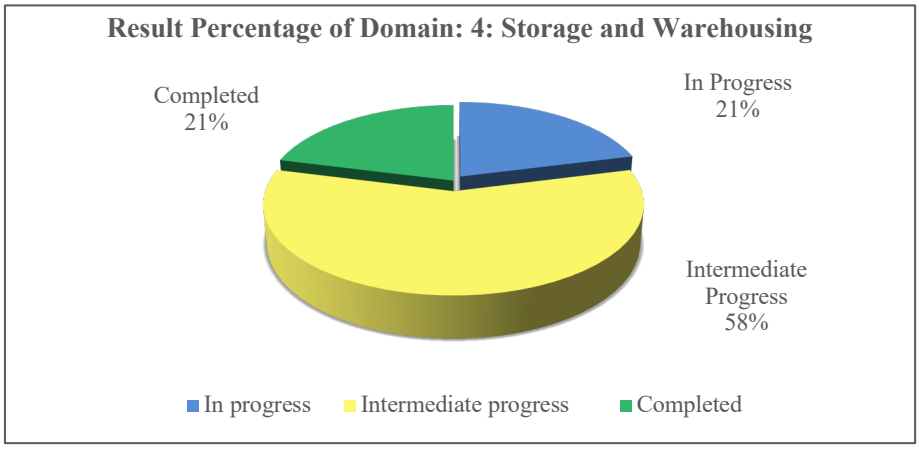


Figure 26: Result Percentage of Domain: 4: Storage and Warehousing

Summary of Figure 26 storage and warehousing domain 4:

Warehouse and storage management received 58% of preparedness plan for emergency, this expresses warehouse numbers, kinds and geographical location preparedness plan, availability of plan for additional laboratories capacities, and established agreements with government, and private health sectors to use their warehouse in emergency. Construct governmental warehouse, and establishes agreement with government, private, and regional warehouse to uses their warehouse in emergency these activities received 21% of the progress, which needs improvements for future.

4.5. Domain 5: Transportation and custom

This component assesses the capability of transportation bodies and logistic capability of vendors to deliver and provision a suitable vehicle that fulfills the laboratories requirement, in the right lead time, with high quality and good condition, and with minimum cost. In addition, it assesses the preparation of a plan to map the routes and find an alternative one for emergencies. Also, it evaluates the level of coordination in

transportation protocols between local, regional, and international partners. However, this will ensure swift delivery of critical supplies to the laboratories across countries and borders, prevent transportation delays, and reduce the mortality rate.

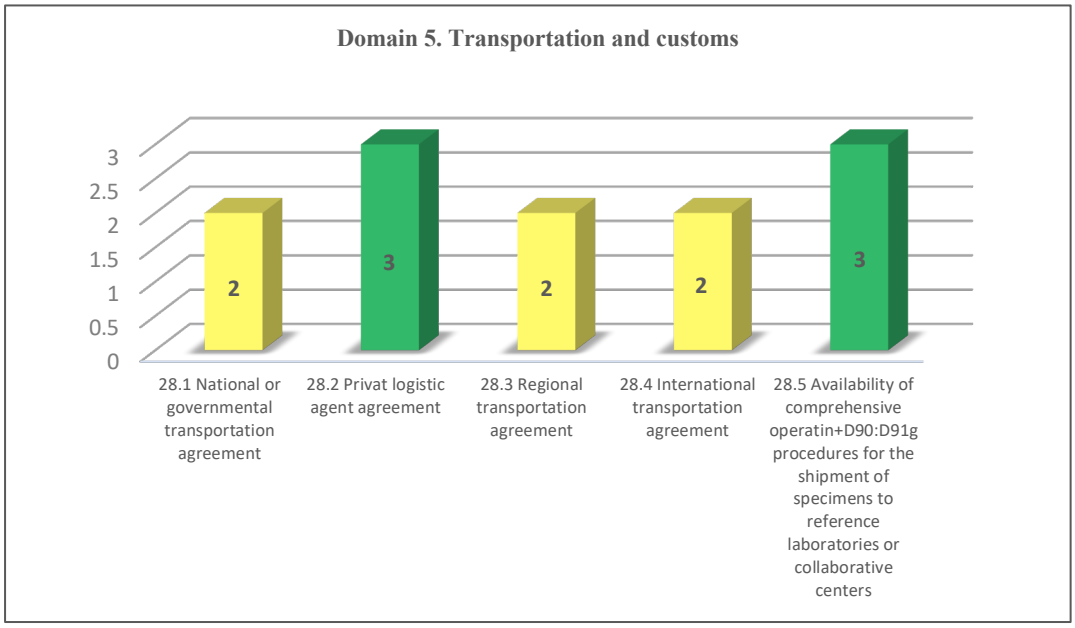


Figure 27: Pre-pandemic transportation agreement with transportation agents

Figure 27 evaluates the existence of contingency transportation agreement with service providers and transportation services to ensure the continued provision of critical resources in an emergency. However, most of transportation agreements were for a private logistic agent, and at a lower extent with local and international level. This means it is better to adopt a collaborative approach in transportation services at the national and international level since it aims to take advantage of centralized coordination, as sharing assets will reduce transportation complexity during the nature of the emergency.

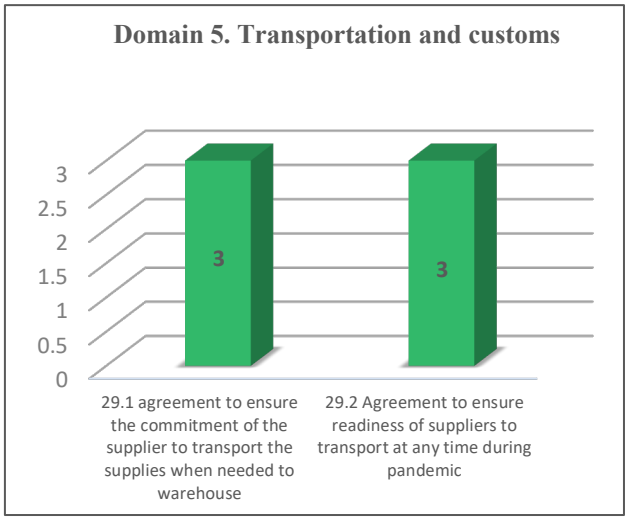


Figure 28: Pre-pandemic transportation agreement with suppliers to warehouse

On the other hand, **Figure 28** received the highest score on this domain, which concerns suppliers' agreements that ensure the commitment of the supplier to transport the supplies when needed to the warehouse.

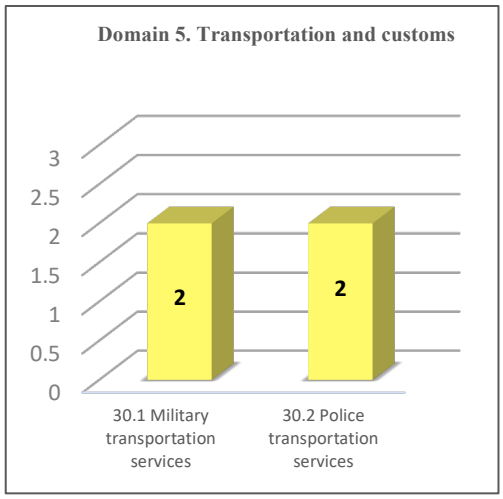


Figure 29: Alternative transportation agreement

Figure 29 shows that all activities received a score of 2 and it's looking for alternative agreement with local transportation bodies in the country.

Supply chain management has collaboration between military and police ministry for transportation services. However, putting on a formal contingency agreement is better to ensure commitment, awareness, and compliance with HMC supply chain management standards in vehicles and transportation protocols, which facilitate a rapid response during emergency and prevent delayed in provision of supplies to the laboratories.

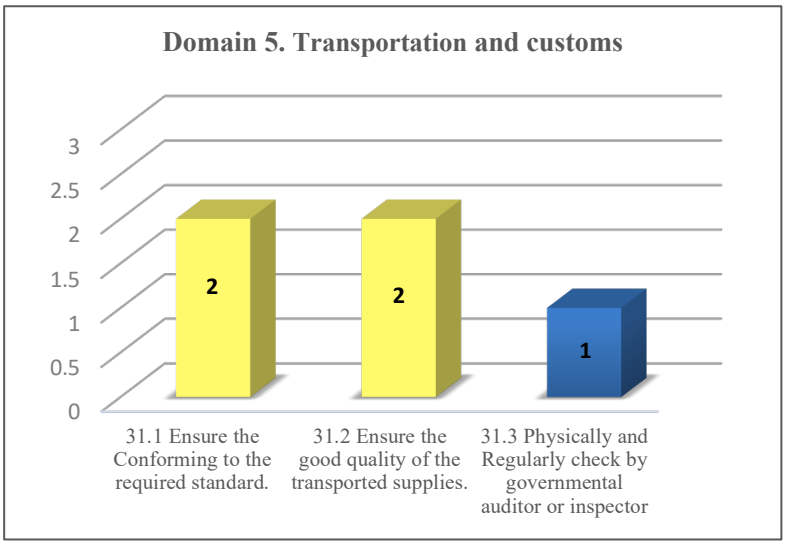


Figure 30: Transportation services assessing

Figure 30 discusses adopting a method for monitoring and evaluating the transport protocols in supply chain management. This includes conforming the vehicles and protocols to the national or international standards to ensure that critical supplies are delivered in sound quality to the providers or laboratories. This is achieved by physically and regularly checked by a governmental auditor or inspector. The lowest score was the regular governmental observation, which needs attention on the future preparedness plan.

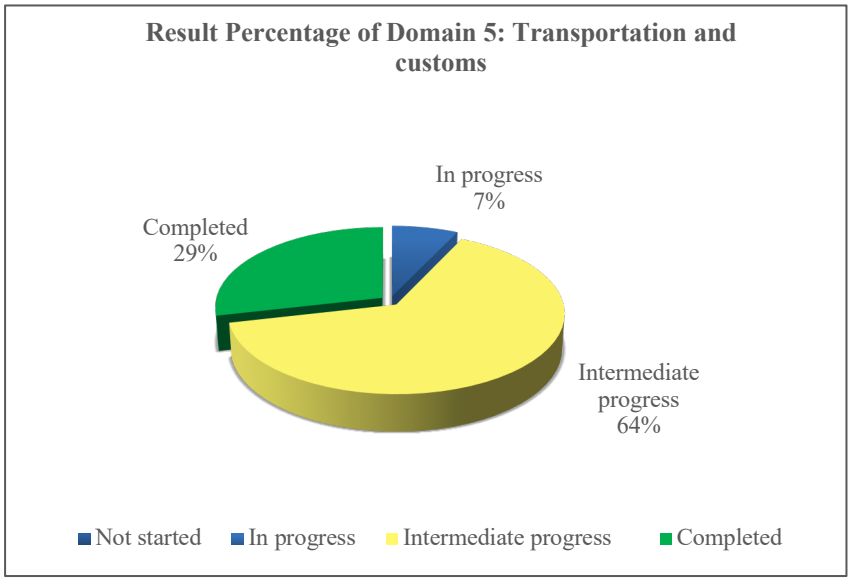


Figure 31:Result Percentage of Domain 5: Transportation and customs

Summary of transportation and customs component; domain 6:

The transportation and customs component shows 64% of preparedness plan for emergency, which express intermediate readiness of emergency through transportation agreements with local and regional bodies, also, and looking for alternative transportation agents, the area for improvements is observation of transportation mechanism to ensure their complying to national or international standards, which has 7% progression.

4.6. Waste management

This component evaluates the preparation of medical waste management protocols for an emergency in supply chain management and laboratory department, and this concerns with creating a list to identify each type of waste and categorized them according to their hazardous, identifying the facilities that will diagnose contagious disease and the amount of waste they produced, ensure the existence of disposal protocols for laboratories medical waste in an emergency, Pre-pandemic coordination with expertise to establish

medical waste management protocols. Share facilities with local and regional health sectors for waste disposing and processing.

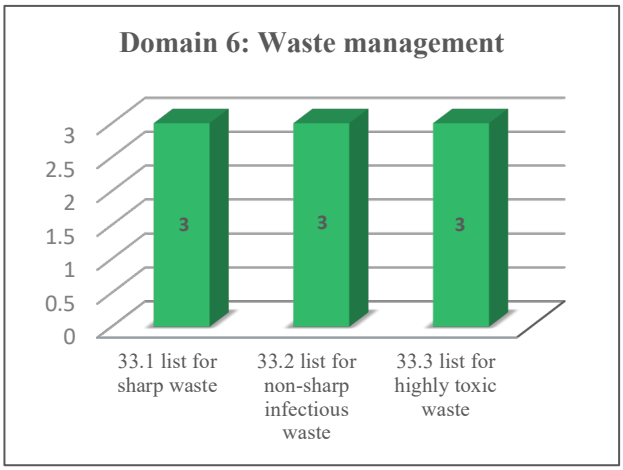


Figure 32: Waste identifying and categorization

Figure 32 Waste identification and categorization received the highest score in this activity: preparedness of a list that identifies all kinds of medical hazards and how to deal with them.

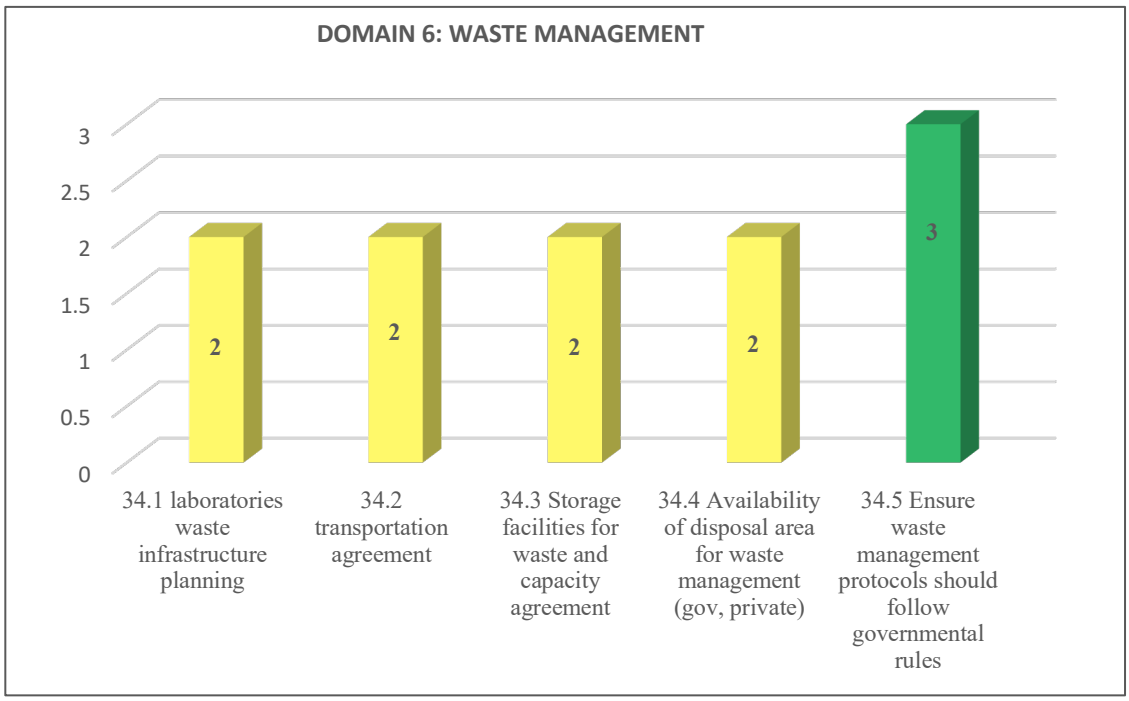


Figure 33: Waste identifying and categorization

Figure 33 shows the laboratories infrastructure planning before an emergency and identifies the facilities that produced hazards; this is accomplished through preparedness of facilities for storage the laboratories medical waste and has a huge capacity that contains the medical waste, put on agreement with local health sectors to use their facilities for medical waste storage purpose. Furthermore, to establish an agreement with transportation bodies in the country (private and government) to transport medical waste from laboratories to the plants, the waste management transportation protocols should comply with the governmental guideline. Therefore, the highest practices that received a score of 3 were the transportation agreements and conforming to the governmental standards.

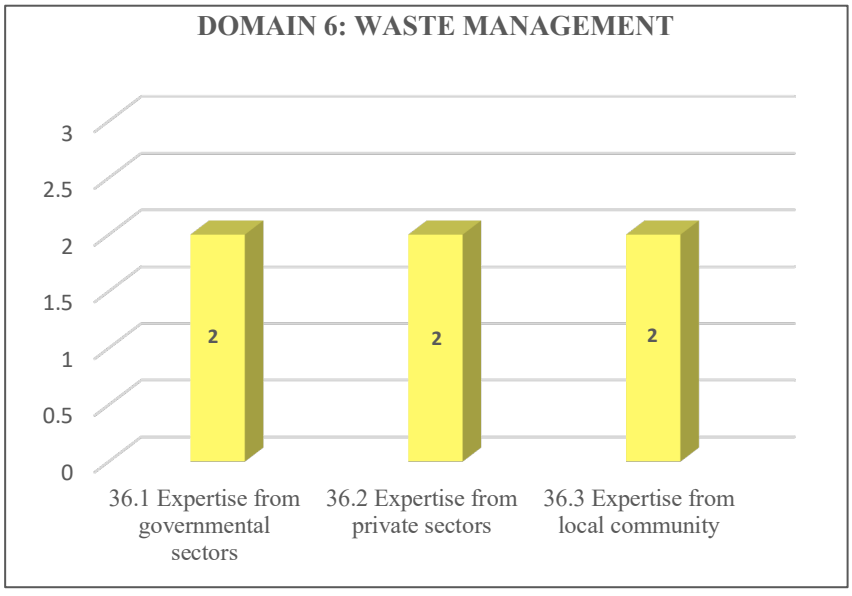


Figure 34: Pre-pandemic coordination

All activities in **Figure 34** had a score of 2 in the pre-pandemic coordination aspect; this means there is a need for activation of the corporation between expertise is in supply chain management in-country health sectors, to establishing a medical waste

management protocol for all health sectors at the national level and standardize these procedures, to contains the huge medical waste that produces during a pandemic, and prevents country pollution.

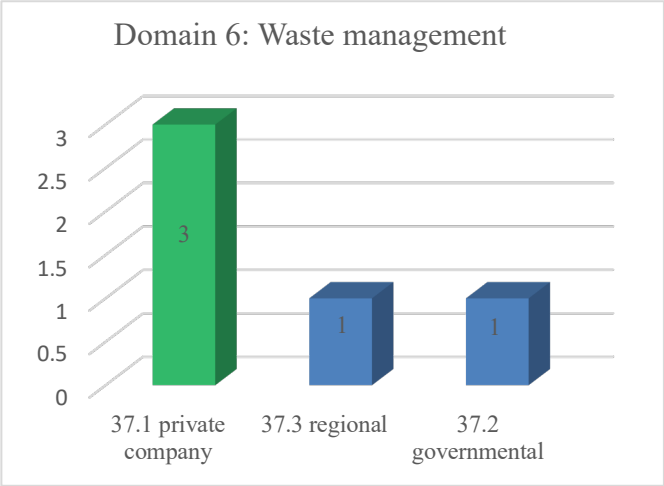


Figure 35: Pre-pandemic waste disposal agreement

Figure 35 concerns with identified roles and responsibilities for partners and stakeholders in medical waste handling, processing, storage, and transportation. These activities received the lowest score in the waste management component, and activation of this practices at national and regional levels will improve responding in emerge.

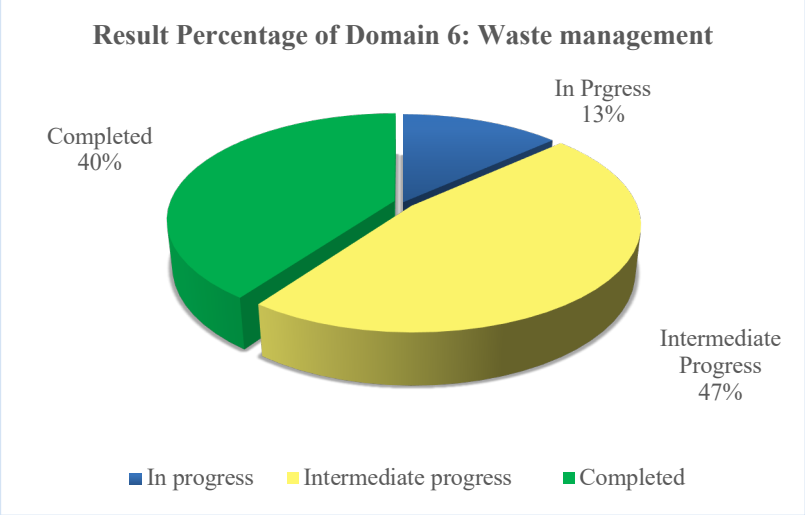


Figure 36: Result Percentage of Domain 6: Waste management

Summary of waste management component; domain 6:

Most of activities on this domain received 47% of preparedness plan, this percentage demonstrates planning for the facilities that will diagnose contagious disease and the estimates the amount of waste they produced, and coordination between expertise in government and private health sectors to establish disposal protocols for laboratories medical waste management and transportation in an emergency. 13% of this component was in progress in planning and needs of improvements in coordination and agreements between governments and privates' health sector.

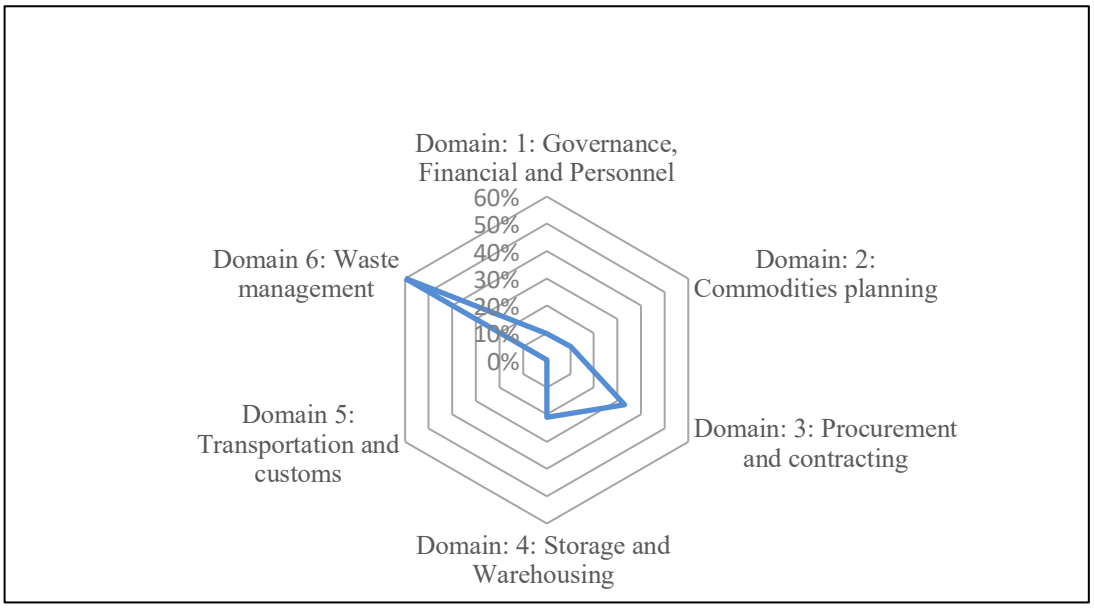


Figure 37: Comparison of the percentage of completed components between domains

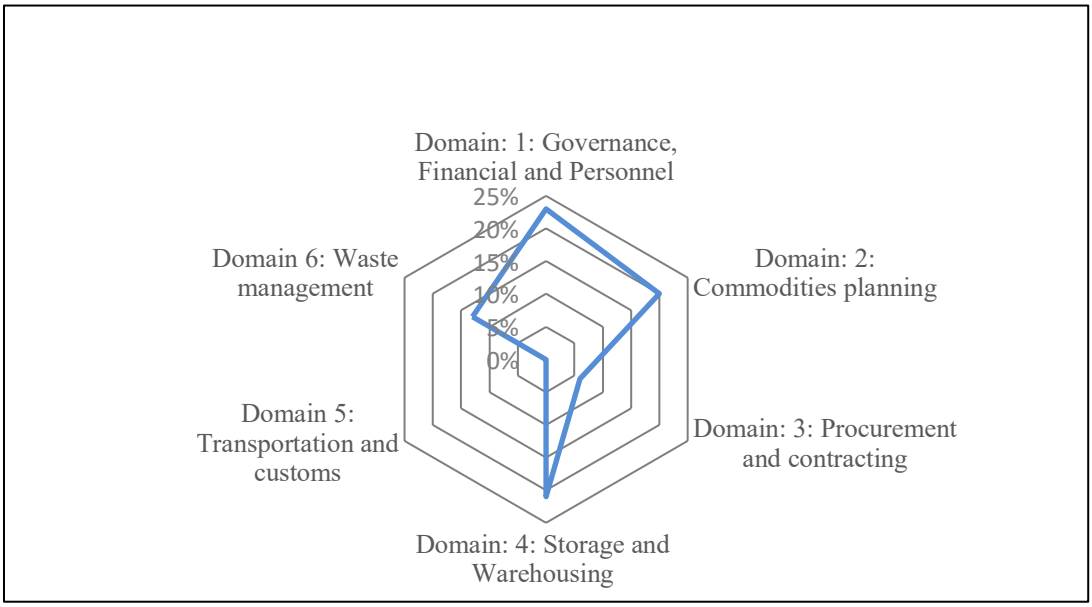


Figure 39: Comparison of the percentage of Intermediate progress components between domains

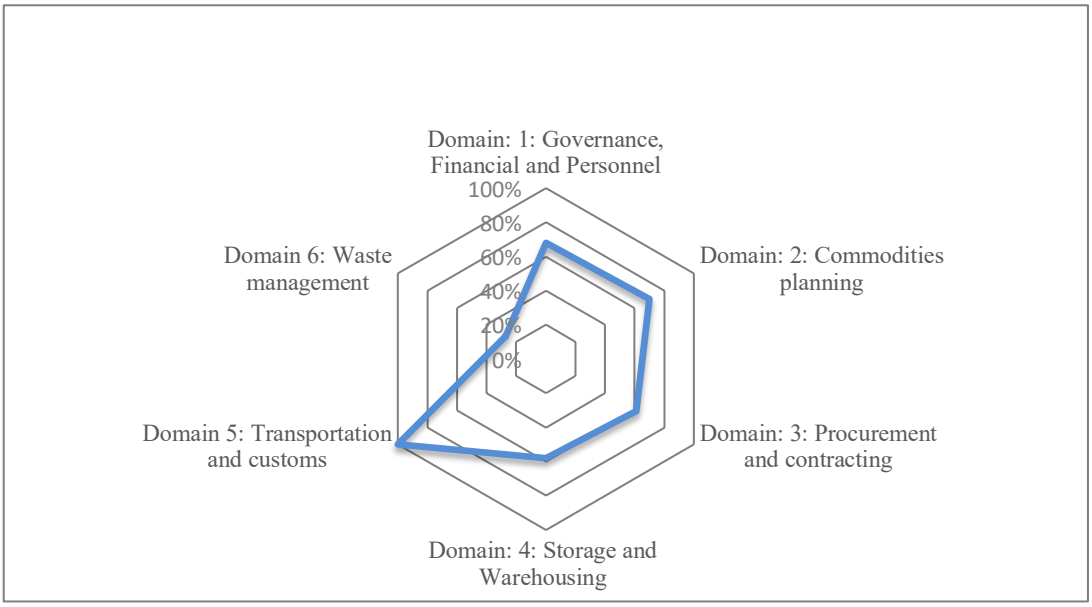


Figure 40: Comparison of the percentage of Intermediate progress components between domains

5. CHAPTER FIVE: DISCUSSION

The study found that laboratories SCM have a Contingency plan for funds source and most of the financing support was from the government during the disaster.

Regarding coordination and collaboration between local, regional, and international partners before the pandemic, the study found that SCM for laboratories requires to move towards long term agreements and coordination through put in place contingency contracts for contribution in forecasting and quantification to predict the accurate quantity of critical supplies, procurement, and suppliers selecting, providing supplies and personnel during an increase in demands, warehouse sharing and construction for storage essential commodities, transportation planning, medical waste planning, and facilities sharing. Long-term agreements will ensure commitment and swift responding of partners in an emergency (Sharma, A. et al 2020; Kuo, S., et al 202; Vong, et al).

Regarding information technology IT, the study found that interoperability between all health sectors through adopting promising solutions and investing in IT will facilitate SCM information's exchange to be able to predict shortage in supplies in laboratories and increase the transparency along with SC (Dey, S., et al 2020; Choi, Guo, & Luo 2020; Fusco, A. et al. 2020; Mathew, J. et al. 2013; Parsa, P. 2020).

Furthermore, the study found that there is a need for creating permanent team specified for emergencies and equipped with a simulation training program, the team should be a focal point from all SCM in health sectors, this will increase the visibility and exchange of information's, which helps rapid response in disasters (USAID2018). The study discovered there is a lack of training programs before pandemic and emphasis in the simulation which is the most effective program for emergency preparedness (USAID 2018; Paul et al. 2020; Ivanov and Das 2020).

Notably, there is a deficit in implementing an evaluation system or indicators such as

KPIs for monitoring and assessment SCM preparedness plans. Furthermore, the study found the importance of adopting forecasting methods and tools to predict the estimated number of critical supplies for emergencies (Ivanov, D. et al 2020).

On the other hand, the study found that diversification in sources and suppliers for laboratories will overcome the shortage in critical supplies in an emergency, also, identifying an alternative supplier and put on preparedness agreement will minimize supplies disturbance in disasters, furthermore, the study emphasis on the encouragement of domestic suppliers and support local plants (Sharma, A., et al 2020)

Furthermore, the study underlined assessing laboratories infrastructure for an emergency before procurement of essential pandemic resources, as preparedness plan during surge capacities on supplies and specimens' storage, and acquisition of new equipment's for diagnosed contagious disease and putting plans for additional spaces for a future pandemic. On the other hand, the study emphasis on the warehouse preparedness for emergency through constructing alternative warehouse in addition to the main one, increasing the number of warehouses distributed in a different geographical area, establishing long term agreements with government and private health sectors or suppliers to share or rent their warehouse and cold chain in an emergency, the estimated quantities for laboratories supply storage and its proportionality to the warehouse capacities should be considered in this context (Okeagu, C. et al 2020; USAID 2018). In addition, the study underlined the inventory management strategy, since employed both JIT and safety stock strategy for six months and more, will keep on hand stock for laboratories essential supplies for an emergency, and prevent shortage during a sudden increase in demands.

Additionally, the study highlights the importance of the planning for transportation routes across the country and borders by establishing contingency agreements with local,

regional, and vendors, and specifying the defined terms and conditions to ensure receive laboratories supplies in good conditions and with the minimum leading time.

Finally, the study found that coordination and pre-pandemic agreement with health sectors to put on plans for managing medical wastes and establishes protocols that standardized in all health sectors, through construct plants and share their facilities for hazards wastes processing, incineration, and disposing of hazardous waste, this will assist during a pandemic when there is a sudden increase in medical wastes.

Each component of emergency supply chain management will be discussed in detail, as outcomes of graph analysis.

5.1. Funds

During the epidemic the most used finance for HMC laboratories demands was the preparedness budgets which incorporated into HMC routine SC strategic planning annually, was allocated for critical supplies purchasing, preparing warehouse and transportation, inventory management of emergency supplies, and personnel training. Most of the funds were sourced from the government to overcome inflation of supplies demands, and to surge capacities in laboratories.

According to USAID 2019, there should be two kinds of finance that support the country during threats, these include preparedness budget and reserved budget, pre-pandemic strategic plans should be put in place to calculate these budgets and reviewed annually to serve hospitals in disaster. A study of UNICEF and global logistic cluster with the corporation between different bodies, state that investing in supply chain preparedness leads to cost-saving, lead time reduction, and higher service quality.

5.2. Coordination of Laboratory Supply Chain Management with partners to overcome supply shortage

At the onset of the pandemic, DLMP identified an early shortage of supply of PPE's and

N95 masks for frontline healthcare workers including laboratory personnel. This shortage is due to supply chain disruption, and lockdown in countries especially china whose export worlds face mask, Qatar has an early quick response and overcome supplies shortage, similarly, in Taiwan and Denmark, they experience commodities shortages and have a very early response to pandemic through the deployment of containment measures to mitigate the pandemic effects on SCM. On the other hand, US, Italy, and UK have experienced a shortage in PPE's and have a low response to COVID19 (Salvador-Carulla, L.et al 2020).

Qatar is supported by a strong health system that has a business continuity plan to mobilize all laboratories' resources, including manpower, supplies, equipment, funds, spaces, and transportation, to overcome this surge in laboratories capacity and prioritize COVID 19 supplies to prevent the increase in mortality rate. Similarly, US began investing in its business continuity planning that enhances the rapid response of pandemics (Francis, J. R., 2021).

Furthermore, to overcome critical supplies shortage, reference laboratories in HMC have a strong relationship with government and semi-governmental health institutions, they have service level of agreement (mutual cooperation) with Sidra laboratory, Military laboratory, police laboratory, these laboratories were assisted HMC at the onset of epidemic and serves as backup laboratories in an emergency, through provides nasal and buccal swap, also, some laboratories have RT-PCR to diagnosed expected cases from population and to minimize HMC laboratory overwhelming, but the standardization of policies and equipment's of these laboratories with HMC was concerns as a barrier in the epidemic. Therefore, a combination of efforts of all governmental health sectors to provide and mobilize all critical resources to contain the virus and ensure public safety, led to a swift recovery in the first phase of the pandemic facilitate quick recovery from

the country epidemic with a low mortality rate (Sharma, A. et al 2020; Kuo, S., et al 2021; Vong, et al 2016). According to NEJM. 2020 it's crucial to collaborate with partners before any disaster to facilitate the exchange of essential supplies from lower mortality rate countries to a higher one. WHO and USAID 2018 encourage countries to put in place a preparedness plan for surge capacities in pandemics through establishing a main multisectoral committee led by high-level health authorities and technical sub-committee (Vong, et al 2016) In this context, Qatar adopted National Committee Center (NCC) a state-of-the-art center equipped with the most advanced technologies, acting as a permanent informational center for the country. It includes focal points from each institution in Qatar (Ministry of; health, finance, planning, development, transport, military, police, and others). This committee is met regularly and all ministries in the country reported to them continuously, it's employed in COVID 19 crisis through acts as a source of critical information in an emergency to increase the transparency of the supply chain and minimize critical resources shortage, which helps overcome country's epidemic.

On the other hand, SCM in HMC established a sub-committee that is met monthly, and includes the focal point person from each supply chain section; administrative, procurement, forecasting, warehouse management, laboratory SC coordinator, and medical lead, the committee was employed in an epidemic. This committee is reporting to the NCC committee and supreme committee for the crisis. De Sousa Jabbour, A. et al, state that working together between country's entities will create a community perspective, and increase visibility and understanding of the SC strategy that mitigates the threats (De Sousa Jabbour, A. et al 2020). Similarly, Taiwan was addressing the medicine and supplies shortage that result from a disturbance in SC by establishing transparent preparedness and contingency plans through collaboration with

interdependent stakeholders and private sectors (Kuo, S., 2021). Also, Indonesia, Myanmar, and Sri Lanka had encouraged committees at the subnational level to develop preparedness plans.

According to USAID 2019, It is important to have a permanent reporting system for emergencies between Emergency Operating Center (EOC) at the national level, and SCM leads to facilitate the exchange of information's and enhance the response in an emergency, the EOC will be the lead's links to the broader emergency response efforts, including coordination with some entities as the military, communications staff, international organizations, and private sectors.

Regarding coordination with private sectors, according to USAID 2019 and NEJM. 2020 integration with the private health sectors in contingency plan and coordinate with them concern important step, especially when they experience increased of demands of their laboratories services as a result of a preoccupation of the government sectors with managing COVID 19. It's crucial to collaborate with partners before any disaster to facilitate the exchange of essential supplies from lower mortality rate countries to a higher one (NEJM. 2020).

5.3. Laboratories SC information sources and network

SCM adopted LMIS logistic software system designed and tailored to fit SC requirements in laboratories and serves as a communicating system between reference laboratory, SCM department in HMC, and suppliers this system facilitate transparency and improve the flow of information's along with HMC supply chain networks, also acts as a monitoring system for managing inventories and re-order the supplies to refill the SC stockpiles in routine and emergency.

DLMP logistic digital system needs to be upgraded to support laboratories in an emergency through increase visibility and transparency along HMC supply chain,

suppliers and should be connected to the country's health sectors. In addition, centralization of SC networks is a crucial step in an emergency, which helps SCM in commodities tracking, re-ordered, and refilling the stock. it's vital to plan and execute before pandemic to implement and upgrade information technology to build strong infrastructure between health sectors, and train appointed persons to overcome challenges faced during threats (Black, S.,2020).

Regarding epidemiological data, MOPH adopted a highly evolved system that links the country's laboratories data in governmental health sectors and private sectors with key epidemiological data for timely data analysis, which assists to knows the expected population demands of critical supplies in emergency and improving SCM transparency. SCM needs to establish a robust IT infrastructure (big data, AI) to interact and communicate with all health sectors in the country during an outbreak (Dey, S., et al 2020). Okeagu, C. et al state that communication between SCM parties will standardize the medical regulation and reduce the time for response in an emergency. According to Tang and Lee state that sharing information in SC networks is a preparedness way to reduce pandemic risk and SC disruption, also prevent stockouts and overstock of critical supplies in laboratories.

5.4. Designation emergency SCM team and Preparedness plan for developing and training ESCM team and stakeholders

On a routine basis, the laboratories department created a team that includes; focal point from the supply chain management department, chairman, operation directors, Vice Chairman, division head, and key supervisors from laboratories, this team is employed to share information about equipment's and supplies requirements for each laboratory section, which reported to SCM committee for fulfillment. The roles and responsibilities are identified and written. On the other hand, the success of prevention of Cholera in

South Sudan is due to two elements in governance, first, predetermined roles and responsibilities of emergency teams, second, preexistence coordination structure (Abubakar, et al 2015).

USAID 2018 states that it's crucial to create a defined emergency SCM team for threat preparedness and separated from routine SCM team. This team has focal point from SCM of (public sectors, private sectors, and international organization), their roles and responsibilities must identify before country faced epidemic as preparedness plan. This team should include different disciplines and expertise in the supply chain aspect (technical expertise in forecasting, procurement expertise, logistic expertise, animal and human medicine) (Vong, Sirenda, et al 2016).

SCM in HMC planned for the future training program as lesson learned from the first wave of COVID 19, the best program for emergency preparedness training is simulation. (Paul et al. 2020; Ivanov and Das 2020) claims that simulation is an essential tool to predict required performance capacity and disruptive scenarios. MOPH constructed will equip theaters for emergency training purposes especially simulation programs, so coordination between different health sectors to activate this theater will consider the first step for future emergency training (WHO, simulation manual 2017). USAID 2018 states that training programs before emergency have a high impact on countries response during a disaster through developing expertise among staff and partners, and investing in human resources capabilities across SC, in addition, the training program should cover all ESC protocols and existing plans at national, regional to aid readiness at all governmental levels, and should incorporate lesson learned from the pandemic.

5.5. Human resources management

Reference laboratory experience staff absenteeism at an early phase of pandemic, because of sickness and quarantine, they faced a shortage in trained expertise staff that

perform diagnostic tests for COVID 19 either through swap collection or conducted tests, therefore, at the onset of outbreak HMC has business continuity plan and they employed this plan through mobilizing personnel from different sections in laboratories and trained them to overcome staff shortage. Also, HMC cooperated with governmental health sectors and some entities to the provision of personnel during a pandemic, such as; military clinic, police clinic, red-crescent, universities, and PHCC. In addition, red-crescent played a vital role in country outbreaks through assisting HMC in the provision of trained personnel to collect samples from infected or expected cases.

Notably, planning to coordinate with the local health sectors to engage and train manpower before an emergency, will trigger a quick response to overcome staff shortage in a future emergency. Also, the acquisition of local talent from different universities and other institutions and training them for emergency purposes will help in swift outbreak responses.

5.6. Commodities planning

DLMP has s comprehensive list for all laboratories' inventories depending on the system requirement. It's crucial to create a list to identify the type of laboratory critical resources needed in a pandemic in a national laboratory which includes 6 domains (Supplies related to samples, Transportation system, Semi- Durables, Personal Protective Equipment's) PPEs, and Intermittent pneumatic compression (IPCs), Consumables and RT-PCR complementary Equipment).

The forecasting method in SCM in HMC was based on historical data (3 months of epidemiological data extracted from MOPH at the onset of disease. According to USAID 2019, it's important to predict the quantities of commodities based on the experience of history outbreaks such as H1N1 or lessons learned from the country's epidemic. Also, it's crucial to work with experts to identify the usual consumption ratio for each

contagious disease case, and this ratio is used to calculate quantities required in the event of an outbreak. Sambit states that forecasting assists in managing asset principal acquisition, labor, the viability of new products, and inventories (Sambit 2017). Furthermore, establishing a forecasting tool assist in predicting exact quantities for emergencies with concern to a geographical area, population demographic, and disease stage. Notably, pre-assessing the national laboratory infrastructure and its capability to contain the increase in demand during threats will aid in the preparation of stockpiling area, increase cold chain area, and find an alternative storage area near the national laboratory to store the massive supplies during a pandemic.

5.7. Procurement and contracting

Laboratory SCM in HMC established a long-term agreement with suppliers and it's reviewed annually. This agreement is used in routine SCM and helps in supplier's corporation with DLMP to have priority in supplies provision. Also, there is a list of certified suppliers that should be registered and classified through the ministry of finance (Government Procurement Regulatory Department) to receive invitations for HMC laboratories' tender and purchase orders or contract awards. In addition, SCM communicates with all first-line suppliers to prioritize Qatar HMC laboratories on the world list for the provision of critical resources, also, they open new channels with different countries to feed critical diagnostic and preventive resources for laboratories such as; China and Turkey. On the other hand, as part of the contribution of local suppliers in response to an early phase of the country epidemic, Al Maha private local medical supplies plant, contribute to providing public health preventive supplies such as; surgical masks, disinfectant solutions, and gloves on the first phase of pandemic, this initiative needs coordination before emergency for improvement and encouragement from MOPH through reducing plants costs, and regular observation. According to

USAID 2018, It is preferable to create an emergency agreement with suppliers to ensure swift response through prioritizing and provisions of laboratories critical supplies, this agreement should include; identifying potential risks, specify transport methods, and outlining the quantity of essential commodities that will be received, time for the provision of critical supplies, replenish of critical commodities, transportation method and the lead time for each supplier in an emergency. Also, there should be a list of the first line and alternative suppliers, which helps in prioritizing laboratories' provision of supplies. Importantly, local suppliers' concerns as a vital channel that is triggered in the first phase of an emergency. Zhu and Patel state that supporting domestic suppliers through reducing facilities licensing and product cost and maintaining continuous evaluation and monitoring of them is crucial steps for future threats (Zhu, G, et al 2020; Patel, A, et al 2017).

5.8. Storage and Warehousing

Most of the laboratory's resources are stored in a huge main warehouse allocated for HMC, which is highly organized and complies with international standards, also there is a small warehouse located in a rural area that serves laboratories in these locations and facilitates quick access to critical supplies. In addition, HMC posses' huge cold chain, which is located in the hub of the country.

On the other hand, SCM has a strategy of Just in Time and safety stock that assists in keeping on-hand stock for 3 months this helped DLMP use this stock in the short moment until replenishment from suppliers. The essential supplies needed in the COVID19 pandemic are diagnostic and preventive resources such as; nasopharyngeal swap, N95 mask, PPE, and COVID19 assays that were under manufacture research and evolving because of virus nature uncertainty.

According to USAID 2019, it's crucial to have a central owned governmental

warehouse, and alternative ones to ensure a backup plan in case of increased demand in disasters or destruction of the central warehouse due to natural or chemical disaster. In addition, contingency agreement with private health sectors, government health sectors, and suppliers concerned as an alternative plan during the country's emergency.

Regarding inventory management strategy, applied safety stock strategy for 6 months and continuous replenishment of commodities in the warehouse will assist laboratories and SCM during countries lockdowns and SC interruption.

5.9. Transportation and customs

HMC has a distinctive transportation system with a defined mapping system to orient the routes for health commodities transportation in Qatar. The laboratories' commodities are transported from the main warehouse to the distribution center located in a different geographical area, then it's delivered to the HMC laboratories to fulfill the requirements, also DLMP has a service level of agreement with governmental health sectors that corporate in pandemic through sharing transportation mechanism to deliver critical supplies out of the border and across the country. Military plays a major role in air-force transportation through transport essential medical supplies from countries to fulfill the health care requirements, also Red Crescent has a vital role in carrying infected patients to the HMC, ministry of interior also play an important role in delivering patients and supplies. According to USAID 2019, Transportation is depending mainly on established contingency transportation agreements with customs officials, service providers, governmental transportation, private logistic agent, regional agreement, international agreement and identifying transportation mapping across borders and inside the country, with consideration of environmental factors, and type of vehicles that will handle the cold supplies, to ensure the continued provision of critical resources in emergency and helps to prevent improper laboratory supplies handling, also avoid wastage of

commodities during transportation, and reduce the lead time in an emergency (Okeagu, C. et al 2020).

5.10. Waste management

DLMP under the infection control department and follow their roles and guidelines in the waste management aspect. The department established a proper management program for hazardous and materials management to ensure the health and safety of patients, employees, visitors, and the surrounding environment in accordance with international and national standards. There is a well-established waste list and it's categorized according to the type and kinds of hazards it's produced they used color-coded for waste identification. Regarding COVID 19 waste, additional medical and hazardous waste are generated, including contaminated PPE's, masks, gloves, and other protective equipment's, so there was a sudden increase in the proper collection, disposal, and treatment of the general waste. Therefore, the infection control department follows the WHO and national guidelines for COVID19 waste to minimize the hazard for humans and the environment. Furthermore, waste handling training is conducted regularly for all health care employees including laboratories to ensure their occupational safety.

HMC has four plants for waste management located in different geographical areas and has a maximum capacity of up to 10,000 Kg of waste daily, after collection, labeling, and packaging of the hazardous waste it's transferred to the plants for processing, and sterilization, which then transported to the private plant for incineration. The private plants collaborate with HMC to follow their guidelines and roles in waste management and ensure its compliance with international standards. In a pandemic, the infection department allocates all the four plants to serve in an emergency, in addition, they have agreements with private companies to assist in waste burning.

According to USAID 2019, it's crucial to have a categorized waste list, and preparedness plan for medical waste handling and safe disposal of contaminated hazardous waste in an emergency, also it's important to identify the facilities, disposal procedure, and transportation mechanisms.

In addition, building government plants and collaborating with health sectors for waste management will minimize the overall cost and facilitate rapid emergency response, also, the government plant will be sustainable and supported during the country's threats. Importantly, the incorporation regional culture customs for waste management in the disposal plan will ensure that waste management processes are associated with local cultural practices (USAID 2019).

6. RECOMMENDATION AND LESSONS LEARNED

Qatar is on the way to recovery from the COVID19 epidemic because the curve has been flattened, and there is a reduced number of infected cases and mortality rates. However, the millstone is beginning in the supply chain management; the healthcare sectors should assess their supply chain from the lessons learned from the COVID19 pandemic and initiate improvement of strategic and tactical plans to prepare better and improve real-time to be taken in a future crisis.

The recovery process required a reassessment of the supply chain structure in terms of location, production capacity, material flow management, and information management to identify the gaps and rearrange the supply chain structure (Ali et al., 2017). This will achieve through collaboration and integration between crucial members of SC and local partners (Govindan et al., 2020). In addition, gathering data by brainstorming with experts and formal group discussion with key persons from local SC in health sectors will contribute to identifying gaps, bottlenecks, opportunities to change and innovate and discuss the solutions for SC enhancement (Terzieva, 2014). Notably, using strategic

tools will help to gather valuable pieces of information for SC improvement.

According to the best practices and SCM experiences in COVID19, the study will summarize the crucial recommendation for future disasters.

- Allocating a national laboratory for public health, intended for outbreaks and events in the country and focus on public diagnosis during disasters or events, such as world cups, epidemics, or pandemics, serves to contain all kinds of the outbreak, provision comprehensive services for public health and visitors, also act as the focal point between all country's national laboratories and WHO. In addition, it should be configured to accommodate the surge in capacity during threats.
- Collaboration between partners and stakeholders in health sectors in the country to establish preparedness contingency plans to overcome supplies shortages during an emergency, coordinate essential supplies forecasting, quantification, and commodities specification, and contribute to determining a list for all commodities requirements in an emergency.
- Coordination in the level of local, regional, international through creates long terms agreements for an emergency to provide essential supplies, share warehouses, build huge stockpiles, create one group purchasing, map transportation routes across borders, establish plans for hazards waste protocols.
- Establish a center for emergency supply chain management in disasters for all country's health sectors, which is concerned with coordinating and managing all the health commodities between the country's health entities locally, regionally, and internationally before and during an emergency.
- Activate simulation theater through prepare training simulation program to prepare employees in health sectors for future disasters.

- Corporations between all health sectors to standardize the preparedness plan in policies and procedures, improve communication, and put in place long-term agreements will assist in the quick response in disasters.
- Creating a permanent emergency team specified for laboratories supply chain management, this team should be equipped through simulation training with all possible scenarios for threats and engage in creating the strategies and plan before disasters.
- Establishing a permanent committee for unified procurement (one group purchasing) for all medical laboratories in health sectors in an emergency, whose tasks include selecting and evaluating suppliers in cooperation with the World Health Organization, also, selecting, acquisition and evaluating the medical equipment's and commodities in terms of quality and cost, and allowing their circulation in the country, unifying procurement laws in health sectors in the country.
- Put a long-term contingency agreement with multiple suppliers and specify the terms and conditions that serve in a future disaster.
- Implement supplier diversification strategy through broadening the supply chains sources of essential supplies instead of being dependent on only 1 or 2 countries.
- Improve domestic (local) manufacturing; the governments need to work with the health care supply chain to encourage the local manufacturing of the critical resources, especially during supply chain disruption. Also, it is essential to establish policies that support and assist the local manufacturing through reducing the cost and tax of facilities, monitoring them, and ensuring it is complying with high standards

- It is preferable to construct owned governmental warehouse, and the huge cold chain that has capacity proportion to population demands in a pandemic, through corporation with country's health entities, and should be oriented by government supply chain personnel than rental one, to save cost and oversees by government, and ensure its compliance to national and international standards. In addition, constructing a minor warehouse distributed in different geographical areas with the same capacity as the central warehouse to act as a backup during threats should also be under government observation.
- Establishes long-term agreements (LTA's) with government and private health sectors to share or rent their warehouse as an alternative plan during a disaster (military, police, and private sectors).
- Establishes regional stockpiling agreement with countries, serves as a big reservoir for medical resources in the region, and attends to overcome shortage when there is a disturbance in SC in disaster.
- Implement both safety stock strategy and JIT strategy, keep on hand stock for 6 months to mitigate supplies shortage, and put long-term agreements (LATs) for continuous replenishment in an emergency.
- Improve inventory management along the supply chain by upgrading the information technology system (LMIS) to be more transparent.
- Establishes contingency agreements with local, regional, and vendors, and specifies the defined terms and conditions to ensure receive laboratories supplies in good conditions and with the minimum leading time.
- Plan to have a governmentally owned waste management plant under government supervision; this helps in regular observation and ensure its compliance with national and international standards; in addition, it is better to

have owned highly sophisticated equipment's (disposer and incinerators) and controlled by the government to reduce the cost and ensure protect population health and prevent delayed in waste collection and processing by private companies caused by plant overwhelming or close in an emergency, and its cost-effectiveness.

- Support the researchers to develop new critical supplies lines, increase these products during an emergency, and help during rising demands.
- Adopting ERB system between health sectors, a vast information technology system designated for laboratories supply chain management, which specified for supplier management, procurement management, HR management, tracing health commodities, and increases the visibility and transparency along the supply chain, which helps improve laboratories logistic cycle between country's laboratories during disasters.
- Centralizing SC networks between health sectors will help SCM track commodities, re-ordered, and refill the stock.
- Make an investment in technology and system to increase visibility and analytics, and move towards a fully digital supply chain system through;
    - Adopting the blockchain integrated with artificial intelligence to strengthen healthcare SC operation protocols and create the basis for an effective evidence-based decision.
    - Implement an innovative approach to the virtual centralization of the supply chain that helps solve critical problems relevant to time, staff, and budget shortage, and it is used to control hospital costs and improve their services.
    - Apply Collaborative Forecasting Replenishment Planning (CFRP),

which is an inventory practice that is digitalized for facilitating SC alliance and acts as a roadmap and thus helps in standardizing the production planning and movement, allows to share information's with suppliers and providers, develop accurate forecasts and improve product replenishment and operation process.

7. CONCLUSION

This study represents a novel study, it's a combination of supply chain management in the business field and medical field, and limited studies were conducted on emergency supply chain management for health care, and rarely includes laboratories.

The USAID 2018, established a report on best practices in supply chain preparedness for public health emergencies. This study provides a comprehensive guideline that serves health sectors and laboratories to improve their SCM in disaster. Laboratories in Qatar same as most countries faced challenges in the first wave of the pandemic to overcome critical supplies shortage, this due to sudden surge in frontline health care demand of critical supplies to protect them from the pandemic and assist in COVID 19 diagnosis, this happened as consequences of worldwide supply chain disturbance, and most of countries borders were closed, which caused an interruption in the countries supply chain networks and locked in the transportation channels that deliver laboratories critical supplies across countries borders. On the other hand, SCM in HMC responded swiftly at the onset of the pandemic and applied business continuity plans to mitigate interruption on its networks, and had been recovered at the second wave of the pandemic. In this context, laboratories' preparedness for emergencies considers crucial footsteps for future countries' threats, this is achieved through coordination between country health sectors on the laboratories field through allocating national laboratories for public

health and establishing SCM centers that have unified processes and procedures across the country health sectors. In addition, opens communication channels between health sectors to collaborate in preparedness planning in all emergency supply chain management components that emphasized on; securing and provisions of all essential resources needs for contagious disease, looking for planning the critical supplies forecasting and quantification, focusing on applying diversification in sources and suppliers and encourage of domestic suppliers. Also, SCM personnel in laboratories should be put into consideration by preparing them for an emergency by applying for a simulation program. Furthermore, a corporation with health sectors in planning for sufficient warehouse with higher capacities for emergency and planning for transportation routing across countries, in addition, coordinate with laboratories to prepare a plan for waste management protocols. Finally adopting promising solutions in SCM will increase transparency along with supply chain management between health sectors in an emergency.

8. LIMITATION

The study finding has limitations. First, the result is based on a broad review of procedures and protocols by checklist rather than using quantitative analysis, this is because the study was conducted during the pandemic phase, there was overwhelming in most of HMC departments, so there were obstacles to gathering huge information.

Second, because of the pandemic, the study is limited to the SCM of laboratories, to improve generalizability the study could be conducted in other hospitals on the laboratories field in the country and benchmarks with countries.

9. PROSPECTIVE

Each component in ESCM in laboratories are vital to be consider and it opens the line of further researches.

10. REFERENCES

1. Araz, O. M., Choi, T. M., Olson, D., & Salman, F. S. (2020). Data analytics for operational risk management. Decision Sciences, 51(6), 1316-1319.
2. Azuike, E. C., Adinma, E. D., Nwabueze, S. A., Azuike, E. D., Mbanuzuru, V. A., Epundu, U. U.,. & Obi, D. C. (2015). Healthcare waste management: what do the health workers in a Nigerian tertiary hospital know and practice. Science, 3(1), 114-8.
3. *Black, S., & GLASER-SEGURA, D. (2020). Supply Chain Resilience in a Pandemic: The Need for Revised Contingency Planning. Management Dynamics in the Knowledge Economy, 8(4), 325.*
4. Balmer C, Pollina E. Italy's Lombardy asks retired health workers to join coronavi- rus fight. World Economic Forum, Reuters. 2020 (https://www.weforum.org/agenda/2020/ 03/italys-lombardy-etired-health-workers -coronavirus-covid19-pandemic).
5. Bhakoo, V.; Singh, P.; Sohal, A. Collaborative management of inventory in Australian hospital supply chains: Practices and issues. *Supply Chain Manag.* 2012, *17*, 217–230.
6. https://files.asprtracie.hhs.gov/documents/aspr-tracie-partnering-with-the-healthcare-supply-chain-during-disasters.pdf (USAID 2008)
7. https://www.jsi.com/JSIInternet/Inc/Common/_download_pub.cfm?id=11109&lid=3
8. Choi, T. M., Guo, S., & Luo, S. (2020). When blockchain meets social-media: Will the result benefit social media analytics for supply chain operations management? Transportation Research Part E: Logistics and Transportation Review, 135, 101860.
9. Callihan, D. R., Downing, M., Meyer, E., Ochoa, L. A., Petuch, B., Tranchell, P., & White, D. (2021). Considerations for Laboratory Biosafety and Biosecurity During the Coronavirus Disease 2019 Pandemic: Applying the ISO 35001: 2019 Standard and High-Reliability Organizations Principles. *Applied Biosafety.*
10. Chen, X., Chong, W. F., Feng, R., & Zhang, L. (2020). Pandemic risk management: resources contingency planning and allocation
11. COVID, W. (19). essential supplies forecasting tool. 2020.

12. Dolgui, A., Ivanov, D., & Rozhkov, M. (2020). Does the ripple effect influence the bullwhip effect? An integrated analysis of structural and operational dynamics in the supply chain. International Journal of Production Research, 58(5), 1285-1301.
13. de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Hingley, M., Vilalta-Perdomo, E. L., Ramsden, G., & Twigg, D. (2020). Sustainability of supply chains in the wake of the coronavirus (COVID-19/SARS-CoV-2) pandemic: lessons and trends. Modern Supply Chain Research and Applications.
14. Duque-Uribe, V., Sarache, W., & Gutiérrez, E. V. (2019). Sustainable supply chain management practices and sustainable performance in hospitals: a systematic review and integrative framework. Sustainability, 11(21), 5949.
15. Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1995). The impact of quality management practices on performance and competitive advantage. Decision sciences, 26(5), 659-691.
16. Fusco, A., Coraci, D., Frizziero, A., Giovannini, S., Biscotti, L., & Padua, L. (2020). Global approaches for global challenges: the possible support of rehabilitation in the management of COVID-19. Journal of medical virology, 92(10), 1739-1740.
17. Gaur, V., & Gaiha, A. (2020). Building a transparent supply chain. Harvard Business Review.
18. Guidance for procurement of in vitro diagnostics and related laboratory items and equipment. Geneva: World Health Organization; 2017.
19. Hendricks, K. B., & Singhal, V. R. (2003). The effect of supply chain glitches on shareholder wealth. Journal of operations Management, 21(5), 501-522.
20. Hill, R. R, Hazen, B. T., Skipper, J. B., Boone, & C. A., (2018). Back in business: Operations research in support of big data analytics for operations and supply chain management. Annals of Operations Research, 270(1), 201-211.
21. Hotrawaisaya, C., Said, R., Joseph, C., Rahmat, M., Abdullah, W. N., Radjeman, L. A., & Moryadee, C. (2020). Development of supply chain management sustainability index (SCMsi). International Journal of Supply Chain Management, 9(1), 902-907.
22. Ivanov, D., & Das, A. (2020). Coronavirus (COVID-19/SARS-CoV-2) and supply chain resilience: A research note. International Journal of Integrated Supply Management, 13(1), 90-102.

23. Ivanov D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation research. Part E, Logistics and transportation review, 136, 101922.
24. Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. International Journal of Production Research, 57(3), 829-846.
25. Ivanov, D., Sokolov, B., & Dolgui, A. (2014). The Ripple effect in supply chains: trade-off 'efficiency-flexibility-resilience' in disruption management. International Journal of Production Research, 52(7), 2154-2172.
26. John Snow, Inc. 2017. Quantification of Health Commodities: A Guide to Forecasting and Supply Planning for Procurement. Arlington, Va.: John Snow, Inc.
27. Kowalski, J. C. (1986). Just-in-time for hospitals--so what's new? Hospital material management, 11(11), 6-9.
28. Kelle, P.; Woosley, J.; Schneider, H. Pharmaceutical supply chain specifics and inventory solutions for a hospital case. *Oper. Res. Heal. Care* **2012**, *1*, 54–63.
29. Knowledge@wharton. Coronavirus and Supply Chain Disruption: What Firms Can Learn.
30. Lee, H. L., Padmanabhan, V., & Whang, S. (1997). The bullwhip effect in supply chains. Sloan management review, 38, 93-102.
31. Lynch, D. (1991). Just-in-time and stockless programs for hospitals: fad or trend? Hospital materiel management quarterly, 12(4), 17-21.
32. Landry, S.; Philippe, R. How Logistics Can Service Healthcare. *Supply Chain Forum Int. J.* **2004**, *5*, 24–30.
33. Mathew, J., John, J., & Kumar, S. (2013, May). New trends in healthcare supply chain. In annals of POMS conference proceedings; Denver (pp. 1-10).
34. Mikic, M., Puutio, A., & Gallagher, J. (2020). Healthcare products trade and external shocks: The US-China trade war and COVID-19 pandemic.
35. Nikolopoulos, K., Punia, S., Schäfers, A., Tsinopoulos, C., & Vasilakis, C. (2021). Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions. European Journal of Operational Research, 290(1), 99-115.

36. NEJM. (2020a). Critical supply shortages—The need for ventilators and personal protective equipment during the COVID–19 pandemic. *NEJM*.
37. Oruezabala, G., & Rico, J. C. (2012). The impact of sustainable public procurement on supplier management—The case of French public hospitals. Industrial Marketing Management, 41(4), 573-580.
38. Okeagu, C. N., Reed, D. S., Sun, L., Colontonio, M. M., Rezayev, A., Ghaffar, Y. A., ... & Kaye, A. D. (2020). Principles of supply chain management in the time of crisis. *Best Practice & Research Clinical Anaesthesiology*.
39. Péré, H., Podglajen, I., Wack, M., Flamarion, E., Mirault, T., Goudot, G., ... & Veyer, D. (2020). Nasal swab sampling for SARS-CoV-2: a convenient alternative in times of nasopharyngeal swab shortage. Journal of clinical microbiology, 58(6).
40. Pillai, S. V. Supply Chain Management in Healthcare Industry: A Critical Review.
41. Parsa, P., Shbool, M. A., Sattar, T., Rossetti, M. D., & Pohl, E. A. (2020). A Collaborative Planning Forecasting and Replenishment (CPFR) Maturity Model. *Int. J Sup. Chain. Mgt Vol*, *9*(6), 49.
42. Paul, S. K., & Chowdhury, P. (2020). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. International Journal of Physical Distribution & Logistics Management.
43. Paul, S., & Venkateswaran, J. (2020). Designing robust policies under deep uncertainty for mitigating epidemics. Computers & Industrial Engineering, 140, 106221.
44. Patel, A., D'Alessandro, M. M., Ireland, K. J., Burel, W. G., Wencil, E. B., & Rasmussen, S. A. (2017). Personal protective equipment supply chain: lessons learned from recent public health emergency responses. *Health security*, *15*(3), 244-252.
45. Queiroz, M. M., Ivanov, D., Dolgui, A., & Wamba, S. F. (2020). Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review. Annals of operations research, 1-38.
46. Saeed, M. A., Waseek, I., & Kersten, W. (2017). Literature review of drivers of sustainable supply chain management. In Digitalization in Maritime and Sustainable Logistics: City Logistics, Port Logistics and Sustainable Supply

Chain Management in the Digital Age. Proceedings of the Hamburg International Conference of Logistics (HICL), Vol. 24 (pp. 159-184). Berlin: epubli GmbH.

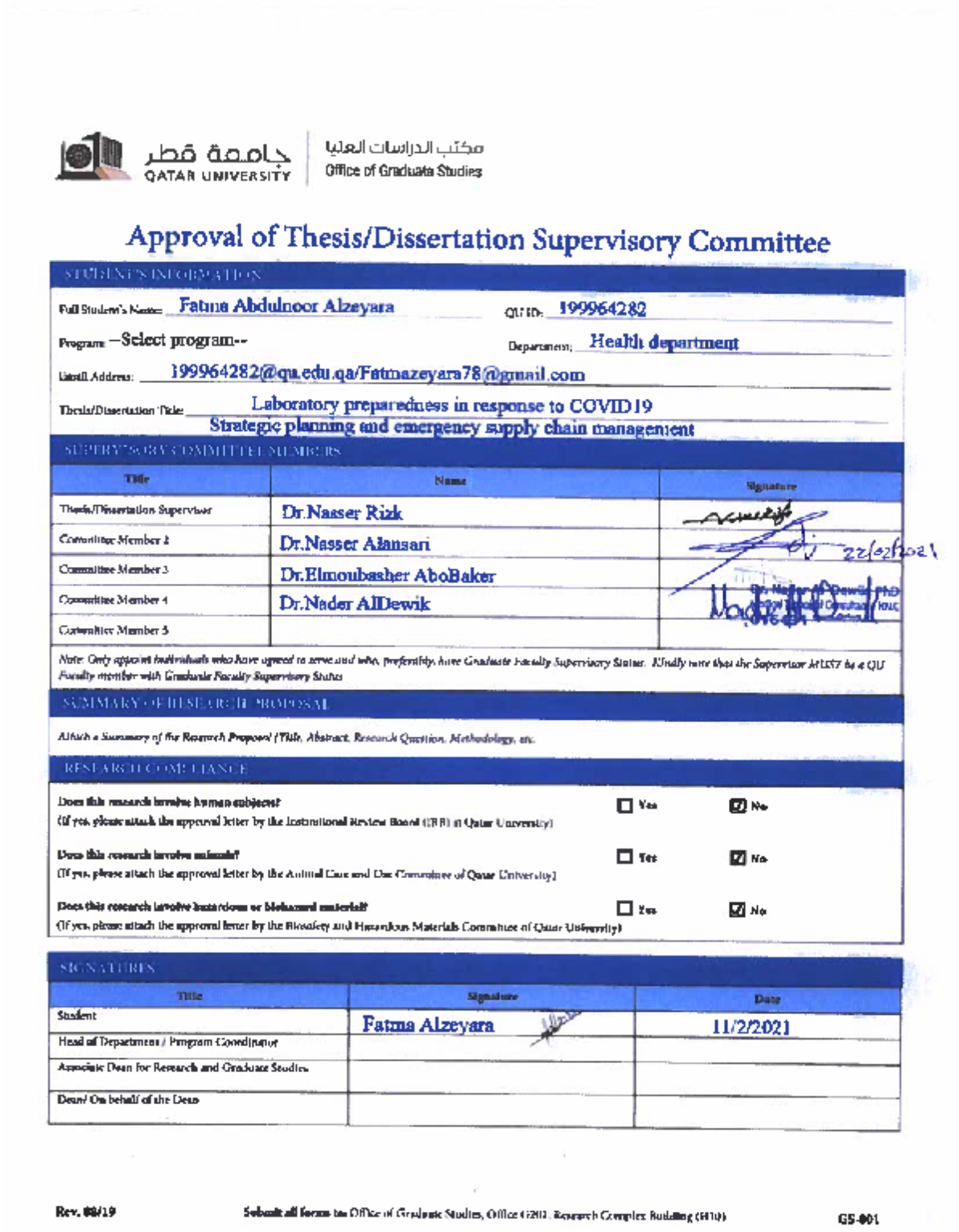
47. Sambit, T. (2017). *Basics of demand management for idiots*. https://www.slideshare.net/satripat/basics-of-demand- management-for-idiots
48. Schneller, E. S., Smeltzer, L. R., & Burns, L. R. (2006). Strategic management of the health care supply chain. San Francisco, 5.
49. Sloan, P. (2009). Redefining stakeholder engagement: From control to collaboration. Journal of Corporate Citizenship, (36), 25-40.
50. Sheffi, Y. Who Gets What When Supply Chains Are Disrupted? MIT sloan Manag. Review. 2020.
51. Sharma, A., Gupta, P., & Jha, R. (2020). COVID-19: Impact on health supply chain and lessons to be learnt. *Journal of Health Management*, *22*(2), 248-261.
52. Tang, C.S., 2006. Perspectives in supply chain risk management. International journal of production economics, 103(2), pp.451-488.
53. Team, IHME COVID-19 health service utilization forecasting, & Murray, C. J. (2020a). Forecasting COVID-19 impact on hospital bed-days, ICU-days, ventilator-days and deaths by US state in the next 4 months.
54. *USAID. Technical Report: Best practices in supply chain preparedness for public health emergencies. March 1, 2019.*
55. USAID | Deliver project, Task Order 1. 2008. Guidelines for Managing the Laboratory Supply Chain: Version 2. Arlington, Va.
56. Meerkatt et al. "UNICEF/WFP Return on Investment for Emergency Preparedness Study," (2015).
57. Volland, J., Fügener, A., Schoenfelder, J., & Brunner, J. O. (2017).material logistics in hospital: a literature review. *Omega*, *69*, 82-101.
58. Vong, Sirenda, Reuben Samuel, Philip Gould, Hammam El Sakka, Bardan J. Rana, Vason Pinyowiwat, Supriya Bezbaruah, and Roderico Ofrin. "Assessment of Ebola virus disease preparedness in the WHO South-East Asia

Region." *Bulletin of the World Health Organization* 94, no. 12 (2016): 913.

59. WILSON, R. L. (1992), Muralidhar, K., SWENSETHJ, S. R., Describing processing time when simulating JIT environments. The international journal of production research, 30(1), 1-11.
60. World Health Organization. (2013). Manual for procurement of diagnostics and related laboratory items and equipment.
61. World Health Organization. (2017). Guidance for procurement of in vitro diagnostics and related laboratory items and equipment. World Health Organization. (2020). Assessment of risk factors for coronavirus disease 2019 (COVID-19) in health workers: protocol for a case-control study.
62. World Health Organization. "WHO Simulation Exercise Manual," (2017).
63. World Health Organization, 2009. Hospital preparedness checklist for pandemic influenza. The Regional Office for Europe of the World Health Organization.
64. WHO/2019-nCoV/hospital_readiness_checklist/2020.2.
65. WHO (2020). Personal protective equipment. WHO. https://www.who.int/medical_devices/meddev_ppe/en/ World Economic Forum. (2020). Supply chains have been upended. Here's how to make them more resilient.
66. https://www.humanitarianlibrary.org/sites/default/files/2019/05/LOG-WarehousingandInventoryManagement-130519-0911-13124.pdf
67. Zhu, G., Chou, M. C., & Tsai, C. W. (2020). Lessons learned from the COVID-19 pandemic exposing the shortcomings of current supply chain operations: A long-term prescriptive offering. Sustainability, 12(14), 5858.
68. https://webcache.googleusercontent.com/search?q=cache:dq3WyO8DL5sJ:https://www.canada.ca/en/public-health/services/flu-influenza/canadian-pandemic-influenza-preparedness-planning-guidance-health-sector/laboratory-annex.html+&cd=1&hl=ar&ct=clnk&gl=qa

11. Appendix

11.1. Appendix "1"



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QATAR UNIVERSITY

مكتب الدراسات العليا
Office of Graduate Studies

Approval of Thesis/Dissertation Supervisory Committee

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Thesis/Dissertation Title: Laboratory preparedness in response to COVID19
Strategic planning and emergency supply chain management

SUPERVISORY COMMITTEE MEMBERS

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Committee Member 2	Dr.Nasser Alansari	22/02/2021
Committee Member 3	Dr.Elmoubasher AboBaker	
Committee Member 4	Dr.Nader AlDewik	
Committee Member 5		

Note: Only appoint individuals who have agreed to serve and who, preferably, have Graduate Faculty Supervisory Status. Kindly note that the Supervisor MUST be a QU Faculty member with Graduate Faculty Supervisory Status

SUMMARY OF RESEARCH PROPOSAL

Attach a Summary of the Research Proposal (Title, Abstract, Research Question, Methodology, etc.

RESEARCH COMPLIANCE

Does this research involve human subjects? ☐ Yes ☑ No
(If yes, please attach the approval letter by the Institutional Review Board (IRB) of Qatar University)

Does this research involve animals? ☐ Yes ☑ No
(If yes, please attach the approval letter by the Animal Care and Use Committee of Qatar University)

Does this research involve hazardous or biohazard materials? ☐ Yes ☑ No
(If yes, please attach the approval letter by the Biosafety and Hazardous Materials Committee of Qatar University)

SIGNATURES

Title	Signature	Date
Student	Fatma Alzeyara	11/2/2021
Head of Department / Program Coordinator		
Associate Dean for Research and Graduate Studies		
Dean/ On behalf of the Dean		

Rev. 08/19 Submit all forms to Office of Graduate Studies, Office 6203, Research Complex Building (RCB) GS-001

11.2. Appendix "2"

Laboratories preparedness in response to COVID19 pandemic
Strategic planning/Emergency supply chain management checklist

#	Objectives	Plan component		Not started	In progress	Intermediate progress	Completed
1.	**Pre-pandemic management plan document**	Ensure all preparedness plans for pandemic management includes; financial mechanisms, authorized administrative, procedures for the purchase and procurement of supplies is written and updated regularly.	1.1 Ensure availability of financial sources for emergency response				
			1.2 Written and updated financial process plan for accessing emergency fund				
			1.3 Written and updated purchasing and procurement plan				
2.	**Contingency plan for laboratories SCM source of funds**	Contingency plan to determine the laboratories SCM sourced and procedures of funds	2.1Govermental source				
			2.2 Private source				
			2.3 Donation (International /National/Community engagement)				
3.	**Coordination of SCM local partners to overcome supply shortage**	Establish pre-pandemic coordination plan between local health sectors (private sectors, local health institutions, and government entities) to provide physical capacity (supplies and warehouse) to surge capacity and overcome supplies shortage in laboratories	3.1 Private sectors				
			3.2 Local health institutions				
			3.3 Governmental entities (Ministry;health,finance,planning, development,transport)				
4.	**Coordination of SCM regional and international partners to provide supplies**	Coordinate and established agreement with regional and international partners of SCM to surge capacity and overcome supplies shortage in laboratories	4.1 Regional partners				
			4.2 International partners				

5.	**Coordination plan with SCM to develop forecasting tools**	Coordinate and develop preparedness plan to prepared and established sophisticated forecasting tools for supplies used in pandemic	5.1 National expertise in term of consultants				
			5.2 Regional partners				
			5.3 International partners				
6.	**SOP's for emergency Supply and logistic components**	Ensure written, update, and implement of all SOPs related to the laboratory's emergency Supply and logistics component (stockpile mobilization, telecommunications use, transportation, resources mobilization, security management).	6.1 Resources mobilization				
			6.2 Stockpile mobilization				
			6.3 Telecommunications use				
			6.4 Transportation				
7.	**Existence laboratories SC Information sources and network**	Development of pre-pandemic information network systems for laboratories to improved communication and information's flow along supply chain networks (LMIS)	7.1 Existence of LMIS designated according to the laboratories needs				
			7.2 upgrade Laboratories LMIS				
			7.3 Develop and implement plans to link laboratory data with key epidemiological data for timely data analysis				
8.	**IT infrastructure**	Availability of robust IT infrastructure for evolving and updating (availability of Big data and AI)	8.1 IT server infrastructure				
9.	**Designation of SCM core team**	Develop pre-pandemic designation of laboratories emergency supply chain core team and predetermined their roles and responsibilities (technical	9.1 Existence of core team				
			9.2 Designated of roles and responsibilities				

		lead, commodity plan lead, procurement lead, logistic lead)	9.3 Written document of the designation structure				
10.	**Preparedness plan for developing and training Core team and stakeholders**	Pre-pandemic Plan for developing and training the laboratories key stakeholders and ESCM team that involved in preparedness	10.1 Availability of pre-pandemic training program plan				
			10.2 Training programs exist at national level				
			10.3 Carried in routine basis for the ESCM team				
			10.4 Simulation as training program				
11.	**Monitoring and evaluation system for planned measured**	Begin establishing metrics and monitoring and evaluation systems to assess the effectiveness and impact of planned measures	11.1 Evaluation and Monitoring for all SCM system				
12.	**Human resources management**	Develop preparedness plan for laboratories supply chain human resource management in pandemic to ensure adequate staff capacity and continuity of operations	12.1 Plan for training existing staff in specific skills				
			12.2 Plan for mobilizing existing trained staff and other qualified staff with specific skills				
			12.3 plan for mobilizing other qualified staff from outside HMC				
			12.4 Plan for surge capacity of critical skills to continue laboratories functions during staff absenteeism				
			12.5 Monitored and assessed trained staff to ensure that they are appropriately selected to their duties				

13.	**Commodities identification**	Create a list to identify the type of laboratories resources needed in national laboratories includes 6 domain (Supplies related to samples, Transportation system, Semi-Durables, PPEs and IPCs, Consumables and RT-PCR complementary Equipment) needs for each pandemic disease	13.1 Presence of comprehensive list including all critical laboratories items for pandemic and its specifications				
			13.2 Updating all consumables of equipment's needs for pandemic				
14.	**Kinds of methods for Quantity forecasting**	Quantity estimation of laboratories critical commodities build on the specific methods or tools	14.1 Forecasting (F&Q) build on historical data (H1N1)				
			14.2 Assessment of current capacity of references laboratory lab				
			14.3 Number of people estimated to be at risk by Epi-data				
			14.4 Hazard assessment				
			14.5 Forecasting build on specific validated tools				
15.	**Coordination in forecasting**	Laboratories quantity forecasting and quantification carried by coordination with expertise partners (technical expertise in forecasting models, key laboratory person on private sectors and governmental institution, MOPH, emergency departments team)	15.1 Existence of Coordination bodies for quantity prediction and quantification of critical resources at the national laboratories level				
16.	**Written document and procedures**	Availability of written document and procedures for laboratories commodities planning (Q&S) and forecasting in emergency	16.1 Quantity estimation and forecasting document				
			16.2 Resources specification document				

17.	**Pre-pandemic agreement with suppliers**	Establishing a contingency agreement with suppliers identify potential risks, specify transport methods, and outline the quantity of essential commodities you will receive, replenish of critical commodities, and the lead time from each supplier in pandemic	17.1 Availability of pre-pandemic procurement agreement				
			17.2 Agreement with local suppliers				
			17.3 Agreement with regional suppliers				
			17.4 Agreement with international suppliers				
			17.5 Updated agreement regularly (1-2) yrs				
18.	**Pre-pandemic identifying a Pre-qualification Suppliers**	Pre-pandemic plan to identify a list of pre-qualified suppliers that will provision of commodities in pandemic and should be updated	18.1 List for all pre-qualified suppliers				
			18.2 List of first line suppliers				
			18.3 List of alternative suppliers				
			18.4 Update supplier list regularly				
19.	**equipment's maintenance contract**	Ensure all maintenance process for essential equipment that used in pandemic is reviewed and updated in contract	19.1 Apply all terms of contract stated clearly including maintenance				
			19.2 training of national reference lab. Staffs				
			19.3 ensure the backup equipment is included in plan (biosafety cabinet, PCR machines and incubators for cell culture)				
19.	**Assessing physical and environmental infrastructure Before procuring supplies**	Assessing Physical and environmental infrastructure of facilities before procuring commodities proceed for pandemic (space capacity, temperature, humidity, electricity, etc.)	19.1 assessing and mapping laboratories physical infrastructure and its compliant to national or international standards				
			19.2 Ensure that facilities have plans for increased demand on critical supplies				
			19.3 plan to address the need for additional space through the utilization of other laboratories				

			19.4 plan for sufficient storage capacity for storage of specimens, virus isolation,etc.				
20.	**Documentation**	Availability of written document and procedures for procurement protocols in pandemic	20.1 Availability of procurement documents				
			20.2 Updated regularly				
21.	**Pre-pandemic plan for laboratories warehouse management**	Establish laboratories contingency plan and strategy for Warehouse management during pandemic (surge capacity, restock, alternative warehouse)	21.1 Laboratories preparedness plan for surge capacity				
			21.2 Laboratories preparedness plan for alternative warehouse				
			21.3 Laboratories preparedness plan for stock replenish				
			21.4 Laboratories preparedness plan for inventories management				
			21.5 All plans are updated				
22.	**Numbers and kinds of warehouse for pandemic**	Warehouse numbers are meet the forecasting of essential commodities quantities	22.1 Sufficient number of warehouse and capacity to contain all critical supplies				
			22.2 Central owned government warehouse				
			22.3 Rent warehouse				
23.	**Warehouse location**	Warehouse is distributed in many geographical areas to ensure access of supplies in remote area	23.1 Easies accessibility to all emergency warehouses during the pandemic				
			23.2 Distributed in different geographical site to ensure rapid accessibility				
24.	**Warehouse environmental condition**	Warehouse environment is suitable for critical commodities storage and comply to WHO standards (accessibility, security, ambient	24.1 The stores conforming to the specifications according to the WHO standards				

		temperature, ventilation, light exposure, humidity)					
25.	**Additional storage Within National laboratory and hospital**	Identify physical space within the National laboratory and hospital for the storage and stockpiling of additional supplies	25.1 Availability of the additional storage and stockpiling space				
			25.2 Availability of additional cold chain storage area				
			25.3 documented procedure about reagents stockpiling				
26.	**Temporary Warehouse agreement**	Establish agreements for temporary local warehouse in pandemic. (rent , contribution & Shear, Donation or Build temporary warehouse)	26.1 Agreement with private sectors				
			26.2 Agreement with suppliers				
			26.3 Agreement with governmental institutions				
27.	**Agreement for stockpiling and restock**	Establish agreement to stockpiling critical inventories on warehouse during pandemic and ensure replenish the stock of the essential commodities with supplier during pandemic	27.1 Agreement for regional stockpiling supplier				
			27.2 Agreement for international stockpiling supplier				
28.	**Pre-pandemic transportation agreement with transportation agents**	Establishing a contingency transportation agreement with service providers and transportation services to ensure continual provision of critical resources	28.1 National or governmental transportation agreement				
			28.2 Privat logistic agent agreement				
			28.3 Regional transportation agreement				
			28.4 International transportation agreement				
			28.5 Availability of comprehensive operating procedures for the shipment of specimens to reference				

			laboratories or collaborative centers				
29.	**Pre-pandemic transportation agreement with suppliers to warehouse**	Develop transportation agreements with suppliers for emergency supply chain distribution procedure includes (# of vehicles, vehicles capacity, # and capacity of cold chain vehicles, time of response,)	29.1 agreement to ensure the commitment of the supplier to transport the supplies when needed to warehouse				
			29.2 Agreement to ensure readiness of suppliers to transport at any time during pandemic				
30.	**Alternative transportation agreement**	Develop alternative emergency transportation agreement with alternative bodies or partners	30.1 Military transportation services				
			30.2 Police transportation services				
			30.3 Others				
31	**Transportation services assessing**	Ensure all transportation services is monitored and evaluated by government	31.1 Ensure the Conforming to the required standard.				
			31.2 Ensure the good quality of the transported supplies.				
			31.3 Physically and Regularly check by governmental auditor or inspector				
32.	**Documentation**	Ensure all policies and procedures for transportation protocol in pandemic is written and updated	32.1 Availability of documentation				
			32.2 Updated				
33.	**Waste identifying and categorization**	Pre-pandemic planning and create list to identify each type of waste and categorized them according to their hazardous	33.1 list for sharp waste				
			33.2 list for non-sharp infectious waste				
			33.3 list for highly toxic waste				

34.	**Pre-pandemic planning to determine the waste producing facilities**	Pre-pandemic planning to determine main laboratories that will diagnose the pandemic disease to identify the most waste where located for infrastructure planning, storage, and transportation preparedness	34.1 laboratories waste infrastructure planning				
			34.2 transportation agreement				
			34.3 Storage facilities and capacity agreement				
			34.4 Availability of disposal area for waste management (gov, private)				
			34.5 Ensure waste management protocols should follow governmental rules				
35.	**Waste protocols**	Establish protocol for disposal of categorized waste in pandemic	35.1 SOP's for waste disposal protocol				
36.	**Pre-pandemic coordination**	Pre-pandemic coordination with expertise to establish waste management protocol	37.1 Expertise from governmental sectors				
			37.2 Expertise from private sectors				
			37.3 Expertise from local community				
37.	**Pre-pandemic waste disposal agreement**	Pre-pandemic agreement for waste disposal responsibilities	38.1 private company				
			38.3 regional				
			38.2 governmental				

	Names	AFFLITION	Signature
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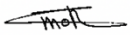
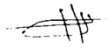
	Dr. Elmobasher Abu Baker	Acting Head of Communicable Diseases Control Programs Public Health Department	
	Dr.Eman Salah Dafaalla Abdalkheir	Supply Chain Manager Federal Ministry of Health, Sudan General directorate of Emergency and Epidemic Controlled	
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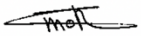
	Dr. Elmobasher Abu Baker		
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11.3. **Appendix "3"**

SWOT analysis of laboratory supply chain management in HMC

Strength	Weakness
1. Laboratories supply chain under the main SC department 2. SC department have designed structure includes; (procurement section, warehouse management section, forecasting section, administrative section, inventories management section and technical section) the roles, responsibilities, accountability, and authority are identified 3. Leaders have rational and right decision making 4. SCM have Clear vision and mission 5. Availability of written policies and procedures for all logistic protocols for routine SCM. 6. Follow JIT and safety stock strategy in inventory management 7. Multiple partners 8. strong relationship with suppliers 9. good vendors management and good in negotiation with vendors 10. have strict policies and rules in purchasing procedures	1. Needs to set comprehensive system for emergency supply chain management, which includes; - Creates SCM center for emergency for all local health sectors. - Create emergency team and training program for key stakeholder in local health sectors. - pre-pandemic agreements for coordination with health sectors to improve all SCM protocol in emergency. - Communication improvements between local health sectors before emergency in all SCM protocols. - Uses sophisticated tools and expertise for forecasting - Documentation of policies and procedures for supply chain management in emergency. - weakness flow of information's along supply chain. - broaden in sources of supplies - number of warehouses should proportionate to the number of forecasting supplies. - Establishes emergency agreements with suppliers to provides supplies, during emergency - Personnel management and training in emergency. - Warehouse and storage planning before emergency.

Opportunities	Threats
1. coordination with local and international partners for pandemic forecasting 2. move toward digital innovation, through employed information technology network to improve supply. 3. employed diversification approaches in procurement planning in emergency 4. Adopt One supply chain procurement approach 5. Used rail for transportation as solution in emergency to prevent delayed in delivery of products 6. Construct centralized national warehouse near seaport and airport for all health sectors in Qatar, and mapped the transportation route 7. Employed simulation a training program for SCM team 8. adopted sophisticated tools for emergency forecasting such as (optimization model). 9. Agreement with local suppliers to provide PPE during pandemic 10. Long- term agreement with local and international suppliers to provide diagnostic and preventive resources during pandemic. 11. Encourage local suppliers.	1. Uncertainty in patients demand, uncertainty in cost, uncertainty in supply. 2. Disruptive risk that caused by nature 3. Pandemic disease that overwhelming supply chain capacities 4. Destruction of supply chain networks. 5. Inability of capability to meet demand in pandemic. 6. Shortage of critical supplies causes increase patient's death. 7. Government regulatory and policies 8. Delayed procurement procedures. 9. Budgeting and funding issues. 10. Supplier's risk: - Shortage of diagnostic and preventive resources in market. - Plants closed in threats. - Shortage in row materials.