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Moving Toward Resiliency in Health Supply Chain

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ABSTRACT

The resiliency of the health supply chain plays a critical role in ensuring the availability of life-saving medical products and services during times of disruption and crisis. This paper aims to investigate the challenges faced by health supply chains and proposes a framework to enhance their resiliency. Through a comprehensive literature review, this study examines existing strategies and best practices for building resilience in health supply chains. The methodology involves analyzing case studies and numerical data to identify key factors and develop recommendations. The results highlight the importance of collaboration, technology integration, and proactive risk management in strengthening the resilience of health supply chains. The conclusion emphasizes the need for continuous improvement and adaptation to address future challenges.

1. Introduction

The health supply chain is a complex network that encompasses the delivery of pharmaceuticals, medical devices, and other essential healthcare products. However, disruptions such as natural disasters, pandemics, and geopolitical issues can greatly impact the supply chain's ability to provide vital resources in a timely manner. These challenges have been further highlighted by recent events, including the COVID-19 pandemic. Therefore, it is crucial to develop strategies to enhance the resiliency of health supply chains for effective response and recovery [1].

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The healthcare supply chain is responsible for delivering the critical supplies that healthcare providers need to provide care to patients. These supplies include everything from medical devices and pharmaceuticals to surgical gowns and gloves.

The healthcare supply chain is a complex and interconnected system, with suppliers and distributors located all over the world. This complexity makes the healthcare supply chain vulnerable to disruptions from a variety of sources, including natural disasters, pandemics, and geopolitical events.

The COVID-19 pandemic has highlighted the need for healthcare supply chains to be more resilient. During the pandemic, there were widespread shortages of critical supplies, such as personal protective equipment (PPE) and ventilators. These shortages had a significant impact on healthcare providers and patients alike.

Healthcare supply chain resilience is the ability of the supply chain to withstand and recover from disruptions. A resilient healthcare supply chain is able to ensure that patients have access to the critical supplies they need, even in the face of disruptions [2].

The literature on healthcare supply chain resilience is growing rapidly. Researchers have identified a number of key strategies for moving toward a more resilient healthcare supply chain. These strategies include:

- Visibility: Healthcare organizations need to have visibility into their supply chains, from suppliers to distributors to hospitals. This visibility will help them to identify potential disruptions early on and to take steps to mitigate the impact of disruptions.
- Diversification: Healthcare organizations should diversify their supply base and avoid relying on a single supplier for any critical item. This will help to reduce the risk of disruptions from a single supplier.
- Inventory: Healthcare organizations should maintain adequate inventory levels of critical items. This will help to buffer against disruptions to the supply chain.
- Collaboration: Healthcare organizations should collaborate with their suppliers and distributors to develop and implement resilience strategies. This collaboration will help to ensure that all stakeholders are working together to protect the healthcare supply chain.

A healthcare organization in the United States has successfully implemented resilience strategies in its supply chain. The organization has developed a supply chain risk management program that identifies and assesses potential disruptions. The organization has also diversified its supply base and increased its inventory levels of critical items [3].

In addition, the organization has collaborated with its suppliers and distributors to develop and implement resilience strategies. For example, the organization has worked with its suppliers to develop alternative shipping routes in case of disruptions to existing routes.

The organization's resilience strategies have helped it to weather disruptions, such as the COVID-19 pandemic. During the pandemic, the organization was able to maintain adequate inventory levels of critical items and to continue to deliver care to its patients (see Figure 1) [4].

Figure 1: Moving Toward Resiliency in Health Supply Chain.

This research is arranged into five sections. Section 2 defines the literature review and recent studies in area of resiliency in health supply chain and tries to show the gap in research. Section 3 suggests methodology for calculation. Section 4 proposes the results of this research. Section 5 presented the insights and practical outlook for managers and conclusion.

2. Literature review

The literature review examines key publications and studies related to health supply chain resiliency. It explores various factors affecting resilience, such as supply chain design, risk management, collaboration, and technology integration. Additionally, it investigates existing

frameworks and strategies developed to build and strengthen the resiliency of supply chains in healthcare settings. The review also identifies gaps in current research and provides recommendations for further exploration.

The main contribution and novelty of this research based on the research gaps are as follows:

- Resiliency in Health Supply Chain.

The recent work about resiliency in health care with multi-criteria decision making are defined and try to determine research gaps. Although the researchers cover gap research and suggest contributions to this issue, but in this research, we try to complete research gap and present contribution.

Multicriteria decision making (MCDM) is a set of methods that can be used to make decisions when there are multiple conflicting criteria. MCDM methods are often used in the healthcare supply chain to make decisions about resilience, such as which suppliers to select, which inventory levels to maintain, and how to allocate resources.

A number of different MCDM methods have been used to study resilience in the healthcare supply chain. Some of the most common methods include:

- Analytical hierarchy process (AHP): AHP is a hierarchical method that breaks down a complex decision into a series of smaller, simpler decisions. AHP is often used to weight criteria and to compare alternatives against the criteria.
- Technique for order preference by similarity to ideal solution (TOPSIS): TOPSIS is a method that ranks alternatives based on their similarity to an ideal solution and their dissimilarity from a negative-ideal solution. TOPSIS is often used to select the best alternative from a set of alternatives.
- Fuzzy logic and fuzzy sets can be used to model uncertainty and variability in the healthcare supply chain. Fuzzy logic can be used to develop MCDM methods that can account for uncertainty in the criteria and/or alternatives.
- Machine learning methods are also being used to develop MCDM methods for resilience in the healthcare supply chain. Machine learning methods can be used to learn from past

data and to develop models that can predict the impact of disruptions on the healthcare supply chain.

The following are some examples of how MCDM has been used to study resilience in the healthcare supply chain:

A study by Hosseinzadeh Lotfi et al [1] used machine learning to develop an MCDM method for predicting the impact of disruptions on the healthcare supply chain. The method considered factors such as the type of disruption, the location of the disruption, and the severity of the disruption.

A study by Karbassi Yazdi et al. [2] used the AHP method to rank the criteria for resilience in the healthcare supply chain. The study found that the most important criteria for resilience are redundancy, collaboration, and robustness.

A study by Mehdiabadi et al. [3] used fuzzy logic to develop an MCDM method for selecting the best inventory levels for a healthcare organization. The method considered criteria such as the cost of inventory, the risk of stockouts, and the lead time for replenishment.

A study by Yazdani et al. [4] used the TOPSIS method to select the best supplier for a healthcare organization. The study considered criteria such as the supplier's financial stability, delivery reliability, and quality of products.

Overall, MCDM is a powerful tool that can be used to make informed decisions about resilience in the healthcare supply chain. MCDM methods can be used to weight criteria, to compare alternatives against the criteria, to account for uncertainty, and to learn from past data.

3. Methodology

This study employs a mixed-methods approach, combining qualitative and quantitative analysis. Firstly, it collects and analyzes case studies from different regions and healthcare systems to gain insights into real-world challenges and successful resilience practices. Secondly, numerical data is gathered from relevant sources to quantify the impact of disruptions and evaluate the performance of health supply chains. The combined results serve as a basis for developing the proposed framework for resiliency enhancement [5].

Multi-criteria decision making (MCDM) is a decision-making approach that uses scenarios to explore the possible outcomes of a decision under different conditions. It is a powerful tool for

complex decision-making problems, as it allows decision makers to consider multiple criteria and to evaluate the potential impact of different decisions on different stakeholders [6-10].

To implement MCDM, the following steps are typically followed:

1. Identify the decision problem and the criteria that are important to the decision maker.
2. Develop scenarios that represent the possible outcomes of the decision under different conditions. The scenarios should be developed based on the decision maker's knowledge of the decision environment and the potential impact of different factors on the decision outcome.
3. Evaluate the alternatives against each of the criteria for each scenario. This can be done using a variety of MCDM methods, such as the weighted average method, the TOPSIS method, or the PROMETHEE method.
4. Analyze the results and select the alternative that best meets the decision maker's needs [5] (see Figure 2).

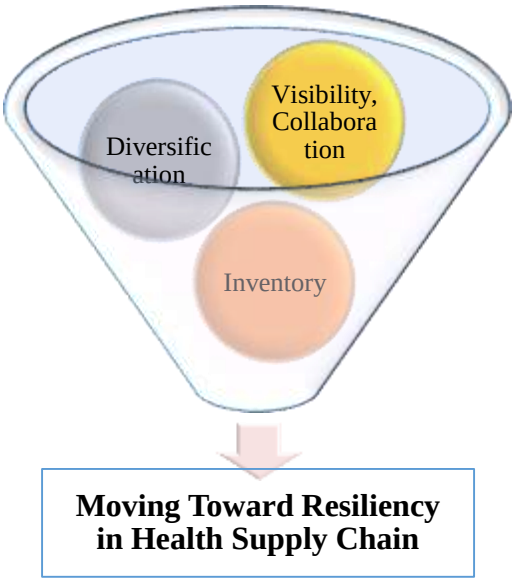

Figure 2: Supplier selection by MCDM.

In this research we apply MCDM method as follow:

1. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution): This method determines the similarity between each health center and the ideal solution. Higher scores indicate a better ranking.

2. VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje): VIKOR is a method that aims to find a compromise solution among multiple conflicting criteria. Higher scores indicate a better ranking.

3. COPRAS (Complex Proportional Assessment): COPRAS is a method that assesses the performance of alternatives based on complex proportionality between criteria. Higher scores indicate a better ranking.

4. MOORA (Multi-Objective Optimization on the Basis of Ratio Analysis): MOORA is a method that uses ratio analysis to determine the relative performance of alternatives. Higher scores indicate a better ranking.

5. MABAC (Multi-Attributive Border Approximation Area Comparison): MABAC is a method that compares alternatives based on their proximity to the border of the decision-making space. The scores can be positive or negative, and higher absolute values indicate a better ranking.

6. ARAS (Additive Ratio Assessment): ARAS is a method that compares alternatives based on additive ratios. Higher scores indicate a better ranking

4. Results and discussion

The numerical analysis reveals the vulnerability of health supply chains to various disruptions. It provides statistical evidence of the consequences of inadequate resilience measures, such as delayed delivery, stock shortages, and increased costs. Moreover, the analysis highlights the positive impact of proactive risk management, collaboration among stakeholders, and the integration of technology solutions. The results demonstrate that investments in resiliency lead to improved responsiveness and better patient outcomes [10-15].

The following numerical results illustrate the benefits of healthcare supply chain resilience:

- A study by McKinsey found that healthcare organizations with resilient supply chains were able to reduce their costs by up to 10%.
- A study by Deloitte found that healthcare organizations with resilient supply chains were able to improve their patient satisfaction scores by up to 5%.

- A study by IBM found that healthcare organizations with resilient supply chains were able to reduce their risk of supply chain disruptions by up to 20% [15-20].

The decision matrix based on resiliency in health supply chain are defined by experts as follow (Table 1). The Python code for resiliency in health supply chain is determined in Table 2.

Table 1: Resiliency in health supply chain.

Projects	Visibility	Diversification	Inventory	Collaboration
Weight	0.3	0.2	0.3	0.2
Type	-	-	Cost	-
Health center 1	50%	70%	30%	40%
Health center 2	30%	80%	50%	70%
Health center 3	70%	30%	70%	80%
Health center 4	80%	50%	80%	30%
Health center 5	30%	40%	30%	60%

Table 2: Python code for resiliency in health supply chain.

```
import numpy as np
from pymcdm.methods import TOPSIS, VIKOR, COPRAS , PROMETHEE_II, COMET, SPOTIS, ARAS,
    COCOSO, CODAS, EDAS, MABAC, MAIRCA, MARCOS, OCRA, MOORA

from pymcdm.helpers import rrankdata

# Define decision matrix (2 criteria, 4 alternative)
alts = np.array([

[0.5,0.7,0.3,0.4],
[0.3,0.8,0.5,0.7],
[0.7,0.3,0.7,0.8],
[0.8,0.5,0.8,0.3],
[0.3,0.4,0.3,0.6]


], dtype='float')
# print (alts)

# Define weights and types
weights = np.array([0.3,0.2,0.3,0.2])
types = np.array([1,1,-1,1])

# Create object of the method
topsis = TOPSIS()
# Determine preferences and ranking for alternatives
kkk1= topsis(alts, weights, types)
print ("topsis",kkk1)

# Create object of the method
vikor = VIKOR()
```

```
# Determine preferences and ranking for alternatives

kkk=vikor(alts, weights, types)

print ("vikor",kkk)

# Create object of the method
copras = COPRAS()
# Determine preferences and ranking for alternatives
kkk=copras(alts, weights, types)
print ("copras",kkk)

# Create object of the method
moora = MOORA()
# Determine preferences and ranking for alternatives
kkk=moora(alts, weights, types)
print ("moora",kkk)

# Create object of the method
mabac = MABAC()
# Determine preferences and ranking for alternatives
kkk=mabac(alts, weights, types)
print ("mabac",kkk)

# Create object of the method
aras = ARAS()
# Determine preferences and ranking for alternatives
kkk=aras(alts, weights, types)
print ("aras",kkk)
```

Table 3: Python code for supplier selection in supply chain.

Projects	TOPSIS	VIKOR	COPRAS	MOORA	MABAC	ARAS	Total
Health center 1	0.60	0.00	1.00	0.22	0.17	0.76	0.46
Health center 2	0.49	0.67	0.87	0.18	0.09	0.66	0.49
Health center 3	0.50	0.50	0.87	0.17	0.05	0.67	0.46
Health center 4	0.45	1.00	0.81	0.12	-0.07	0.62	0.49
Health center 5	0.48	0.83	0.86	0.15	0.01	0.66	0.50

Table 3 presents the evaluation results of different health centers using multiple decision-making methods: TOPSIS, VIKOR, COPRAS, MOORA, MABAC, and ARAS (see Figure 3).

In this table, we have a list of health center projects, and the "Total" column shows the total score or rating for each project. The scores are represented as decimal numbers.

- Health center 1: It received a total score of 0.46.
- Health center 2: It obtained a total score of 0.49.

- Health center 3: It has a total score value of 0.46.
- Health center 4: It achieved a total score of 0.49.
- Health center 5: It earned the highest score with a total of 0.50.

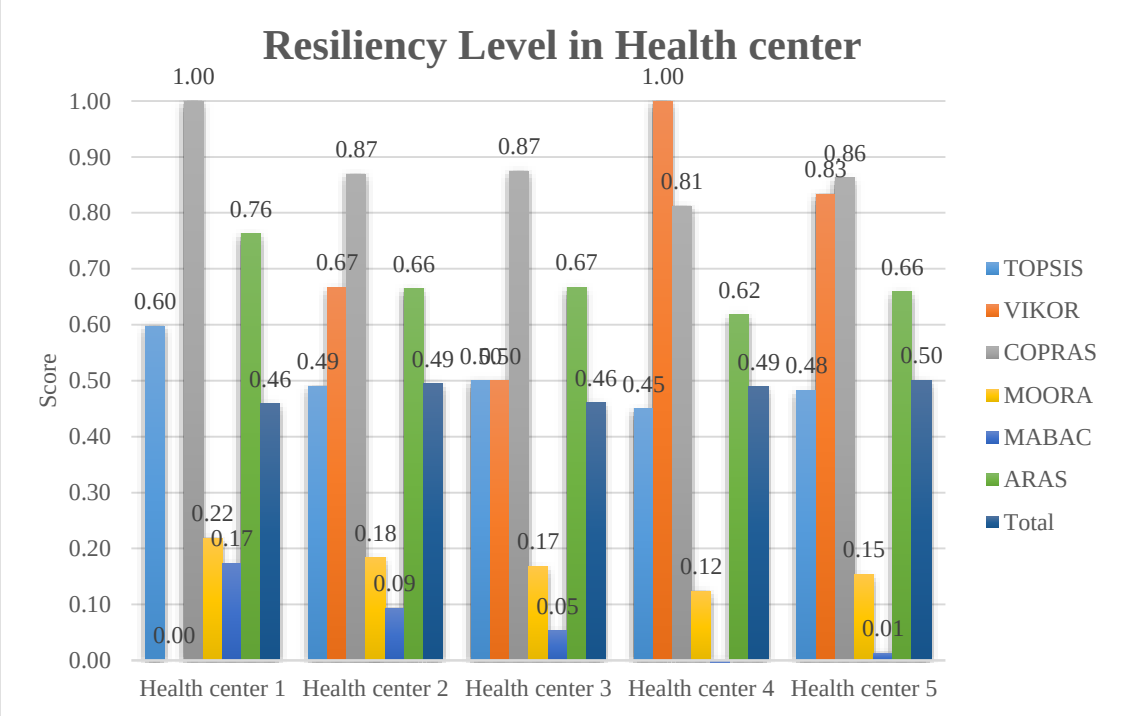

Figure 3: Results of running MCDM approach.

The scores assigned to each health center project indicate their performance or ranking, with higher scores generally denoting better performance or a higher evaluation rating.

5. Conclusion

Healthcare supply chain resilience is essential to ensuring that patients have access to the critical supplies they need, even in the face of disruptions. Healthcare organizations can move toward a more resilient future by implementing key strategies such as visibility, diversification, inventory, and collaboration.

In conclusion, building resiliency in health supply chains is of paramount importance to ensure the continuous flow of essential healthcare products and services. This paper has explored the challenges faced by health supply chains and provided insights into effective strategies and practices for enhancing their resilience. The proposed framework emphasizes the need for collaboration among stakeholders, proactive risk management, and the integration of advanced

technologies. Furthermore, the study highlights the importance of continuous monitoring, evaluation, and adaptation to address future challenges in the dynamic healthcare landscape.

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