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# The Effect of Pharmaceutical Supply Chain Risk Management on Building Resilience in Public Health Facilities across Four Wollega Zones, Ethiopia: A Mixed -Method Approach

**Gemechis Megnaka Hunde**

megnakagemechis@gmail.com

Wollega University

**Temesgen Dinsa Biyi**

Wollega University

**Habte Gebeyehu**

Wollega University

**Daba Zeleke Kedida**

Wollega University

**Tamirat Alemu**

Wollega University

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## Abstract

# Background

Ensuring consistent availability of essential medicines is a critical public health challenge, as pharmaceutical supply chains are vulnerable to disruptions, demand uncertainties, and infrastructure limitations. This study assessed the effect of pharmaceutical supply chain risk management practices on operational resilience within public health facilities.

# Method

This study used an explanatory sequential mixed-methods design: a cross-sectional quantitative phase followed by a phenomenological qualitative phase exploring respondents' lived experiences. The study included 38 health facilities, comprising 18 hospitals and 20 health centers, with 228 respondents. It was conducted from February to March 2025. Quantitative data were collected through self-administered structured questionnaires from supply chain managers, druggists, pharmacists, health facility administrators and system bottle neck focused reform members. Qualitative data were gathered through semi-structured in-depth interviews from health facility administrators and supply chain experts to understand the practices of supply chain risk management. Quantitative data was analyzed using descriptive analysis and Structural Equation Modeling, while qualitative data were analyzed by thematic analysis to identify key themes related to risk management and resilience-building.

# Result

Key pharmaceutical supply chain risks demand, supply, infrastructure, catastrophic, financial, and bureaucratic all demonstrated high severity (mean > 3.5). SCRM practices and resilience indicators were also reported positively. Path analysis revealed that SCRM practices had a significant, strong positive effect on supply chain resilience ($\beta = 0.78$, $p < 0.001$), explaining 61% of its variance. Risk assessment was the most influential SCRM component ($\beta = 0.59$, $p < 0.001$). Qualitative findings identified key barriers to full implementation, including limited awareness, human and financial resource constraints, and a lack of formal guidelines.by limited awareness, human and financial resource constraints, and a lack of guidelines.

# Conclusion

The adoption of structured pharmaceutical supply chain risk management practices significantly enhances operational resilience in public health facilities.

## Background

Supply Chain Management (SCM) coordinates key business processes including material flow, information exchange, demand planning, and customer service to efficiently transform raw materials into finished products and deliver them to end-users. It integrates activities across producers, suppliers, warehouses, logistics providers, and retailers, optimizing each step from sourcing to distribution. By streamlining these interconnected operations, SCM enhances product availability, reduces costs, and improves service delivery across the entire value chain(1).

The Pharmaceutical Supply Chain encompasses the delivery of healthcare products to consumers, requiring a supply of medicines that are safe, reliable, and adheres to established quality standards. This supply chain must be responsive to actual demand and aligned with consumer needs. It is governed by strict regulations throughout the entire process, including sourcing raw materials, manufacturing active ingredients, formulation, packaging, outsourcing, distribution, and product discontinuation(2). The pharmaceutical supply chain carries profound responsibility in combating illness and suffering, demanding precise delivery of the right medicines to the right patients at the right time and condition. Its inherent complexity coupled with direct impacts on health outcomes renders this supply chain uniquely sensitive, where customer service levels below 100% are clinically unacceptable(3, 4). In developing countries, ensuring a reliable supply of medicines is a top priority. Consequently, effective pharmaceutical supply chain management is crucial.

Supply Chain Risk Management and Supply Chain Resilience are closely connected, with effective risk management enhancing the resilience of supply chains, particularly in the pharmaceutical sector (2) .

A supply chain breakdown could impact every step of the product process, resulting in lost revenue, higher expenses, and a smaller market share, more dissatisfied customers, and harm to the brand. A disaster in a small area of the planet can disrupt half of the global supply chains, as demonstrated by the tsunami, earthquake, and nuclear accident in Japan, as well as the flood and nuclear incident in Thailand(5). About 73% of companies worldwide have encountered supply chain disruptions. This underscores that challenges like transportation shortages, rising prices, and raw material shortages driven by various geopolitical factors impact the sustainability of supply chain operations(6).

Supply chain hazards can manifest as disruptions in material flows, information flows, knowledge flows, or control and coordination flows, among other examples. Medical products are sometimes unavailable to healthcare organizations because of supply chain disruptions, inadequate information systems, poor information systems, and a lack of responsiveness and resilience(7, 8).

Early media reports on the war in Ukraine highlighted major disruptions in the availability of medicines and medical devices. These reports pointed to significant challenges in accessing medications during the initial phase of the war, particularly within the first 4–6 weeks following the invasion(9).

The earthquakes and a series of wildfires in the USA have revealed critical hazard in the supply chain of Vital Health Systems, especially regarding the availability of essential medical supplies. These natural disasters have affected supply chain management at numerous hospital facilities across the country.

The sudden surge in demand for vital medical products, coupled with limited inventory, has created a complex and urgent challenge, posing significant risks to patient care and the safety of healthcare workers(10).

The assessment conducted on designing a resilient supply chain: An approach to reduce drug shortages in epidemic outbreaks in Mexico highlighted that, with the country's health system facing structural challenges and only 70% coverage in medicine supply, effectively responding to a public health crisis like the COVID-19 pandemic requires the development of value-driven strategies to manage such emergencies. Building a resilient medicine supply chain to address unforeseen risks necessitates the involvement of all relevant stakeholders and strong leadership from the health department to coordinate and unify efforts(11).

A study conducted in the Malawi healthcare system reveals that relying on single sourcing strategies increases the risk of supply failures. It also highlights that such failures in healthcare delivery can have severe consequences, including patient fatalities(12).

The war Ethiopia's Tigray region healthcare system was severely impacted by the brutal nature of the conflict, leading to widespread damage to health facilities and significant shortages of medications and medical supplies. As a result, patients faced severe challenges in receiving proper care and treatment(13).

Although SCRM is crucial for pharmaceutical supply chains in Ethiopia, limited research has explored the effective management of these risks, which can significantly disrupt health facility operations. While some studies have addressed supply chain risks in sectors such as telecommunications which mainly focus on inbound risks without thoroughly analyzing their impacts(14).Moreover, the contexts of these sectors differ substantially from those of public health facilities, which require specialized management strategies for pharmaceuticals. Only one study has been conducted in the pharmaceutical sector, specifically concerning the Ethiopian Pharmaceutical Manufacturing Companies(15). Despite the adoption of various risk management strategies, their direct impact on enhancing supply chain resilience remains insufficiently explored, particularly in health facilities, which struggle to identify the most effective risk management approaches for resilience.

An important, yet overlooked issue in Ethiopia is the lack of comprehensive studies on pharmaceutical supply chain risks at lower-level supply chains (health facilities). This gap requires attention, as disruptions at these levels can significantly impact health services and disrupt the entire pharmaceutical supply chain. Furthermore, previous studies have mainly focused on either qualitative or quantitative approaches(16).Many studies also fail to incorporate advanced analytical techniques, such as Structural Equation Modeling (SEM)(7). As a result, a significant research gap exists in understanding how these factors interact to enhance resilience. This study aimed to fill that gap by integrating both qualitative and quantitative methods, providing a comprehensive analysis of the relationships between SCRM and SCR. The utilization of advanced statistical techniques, specifically SEM, provided enhanced analytical capabilities to assess how SCRM affected SC resilience.

SEM was essential for this study as it enabled the simultaneous analysis of complex, latent relationships that cannot be directly observed, specifically facilitating the rigorous testing and quantification of the direct effect of Supply Chain Risk Management practices on operational resilience. This capability directly addressed the core research question: What effect does Supply Chain Risk Management practices have on operational resilience within the pharmaceutical supply chains of public health facilities across the Wollega zones?

- By thoroughly evaluating existing practices, this study aims to address risks to medicine availability, providing actionable insights to help health facilities maintain consistent supplies despite disruptions. The findings offer evidence-based recommendations for policymakers and managers to strengthen supply chain resilience, with a focus on the specific challenges of the Four Wollega Zones to yield scalable solutions for similar low-resource settings. Additionally, it fills a critical gap in the academic literature on pharmaceutical supply chain risk management, establishing baseline data for future research while underscoring the importance of a resilient supply chain for sustainable healthcare and public trust in resource-limited contexts.

# Hypothesis

H: Supply Chain Risk Management Practices including Risk Identification (RI), Risk Assessment (RA), Risk Treatment (RT) and Risk Monitoring (RM) had a positive effect on Pharmaceutical Supply Chain Resilience of Public Health Facilities.

# Methods

## 1.1 Study Settings and Period

The study was conducted at the public health facilities across four Wollega Zones of Ethiopia. The Wollega zones, located in the Oromia region of Western Ethiopia, are divided into four administrative zones: East Wollega, West Wollega, Horro Guduru Wollega, and Kellem Wollega. These zones are bordered by the Benishangul-Gumuz and Amhara regions. Within these zones, there are 18 hospitals and 235 health centers; which play a key role in healthcare service delivery. The diverse landscapes and varying levels of infrastructure, transportation, and resource availability across the zones create distinct challenges for managing pharmaceutical supply chains. Additionally, the zones face several risks, including supplier-related risks, demand variability, and logistical challenges, which further complicate the efficient delivery of pharmaceuticals. This diversity provides a valuable context for evaluating the SCRM and resilience strategies of public health facilities across these areas. The study was conducted from February to March 2025.

# 1.2 Study Design

The study employed an explanatory sequential mixed-methods design. This integrated a cross-sectional design for quantitative data to statistically analyze SCRM and SCR within the pharmaceutical supply chain, providing measurable insights. Complementing this, a phenomenological design was used for qualitative data to explore underlying experiences and perspectives. To achieve this, concurrent triangulation study data was utilized. Concurrent triangulation was required for this study to integrate both quantitative and qualitative data, enhancing the overall validity and robustness of the findings.

## 1.2.1 Source Population

The source population for this study comprised all public health facilities located in the four Wollega Zones of Ethiopia: West Wollega, East Wollega, Kellem Wollega, and Horro Guduru Wollega, along with their staff engaged in pharmaceutical supply chain activities. This included personnel directly responsible for PSC management, such as pharmacists, druggists, supply chain managers, store managers, facility administrators, and key decision-makers, such as System Bottleneck Focused Reform (SBFR) members.

## 1.2.2 Study Population

Participants were drawn from employees engaged in pharmaceutical supply chain operations at selected public health facilities. This included pharmacists, druggists, supply chain managers, store managers, facility administrators, and key decision-makers (e.g., System Bottleneck Focused Reform (SBFR) members).

# 1.3 Inclusion and Exclusion Criteria

## 1.3.1 Inclusion Criteria

The study included public health facilities located within the four Wollega Zones;West Wollega, East Wollega, Kellem Wollega, and Horro Guduru Wollega that were actively engaged in pharmaceutical supply chain activities. Eligible participants must occupied relevant roles such as druggist, pharmacist, pharmaceutical supply chain managers, store managers, facility administrators and decision makers. Participants had at least six months of experience in their current positions to ensure they have adequate insight into the supply chain processes.

## 1.3.2 Exclusion Criteria

The study excluded individuals whose roles were not directly related to the pharmaceutical supply chain, those with less than six months of professional experience, employees who declined to participate in the questionnaire, and participants who were unavailable during the data collection period.

# 1.4 Sample size determination and sampling procedures

## 1.4.1 Sample Size Determination

By utilizing a standard sampling formula for statistical significance typically suggests a larger sample size; however, considering resource limitations, a minimum threshold of either 100 facilities or 15% of the total was set, selecting the smaller of the two. The sampling frame was established by stratifying the facilities by type, allowing evaluators to randomly select sites proportionally within each stratum while ensuring that the supply chain between different levels of facilities remains intact(17).

According to reports from the Zonal Health Departments there were 18 public hospitals and 235 health centers, totaling 253 health facilities across the four Wollega Zones(18). As per the USAID LIAT (Logistics Indicators Assessment Tool) guideline, 15% of these facilities amounting to 38 were selected for the study. Given the availability of human resources and sufficient data, all hospitals were included in the survey. 5 ,6,4 an3 hospitals were included from East Wollega,West Wollega,Kellem Wollega and Horro Guduru Wollega respectively. From the health centers, 20 were selected for the research. In total, 38 health facilities from the four Wollega Zones were included in the study.

Yamane (1967) offers a simplified formula for calculating sample sizes (19). As per Zonal Health Departments report, there were 511(386 from hospitals and 125 from health centers) people directly involved in PSC management practices in the selected facilities of these zones. 154,145,108 and 104 people were directly involved in PSC from West Wollega, East Wollega, Kellem Wollega and Horro Guduru Wollega respectively(18). Hence, by using the Yamane's formula, the sample size for this study was calculated as follows:

| | |
|---|---|
| $n=\frac{N}{1+(N)(e2)}$ | Where n = is the sample from the population N= Total populations |
| | e= level of precision which is 5% |
| n ≈ 224 | 95 confidence interval and p = 0.05 are assumed |

Considering a 10% contingency for non-respondents, the final sample size was 246 participants. A total of 186 respondents were proportionally included from hospitals, while 60 respondents were included from health centers. The selection consisted of 10 participants from each of the 15 hospitals, with 12 participants from each of the three tertiary hospitals. For health centers, 3 participants were selected from each of the 20 centers.

## 1.4.2 Sampling Techniques

The sampling procedure that was adopted in this study was the probability sampling method, ensuring that each member of the target group has an equal, non-zero chance of being selected for the sample. Stratified sampling technique was used to classify the public health facilities into different strata according to its type: hospitals and health centers (HCs). This stratification guarantees the representation of both types of facility and enables a comparison of supply chain practices in hospitals and health centers. In addition, health centers are categorized based on their respective zones. There were 68, 69, 49, and 49 health centers in East Wollega, West Wollega, Kellem Wollega, and Horro Guduru

Wollega, respectively(18). Proportionately, 6, 6, 4, and 4 health centers were randomly selected from these zones (Fig. 1).

The health facilities in each stratum were selected by simple random sampling. Simple random sampling within each stratum guarantees that every category where the researcher employed systematic errors includes every facility in equal probability, which means non-representative facilities was not bias the sample.

In-depth face-to-face interviews, employing non-probabilistic purposive sampling, were conducted with supply chain experts, facility administrators, and SBFR members to examine SCRM practices and supply chain resilience. These experts possess adequate knowledge and experience in this area. These interviews was took place in both hospitals and health centers to collect qualitative data. A total of 12 participants were included in the study, selected from all zones. The sample size was determined based on the principle of information saturation. The participants comprised nine key informants from hospitals and three from health centers. Before the actual data collection, two preliminary interviews were took place with supply chain experts to address any ambiguities or misconceptions in the semi-structured interview guides.

# 1.5 Study Variables

## 1.5.1 Dependent Variable

### Supply Chain Resilience

The dependent variable in this study was Supply Chain resilience, which was assessed through several key constructs, including flexibility, adaptability, redundancy, collaboration, agility, robustness, and visibility.

## 1.5.2 Independent Variable

### Supply Chain Risk Management

For this study, the independent variable was Supply Chain Risk Management, measured by constructs such as Risk Identification, Risk Assessment, Risk Treatment, and Risk Monitoring.

# 1.6 Measurements

The study focused on two primary constructs: Supply Chain Risk Management and Supply Chain Resilience. Each construct was evaluated through various indicators or sub-constructs, with latent were measured using different items or questions.

# 1.7 Data Collection Instruments and Procedures

The study was primarily relied on primary data, complemented by secondary data sources to supported and enhance the research. Primary data were collected from public health facilities using a combination

of structured questionnaires and semi-structured in-depth interviews with key respondents. Quantitative data were collected using a structured questionnaire administered by four data collectors, while qualitative insights were gathered through semi-structured interviews. The data collection instrument consisted of five sections **(Annex II).** Section I included seven demographic questions capturing respondents' gender, age, education level, type of health facility, work unit, professional experience, and experience in current position. Section II, structured around six sub-sections, and assessed PSC-related risks via Likert-scale questions. Section III comprised questions evaluating SCRM practices, while Section IV focused on supply chain resilience in pharmaceutical supply chain management. Sections II, III and IV employed a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) for agreement-based responses. Finally, Section V contained four semi-structured, in-depth interview questions for qualitative insights. The questionnaires used were adapted and from related earlier studies customized(7, 15, 20). The full questionnaire is available as Supplementary File 1

Qualitative data were collected by the Principal Investigator (PI).The data collector conducted in-depth; face-to-face interviews with key informant (KI) using semi-structured questionnaires. At the start of each interview, the data collector explained the interview's structure and reminded participants that they can withdraw at any time. During the interviews, the interviewer used a mobile app voice recorder, notebook, and pen to record and take notes. The recording began only after informed consent was obtained from each participant.

The face-to-face in-depth interviews were recorded using mobile app voice recorder, with the participant's consent, to ensure an accurate record that can be reviewed for analysis. The interviewer has also taken basic notes as a backup in case of any issues with the recorder. After each interview, the recording was promptly checked for any problems. Although the duration of the interviews may vary based on each respondent's ability and willingness, the range of 30 to 45 minutes was allotted for the interview session. The audio recording ended once the participant has answered the final question.

Each participant was assigned a unique identification code based on position, age, and years of experience. Interviews employed techniques including participant observation, open-ended questions, probing, and collaborative dialogue, conducted in Afan Oromo and audio-recorded.

# 1.8 Data Analysis and Presentation

The quantitative data was sorted and coded before it was entered into EpiData version 4.6. Subsequently, it exported to SPSS version 27 and AMOS version 26 for analysis. Socio-demographic variables were analyzed descriptively and results were presented as frequencies and percentages.

For the quantitative analysis, statistical methods were employed to evaluate survey data. Descriptive statistics summarized the responses, providing an overview of the data, while inferential statistics identified patterns and correlations within the dataset, allowing for deeper insights into the findings. Additionally, Structural Equation Modeling was utilized to explore complex relationships independent variables and assessed their impact SC on resilience. In parallel, qualitative analysis involved thematic

analysis of data from interviews which helped identify recurring themes, challenges, and effective strategies.

For inferential statistical analysis, a two-step approach using structural equation modeling (SEM) was employed. SEM includes two components: the outer model (measurement model) and the inner model (structural model). The initial step in SEM involved validating the measurement model through various tests, including convergent validity, discriminant validity, indicator reliability, and composite reliability.

To establish convergent validity, it was important to consider the factor loading of the indicators, composite reliability (CR), and the average variance extracted (AVE). The AVE value should range from 0 to 1 and must exceed 0.50 to be deemed sufficient for establishing convergent validity. Discriminant validity can be evaluated using methods such as cross-loading of indicators, the Fornell & Larcker criterion, and the Heterotrait-monotrait (HTMT) ratio of correlation. When examining cross-loading, the factor loadings of indicators for the designated construct should be higher than those for all other constructs, with a cut-off value for factor loading set above 0.70. Composite reliability measures how well the indicator variables converge and share variance. It offers a more accurate evaluation of reliability compared to Cronbach's alpha. A value above 0.70 is generally considered acceptable Composite reliability measures how well the indicator variables converge and share variance. It offers a more accurate evaluation of reliability compared to Cronbach's alpha. A value above 0.70 is generally considered acceptable indicator reliability refers to the proportion of variance in an indicator that can be attributed to the latent variable, with values ranging from 0 to 1. The outer loading value should exceed 0.70, and indicators with outer loadings between 0.40 and 0.70 may be considered for removal if doing so enhances composite reliability and average variance extracted (AVE). Conversely, indicators with outer loadings below 0.40 should always be eliminated. These has ensured measurement quality by retaining strong indicators and eliminating weak or non-contributory ones(21–23)

Before conducting the statistical analysis, the common underlying assumptions, including normality, linearity, multicollinearity, and homoscedasticity, were tested. Data normality was assessed by examining skewness and kurtosis after removing significant multivariate outliers ($p < .001$) identified via Mahalanobis distance. For the medium-sized sample ($50 < n < 300$), normality was considered acceptable based on conventional SEM/AMOS standards, as the absolute skewness and kurtosis values did not exceed 3.29(24). Variables exceeding these limits were flagged as non-normal and addressed accordingly. To test for multicollinearity among predictor variables, tolerance and Variance Inflation Factor (VIF) statistics were used, with cut-off points of $> 0.2$ for tolerance and $< 3$ for VIF. A correlation analysis was performed to evaluate the strength and direction of the linear relationships between the variables. This analysis also helped to identify significant variables for inclusion in regression analysis, while excluding those with insignificant relationships. Pearson's product-moment correlation coefficient (r) was used to evaluate these relationships(22, 25).Following this assumption checks, Exploratory Factor Analysis (EFA) was conducted to extract variables with eigenvalues greater than one and factor loadings above 0.4, utilizing principal component analysis. Additionally, the internal consistency of the measured variables was assessed through reliability tests, employing both Cronbach's α and composite

reliability, with an acceptable threshold set above 0.70 for both metrics. Composite reliability was provided a more nuanced evaluation of reliability by measuring how well indicator variables converge and share variance(26).The analyzed quantitative data were displayed using frequency tables, percentage tables.

Confirmatory factor analysis (CFA) was conducted in AMOS software using maximum likelihood estimation to validate the measurement model. Model fit was assessed using multiple goodness-of-fit indices. Commonly accepted fit indices and their recommended thresholds include GFI, CFI, AGFI, NFI, TLI, and RFI (> 0.90), RMSEA (< 0.50), and CMIN/df (< 5.0) or a p-value > 0.05(27). Following measurement model validation, structural path analysis was performed to evaluate the strength of relationships between constructions. Hypotheses were tested based on standardized path coefficients (β) and statistical significance (p-value)(26, 28, 29) .

Qualitative data analysis employed a systematic thematic approach. The process began with data immersion, involving repeated review of interview transcripts to ensure deep familiarity with participants' perspectives. Next, initial coding was conducted to identify meaningful units related to how respondents interpreted their supply chain experiences. Through iterative pattern recognition, these codes were grouped into provisional themes. Emergent themes then underwent rigorous validation through constant comparison against raw data and team deliberation to ensure interpretive credibility. Finally, thematic synthesis organized validated themes into a coherent narrative structure, maintaining fidelity to participants' lived experiences while addressing the research objectives. This methodology ensured all conclusions were grounded directly in empirical evidence.

Ultimately, the key concepts identified and refined from the qualitative study was cross-checked with significant findings from the quantitative data. This triangulation aimed to enhance the study's credibility, provide a detailed examination of the research topic, and minimize potential biases or limitations, thereby strengthening the trustworthiness of the main findings. The qualitative results were presented through narrative descriptions and quotations from key respondents to illustrate their general concepts.

# 1.9 Data Quality Assurance

To test their content validity, the questionnaires were pre-tested with employees from Bako Hospital and Tibe Health Center which had been randomly selected from West Shoa zone; outside of study area. A reliability test was conducted on the measurement items using Cronbach’s alpha. The obtained Cronbach’s alpha values ranged between 0.706 and 0.841, exceeding the recommended threshold(30) **(Annex III).** Consequently, all items were deemed reliable for use in the actual data collection. This pilot study helped to validate the survey tools, standardize the questionnaire, and identify any potential issues, such as unclear instructions or insufficient time limits. Based on the feedback from the pilot study, necessary revisions were made to clarify, simplify, and improve the comprehensiveness of the items, further ensuring their content validity. To ensure high-quality data, four data collectors with pharmacy backgrounds and over one year of experience in supply chain management were recruited. Additionally, they received a one day training session covering data collection techniques, the study's objectives and

significance, and procedures to maintain data accuracy. Each day, the completeness of the collected questionnaires was reviewed to verify data integrity.

Throughout the data collection phase, frequent follow-ups were conducted to ensure a high response rate and provide any necessary clarifications to respondents. Once the questionnaires were completed, it was reviewed for completeness. The information was re-checked for completeness. Additionally for qualitative data, key respondents were engaged during the data collection process by asking for clarifications, probing deeper and confirming responses to ensure accurate interpretation of the interview guide questions.

The investigator personally conducted the interviews to ensure uniformity in the collected data. To guarantee reliability, the qualitative data quality assurance was measured through dependability, transferability, conformability, and credibility. Incorporating different viewpoints during data collection helps ensure data correctness and appropriateness, thereby helping ensure credibility. This was achieved using methods including member checks, participant validation, investigator triangulation, theoretical triangulation, data triangulation, and strict data collection procedures. Transferability was attained by providing an in-depth overview of participants and the study environment. Dependability required careful data gathering methods and well-documented analysis processes. Conformability was established by examining and confronting personal prejudices. Finally, audit trial triangulation was performed to document the study procedure and confirm it with independent reviewers(31).

# 1.10 Ethical Consideration

### Ethical approval

for this study was obtained from the Institutional Research Ethical Committee of Wollega University (Reference Number: IHS REC/03/113/2025(Annex IV)). This study was conducted in accordance with the Declaration of Helsinki. Following the approval, official letters of cooperation were sent to selected health facilities to obtain their consent for the study. Before beginning data collection at the facilities, permission was obtained from the head of the facility after presenting the cooperation letter. Prior to data collection, the study's objectives were explained to the participants, and verbal consent was obtained from them. Participants were assured that their information would remain confidential and that the study would adhere to ethical standards, using the data solely for research purposes. To maintain confidentiality, participants' names and departmental affiliations were not recorded on the questionnaires; instead, a coding system was used. **Dissemination Plan**

The study's findings will initially be presented to the School of Pharmacy. The final thesis document will then be submitted to the School of Pharmacy, Institute of Health, at Wallaga University. Additionally, the findings will be shared with the Federal Ministry of Health (FMOH), Oromia Regional Health Bureau (ORHB), Zonal Health Departments through workshops or scientific conferences. Finally, efforts will be made to publish the results in reputable national or international journals.

# 1.11 Definition of key terms of study variables

### Supply Chain Risk Management

Supply Chain Risk management in the public sector involves establishing a corporate and systematic approach to evaluate and address risks effectively and economically, while ensuring that staff possesses the necessary skills to identify and assess potential risks. SCRM is identifying potential risk sources and implementing suitable strategies through coordinated efforts among supply chain participants to minimize vulnerability in the supply chain(12, 32).

### Pharmaceutical Supply Chain

PSC is a network structure consisting of upstream and downstream pharmaceutical companies, hospitals, and pharmacies involved in the production and distribution of pharmaceuticals. It encompasses the process of delivering medications or medical services to end patients or users(33).The pharmaceutical supply chain connects a diverse array of stakeholders, including raw material manufacturers, distributors, healthcare institutions, physicians, retailers, and patients, each with their own objectives. This supply chain aims to develop effective strategies and models for the timely delivery of medicines and medical devices to ensure that products reach patients promptly(34).

### Supply Chain Resilience

Supply chain resilience refers to an organization's capability to withstand stress from various external factors and continue operating effectively, even in the face of unexpected or disruptive events(32).Resilient supply chains in hospitals enable them to handle stress from various external factors and ensure continued functionality despite unexpected or disruptive events(7).

### Public Health Facilities

Health facilities, including hospitals and health centers, provide essential medical care. Hospitals offer specialized treatments and emergency services, while health centers focus on primary care and prevention, such as check-ups and vaccinations. Together, they are vital for promoting health and meeting community healthcare needs.

# Results

# 2.1 Socio-demographic characteristics of study participants

Out of 246 questionnaires distributed, 228 were completed and returned, yielding a response rate of 92.7%. Most respondents were male, accounting for 158 (69.3%). Additionally, the largest age group was 30 to 39 years old, comprising 107 respondents (46.9%).A large majority of respondents 176(77.2%) were from hospitals. In terms of educational qualifications, most participants held a Bachelor of Pharmacy (BPharm) degree, representing 150(65.8%) of the sample. Most respondents worked in dispensing units 77(33.8%). Over half of the participants 126(55.3%) had less than five years of

experience at their facility, with a significant portion 98(43.0%) reporting 3–4 years of experience in their current position (Table 1).

Table 1
Socio-demographic Characteristics of Study Respondents from Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Variables | Items | Frequency (%) |
|---|---|---|
| **Gender** | Male | 158 (69.3) |
| | Female | 70 (30.7) |
| **Age** | 20–29 | 78 (34.2) |
| | 30–39 | 107 (46.9) |
| | 40–45 | 31 (13.6) |
| | > 45 | 12 (5.3) |
| **Level of Education** | Diploma | 40 (17.5) |
| | BPharm Degree | 150 (65.8) |
| | MSc/MA | 24 (10.5) |
| | Other | 14 (6.1) |
| **Type of Health Facility** | Hospital | 176 (77.2) |
| | Health Center | 52 (22.8) |
| **Current Department** | Dispenser | 77 (33.8) |
| | SC Officer | 36 (15.8) |
| | Store Man | 39 (17.1) |
| | Pharmacy Head | 35 (15.4) |
| | Facility Administrator | 31 (13.6) |
| | Key Decision Maker | 10 (4.4) |
| **Experience at Facility** | 6months- 1 year | 8 (3.5) |
| | 1–5 years | 126 (55.3) |
| | 6–10 years | 68 (29.8) |
| | 11–15 years | 26 (11.4) |
| **Experience in Position** | < 1 year | 9 (3.9) |
| | 1–2 years | 61 (26.8) |
| | 3–4 years | 98 (43.0) |
| | > 4 years | 60 (26.3) |

# 2.2 Pharmaceutical Supply Chain Related Risks in Selected Public Health Facilities

## 5.2.1 Demand Related Risks

Regarding demand-related risks, 117 respondents (51.3%) acknowledged forecasting challenges, including lead time variability, product diversity, short life cycles, information distortion, and demand exaggeration. Additionally, 26 participants (11.4%) strongly agreed that unanticipated customer demand and market volatility posed significant risks. The aggregate mean response score for this demand-related risk was 3.66(Table 2).

Table 2
Descriptive Statistics of Demand-Related Risks In Public Health Facilities In Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD | DA | NA | A | SA | Mean |
| | *(%)* | *(%)* | *(%)* | *(%)* | *(%)* | |
| Customers' unanticipated or very volatile demand | 1 (0.4) | 25 (11.0) | 78 (34.2) | 98 (43.0) | 26 (11.4) | 3.54 |
| Insufficient or distorted information, orders, or specifications from customers | 1 (0.4) | 17 (7.5) | 74 (32.5) | 112 (49.1) | 24 (10.5) | 3.62 |
| Risks in forecasting (lead times, product variety, short life cycles, etc.) | 0 (0.0) | 12 (5.3) | 74 (32.5) | 117 (51.3) | 25 (11.0) | 3.68 |
| Customers place orders consistent with nominated product specifications | 1 (0.0) | 6 (2.6) | 62 (27.2) | 126 (55.3) | 33 (14.5) | 3.81 |
| Grand Mean | | | | | | 3.66 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree.

## 5.2.2 Supply Related Risks

Most of the respondents 119 (52.2%) agreed that dependency on key suppliers posed a risk. Nearly a quarter 54 (23.7%) strongly agreed that poor partnership/coordination with suppliers was problematic. Additionally, most participants 121 (53.1%) acknowledged poor logistics performance by service providers. Over half 126 (55.3%) confirmed risks from capacity fluctuations or supply market shortages (non-availability of resources). The average response score across these supply-related risks was 3.903 (Table 3).

Table 3
Descriptive Statistics of Supply-Related Risks In Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Poor logistics performance of suppliers (e.g., delivery, dependability) | 0 (0.0) | 5 (2.2) | 68 (29.8) | 125 (54.8) | 30 (13.2) | 3.79 |
| Dependency on key supplier | 0 (0.0) | 4 (1.8) | 58 (25.4) | 119 (52.2) | 47 (20.6) | 3.92 |
| Poor communication with suppliers | 1 (0.4) | 7 (3.1) | 48 (21.1) | 122 (53.5) | 50 (21.9) | 3.93 |
| Poor partnership/coordination with supplier | 2 (0.8) | 4 (1.8) | 49 (21.5) | 119 (52.2) | 54 (23.7) | 3.96 |
| Supplier quality problems | 2 (0.8) | 6 (2.6) | 51 (22.4) | 128 (56.1) | 41 (18.0) | 3.88 |
| Poor logistics performance of logistics service provider | 2 (0.8) | 9 (3.9) | 47 (20.6) | 121 (53.1) | 49 (21.5) | 3.90 |
| Increase in product prices by supplier, product expiration on shelves | 0 (0.0) | 9 (3.9) | 44 (19.3) | 126 (55.3) | 49 (21.5) | 3.94 |
| Capacity fluctuations or shortages on the supply markets (non-availability of resources) | 2 (0.8) | 9 (3.9) | 42 (18.4) | 126 (55.3) | 48 (21.1) | 3.92 |
| Grand Mean | | | | | | 3.91 |

Note. Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree.

# 5.2.3 Regulatory and Legal Related Risks

Regarding regulatory and legal risks, the results showed that 129 respondents (56.6%) agreed changes in the political environment due to new legislation posed a major risk. Additionally, 34 participants (14.9%) strongly agreed that administrative barriers to establishing or operating supply chains represented another significant risk. The overall mean response score for these regulatory and legal - related risks was 3.885(Table 4)

Table 4
Descriptive Statistics of Supply-Related Risks In Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Changes in the political environment due to the introduction of new laws | 3 (1.3) | 7 (3.1) | 43 (18.9) | 129 (56.6) | 46 (20.2) | 3.91 |
| Administrative barriers to the establishment or operation of supply chains | 2 (0.8) | 4 (1.8) | 49 (21.5) | 139 (61.0) | 34 (14.9) | 3.86 |
| Grand Mean | | | | | | 3.89 |

Note. Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA =Neutral, A = Agree, SA = Strongly Agree.

# 5.2.4 Infrastructure Risks (Information Risk, transport risks)

A majority of respondents140 (61.4%) identified breakdowns of internal IT infrastructure and systems as significant risks. More than half of participants 125(54.8%) reported infrastructure unavailability (including water, electricity, IT systems, vehicles, roads, and equipment) as a concern. Additionally, 56 (24.6%) strongly agreed that disruptions in utility supplies (electricity, water, etc.) posed further risks. The grand mean for this category of infrastructure-related risks was 3.96 (Table 5).

Table 5
Descriptive Statistics of Regulatory, Legal and Bureaucratic Related Risks in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Loss of own operation facility due to local disruptions (e.g., fire, strike) | 1 (0.4) | 7 (3.1) | 48 (21.1) | 127 (55.7) | 45 (19.7) | 3.91 |
| Breakdown of internal IT infrastructure and systems | 1 (0.4) | 8 (3.5) | 43 (18.9) | 140 (61.4) | 36 (15.8) | 3.89 |
| Loss of own function capacity due to technical reasons | 0 (0.0) | 6 (2.6) | 44 (19.3) | 122 (53.6) | 56 (24.6) | 4.00 |
| Breakdown of external IT infrastructure | 0 (0.0) | 7 (3.1) | 36 (15.8) | 142 (62.3) | 43 (18.9) | 3.97 |
| Lack of proper storage area with adequate facilities | 0 (0.0) | 3 (1.3) | 45 (19.7) | 137 (60.1) | 43 (18.9) | 3.96 |
| Infrastructure unavailability (water, electricity, IT, vehicle, road, equipment, etc.) | 0 (0.0) | 4 (1.8) | 49 (21.5) | 125 (54.8) | 50 (21.9) | 3.97 |
| Disruptions in the supply of electricity, water, etc. | 0 (0.0) | 3 (1.3) | 42 (18.4) | 127 (55.7) | 56 (24.6) | 4.04 |
| Lack of information transparency between logistics and marketing | 1 (0.4) | 4 (1.8) | 53 (23.2) | 127 (55.7) | 43 (18.9) | 3.91 |
| Paperwork and scheduling | 1 (0.4) | 6 (2.6) | 38 (16.7) | 136 (59.6) | 47 (20.6) | 3.97 |
| Grand Mean | | | | | | 3.96 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree

# 5.2.5 Macro/Catastrophic Risks

The majority of respondents 135 (59.2%) agreed that political instability, war, civil unrest, and other sociopolitical crises posed significant threats to pharmaceutical supply chains. Other participants 42(18.4%) strongly agreed that natural disasters represented a major risk. The average mean score for these macro/catastrophic risks was 3.92(Table 6).

Table 6
Descriptive Statistics of Infrastructure Risks (Information Risk, Transport Risks In Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Political instability, war, civil unrest, or other socio-political crises | 0 (0.0) | 3 (1.3) | 50 (21.9) | 135 (59.2) | 40 (17.5) | 3.93 |
| Diseases or epidemics | 0 (0.0) | 6 (2.6) | 48 (21.1) | 135 (59.2) | 39 (17.1) | 3.91 |
| Natural disasters | 0 (0.0) | 2 (0.9) | 55 (24.1) | 129 (56.6) | 42 (18.4) | 3.93 |
| Grand Mean | | | | | | 3.92 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree

# 5.2.6 Financial-Related risks

More than half of respondents140 (61.4%) agreed that bank interest rate fluctuations were a significant threat. Increased freight charges were strongly agreed upon by 39 (17.1%) of respondents. The grand mean for this risk category was 3.88**(**Table 7**).**

Table 7
Descriptive Statistics of Financial-Related Risks in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Dynamic foreign exchange rates | 0 (0.0) | 3 (1.3) | 62 (27.2) | 130 (57.0) | 33 (14.5) | 3.85 |
| Bank interest rate fluctuation | 0 (0.0) | 5 (2.2) | 48 (21.1) | 140 (61.4) | 34 (14.9) | 3.88 |
| Financial restriction | 0 (0.0) | 6 (2.6) | 56 (24.6) | 130 (57.0) | 36 (15.8) | 3.86 |
| Increase in freight charges | 0 (0.0) | 2 (0.9) | 50 (21.9) | 137 (60.1) | 39 (17.1) | 3.93 |
| Grand Mean | | | | | | 3.88 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree

# 2.3 Pharmaceutical Supply Chain Risk Management Practices

## 5.3.1 Risk Identification Related Pharmaceutical Supply Chain Risk Management Practices

When respondents were asked about Risk Identification practices, the majority 124 (54.4%) agreed that the facility uses a standard process for identifying supply chain risks and that these risks are categorized by their frequency of occurrence. Additionally, 57 (25.0%) strongly agreed that all potential supply chain risks are communicated to all relevant parties. The average response score among participants was 3.86(Table 8).

Table 8
Descriptive Statistics of Risk Identification Related Pharmaceutical Supply Chain Risk Management in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Facility uses a standard process for identifying supply chain risks | 0 (0.0) | 10 (4.4) | 77 (33.8) | 124 (54.4) | 17 (7.5) | 3.65 |
| Supply chain risks are identified by their frequency of occurrence | 0 (0.0) | 2 (0.9) | 58 (25.4) | 124 (54.4) | 44 (19.3) | 3.92 |
| All potential supply chain risks are communicated to all parties | 0 (0.0) | 3 (1.3) | 46 (20.2) | 122 (53.5) | 57 (25.0) | 4.02 |
| Grand Mean | | | | | | 3.86 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree.

## 5.3.2 Risk Assessment Related Pharmaceutical Supply Chain Risk Management Practices

The majority of respondents, 119 (52.2%), agreed that identified risks are quantified and analyzed based on the severity of the hazard, the likelihood of occurrence, and detection by the facility. Additionally, 112 (49.1%) agreed that the facility follows supply chain risk evaluation procedures correctly. Furthermore, 42 (18.4%) strongly agreed that the facility prioritizes its main supply chain risks. The grand mean of the responses was 3.87(Table 9).

Table 9

Descriptive Statistics of Risk Assessment Related Pharmaceutical Supply Chain Risk Management in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| The facility prioritizes its main supply chain risks | 0 (0.0) | 8 (3.5) | 72 (31.6) | 106 (46.5) | 42 (18.4) | 3.80 |
| Identified risks are quantified and analyzed based on the severity of the hazard, the likelihood of occurrence, and detection by the facility | 0 (0.0) | 3 (1.3) | 65 (28.5) | 119 (52.2) | 41 (18.0) | 3.87 |
| The facility follows supply chain risk evaluation procedures correctly | 0 (0.0) | 5 (2.2) | 56 (24.6) | 112 (49.1) | 55 (24.1) | 3.95 |
| Grand Mean | | | | | | 3.87 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree

## 5.3.3 Risk Treatment Related Pharmaceutical Supply Chain Risk Management Practices

Among the participants, 143 (62.7%) agreed that there is continuous training on risk management, while 137 (60.1%) agreed that the contract management system for risk control has been improved. Additionally, 61 (26.8%) strongly agreed that supply insurance is used to manage risks. The average mean score was 3.96(Table 10).

Table 10

Descriptive Statistics of Risk Treatment Related Pharmaceutical Supply Chain Risk Management in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| There is continuous training on risk management | 0 (0.0) | 5 (2.2) | 49 (21.5) | 143 (62.7) | 31 (13.6) | 3.88 |
| The contract management system for risk control has been improved | 0 (0.0) | 4 (1.8) | 53 (23.2) | 137 (60.1) | 34 (14.9) | 3.88 |
| Supplies insurance is used to manage risks | 0 (0.0) | 2 (0.9) | 27 (11.8) | 138 (60.5) | 61 (26.8) | 4.13 |
| Grand Mean | | | | | | 3.96 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree.

# 5.3.4 Risk Monitoring Related Pharmaceutical Supply Chain Risk Management Practices

More than half of the respondents 118(51.8%) agreed that the facility conducts formal cross-departmental risk reviews quarterly and consistently uses risk monitoring checklists for all major departments. Additionally, 61(26.8%) respondents strongly agreed that lessons from past risk incidents are systematically incorporated into updated monitoring procedures. The grand mean score for risk monitoring was 4.01(Table 11)

Table 11
Descriptive Statistics of Risk Monitoring Related Pharmaceutical Supply Chain Risk Management in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| The facility conducts formal cross-departmental risk reviews quarterly | 0 (0.0) | 4 (1.8) | 51 (22.4) | 118 (51.8) | 55 (24.1) | 3.98 |
| Risk monitoring checklists are consistently used for all major departments | 0 (0.0) | 3 (1.3) | 47 (20.6) | 118 (51.8) | 60 (26.3) | 4.03 |
| Lessons from past risk incidents are systematically incorporated into updated monitoring procedures | 1 (0.4) | 2 (0.9) | 44 (19.3) | 120 (52.6) | 61 (26.8) | 4.04 |
| Grand Mean | | | | | | 4.01 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree

# 2.4 Pharmaceutical Supply Chain Resilience Practices in the Public Health Facilities

# 5.4.1 Flexibility

When asked about flexibility, 138(60.5%) respondents agreed that the facility can quickly fulfill patient orders for medicines. Additionally, 154(67.5%) respondents agreed that the facility offers a diverse range of medical products and can customize them to meet specific patient needs. Furthermore, 56(24.6%) respondents strongly agreed that the time required to switch procurement from one medical product to another is minimal in the facility. The grand mean score for these items was 3.95(Table 12)

Table 12
Descriptive Statistics of Flexibility Related Pharmaceutical Supply Chain Resilience in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| The facility can fulfill patient orders for medicines quickly | 1 (0.4) | 7 (3.1) | 45 (19.7) | 138 (60.5) | 37 (16.2) | 3.89 |
| The facility offers a diverse range of medical products and can customize them to meet specific patient needs | 0 (0.0) | 4 (1.8) | 35 (15.4) | 154 (67.5) | 35 (15.4) | 3.96 |
| The time required for switching procurement from one medical product to another is minimal in the facility | 1 (0.4) | 4 (1.8) | 48 (21.1) | 119 (52.2) | 56 (24.6) | 3.99 |
| Grand Mean | | | | | | 3.95 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree.

# 5.4.2 Visibility

The majority of respondents 146(64.0%) agreed that a high proportion of shipments can be tracked in real-time. Additionally, 131(57.5%) respondents agreed that the information shared across their supply chain is accurate and reliable. Furthermore, 72(31.6%) respondents strongly agreed that issues within the facility's supply chain are identified and addressed promptly. These responses yielded an average mean score of 4.07(Table 13).

Table 13
Descriptive Statistics of Visibility Related Pharmaceutical Supply Chain Resilience in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| A high proportion of the shipments can be tracked in real-time | 0 (0.0) | 0 (0.0) | 32 (14.0) | 146 (64.0) | 50 (21.9) | 4.08 |
| The information shared across our supply chain is accurate and reliable | 0 (0.0) | 5 (2.2) | 39 (17.1) | 131 (57.5) | 53 (23.2) | 4.02 |
| Issues within the facility's supply chain are identified and addressed promptly | 0 (0.0) | 4 (1.8) | 39 (17.1) | 113 (49.6) | 72 (31.6) | 4.11 |
| Grand Mean | | | | | | 4.07 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree

## 5.4.3 Redundancy

A majority of respondents 151 (66.2%) agreed that the facility has a sufficient number of backup suppliers for critical medical components. Additionally, 132(57.9%) respondents agreed that the facility maintains an adequate amount of safety stock to buffer against demand variability. Furthermore, 66(24.6%) respondents strongly agreed with this statement regarding safety stock. These responses resulted in an average mean score of 3.98(Table 14).

Table 14
Descriptive Statistics of Redundancy Related Pharmaceutical Supply Chain Resilience in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| The facility has a sufficient number of backup suppliers for critical medical components | 0 (0.0) | 2 (0.9) | 33 (14.5) | 151 (66.2) | 42 (18.4) | 4.02 |
| The facility maintains an adequate amount of safety stock to buffer against demand variability | 0 (0.0) | 3 (1.3) | 37 (16.2) | 132 (57.9) | 56 (24.6) | 4.06 |
| The facility has alternative transportation routes and facilities in place to ensure continuity of operations | 1 (0.4) | 7 (3.1) | 61 (26.8) | 111 (48.7) | 48 (21.1) | 3.87 |
| Grand Mean | | | | | | 3.98 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree.

## 5.4.4 Agility

The survey revealed that 119(52.2%) respondents agreed the facility significantly reduces lead time variations that impact overall performance and responsiveness. Additionally, 116(50.9%) respondents confirmed the supply chain's ability to quickly respond to fluctuations in patient demand. Notably, 67(29.4%) respondents strongly agreed with two key capabilities: the facility's ability to modify order quantities and specifications without significant delays, and its effectiveness in reducing lead time variations. These positive assessments resulted in a grand mean score of 4.08 for supply chain agility (Table 15).

Table 15

Descriptive Statistics of Agility Related Pharmaceutical Supply Chain Resilience in Public Health Facilities in Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Rapid response enabling adjusting patient demand patterns | 0 (0.0) | 4 (1.8) | 37 (16.2) | 116 (50.9) | 71 (31.1) | 4.11 |
| The facility can change order quantities and specifications without significant delays | 0 (0.0) | 6 (2.6) | 43 (18.9) | 112 (49.1) | 67 (29.4) | 4.05 |
| The facility reduces variations in lead time that significantly affect the overall performance and responsiveness | 0 (0.0) | 2 (0.9) | 40 (17.5) | 119 (52.2) | 67 (29.4) | 4.10 |
| Grand Mean | | | | | | 4.08 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree.

# 5.4.5 Collaboration

The study revealed that 110 (48.2%) participants agreed the facility maintains effective collaborative forecasting and planning efforts with partners. Another 102(44.7%) respondents acknowledged a high level of trust and effective communication among supply chain partners. Additionally, 87(38.2%) participants strongly agreed that data is frequently exchanged between the facility and its supply chain partners. These positive indicators resulted in an average mean score of 4.14 for supply chain collaboration (Table 16).

Table 16
Descriptive Statistics of Collaboration Related Pharmaceutical Supply Chain Resilience in Public Health Facilities In Four Wollega Zones, Ethiopia (n = 228), April 2025

| Descriptions | Level of Agreement | | | | | |
|---|---|---|---|---|---|---|
| | SD (%) | DA (%) | NA (%) | A (%) | SA (%) | Mean |
| Data is exchanged frequently between the facility and supply chain partners | 0 (0.0) | 2 (0.9) | 48 (21.1) | 91 (39.9) | 87 (38.2) | 4.15 |
| Collaborative forecasting and planning with partners enhances supply chain efficiency | 0 (0.0) | 4 (1.8) | 33 (14.5) | 110 (48.2) | 81 (35.5) | 4.18 |
| There is a high level of trust and effective communication among the supply chain partners | 0 (0.0) | 5 (2.2) | 44 (19.3) | 102 (44.7) | 77 (33.8) | 4.10 |
| Grand Mean | | | | | | 4.14 |

*Note.* Response scale abbreviations: SD = Strongly Disagree, DA = Disagree, NA = Neutral, A = Agree, SA = Strongly Agree

# 2.5 Inferential statistical analysis of Study Variables

# 2.5.1 Tests for Model Assumptions

The study employed structural equation modeling (SEM) to determine the influence of supply chain risk management on supply chain resilience. Before conducting the analysis, the key statistical assumptions including normality, linearity, multicollinearity, and homoscedasticity were thoroughly assessed to ensure the validity of the results.

### Normality Tests

To assess data normality, multivariate outliers were first identified and removed using Mahalanobis distance ($p < .001$). Subsequently, skewness and kurtosis values were examined, with their absolute Z-scores ranging from 0.304 to 3.131. Since all values fell below the recommended threshold of $Z < 3.29$, the data were confirmed to meet the normality assumption (**Annex V**).

### Linearity

The linear relationship between the variables was assessed through residual scatter plot analysis. As shown in (Fig. 2**)**, the points formed a distinct diagonal pattern with an upward trend, clearly demonstrating a positive linear correlation. This graphical representation confirmed that the data satisfied the linearity assumption required for statistical analysis. The consistent pattern observed in the plot provides strong evidence of a proportional relationship between the independent and dependent variables.

### Multicollinearity

To assess multicollinearity among the independent variables, tolerance (T) statistics and variance inflation factor (VIF) values were computed. All tolerance values exceeded the 0.20 threshold. All VIF values were below the threshold (VIF < 3), indicating no multicollinearity among the variables (Table 17**).**

Table 17
Multicollinearity Test For the Study Variables (n = 228), April 2025

| Predictor Variable | Collinearity Statistics | |
|---|---|---|
| | Tolerance | VIF |
| Risk Identification | .887 | 1.128 |
| Risk Assessment | .860 | 1.163 |
| Risk Treatment | .846 | 1.182 |
| Risk Monitoring | .900 | 1.112 |
| VIF=Variance Inflation Factor | | |

### Homoscedasticity

The homoscedasticity assumption requires that the variance of the dependent variable (or error terms) remains constant across all levels of the independent variables. To test this, standardized residual plots versus predicted values were examined through scatter plots. The results showed an even distribution of error terms across all variables, indicating that each predictor maintained consistent standardized error variance relative to the predicted variable. This confirms that the homoscedasticity assumption was satisfied (**Annex VI**).

## 5.5.2 Bivariate Correlation Analysis of Study Variables

The analysis revealed statistically significant positive correlations between all predictor constructs (Risk Identification, Risk Assessment, Risk Treatment, and Risk Monitoring) and Pharmaceutical Supply Chain Resilience. The majority of supply chain risk management (SCRM) practices demonstrated correlation coefficients between 0.248 and 0.403 with Pharmaceutical Supply Chain Resilience, all statistically significant at $p < 0.001$.All of the predictors had shown moderate correlation with supply chain resilience except risk monitoring which showed weak correlation($r = 0.248$) (Table 18).

Table 18
The Bivariate Correlation Coefficient between the Study Variables (n = 228), April 2025

| Factor | RI_m | RA_m | RT_m | RM_m | PSCR_m |
|---|---|---|---|---|---|
| 1. RI_m | 1 | | | | |
| 2. RA_m | .281** | 1 | | | |
| 3. RT_m | .216** | .296** | 1 | | |
| 4. RM_m | .195** | .162* | .281** | 1 | |
| 5. PSCR_m | .353** | .403** | .307** | .248** | 1 |
| **. Correlation is significant at the 0.01 level (2-tailed) | | | | | |

# 5.5.3 Exploratory Factor Analysis

The exploratory factor analysis (EFA) resulted in the exclusion of sixteen items from further analysis. Specifically, twelve items were removed due to factor loadings below the threshold of 0.4, and four additional items were excluded because of significant cross-loadings. As a result, certain variables from the dependent set (adaptability and robustness) were removed due to low outer loadings, ensuring better reliability and validity of the measurement model. Following these exclusions, five variables flexibility, visibility, redundancy, agility, and collaboration underwent transformation to meet the analysis requirements. Subsequently, five factors with eigenvalues greater than one were extracted, forming the final factor structure.

The remaining 17 items exhibited factor loadings ranging from 0.608 to 0.912, all of which surpassed the recommended threshold of 0.50, confirming their strong association with their respective factors. The five extracted factors in the analysis explained a cumulative 68.374% of the total variance in the dataset, demonstrating strong explanatory power. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy yielded a value of 0.775, indicating that the sample size of 228 respondents was appropriate for factor analysis. Furthermore, Bartlett's Test of Sphericity showed statistically significant results ($p < .001$), confirming that the correlations between variables were sufficiently different from zero and suitable for factor extraction (Table 19)

Table 19
Rotated Factor Loadings, Eigen Value, Variance Explained and Cumulative Variance Explained Of the Study Variables (n = 228), April 2025

| Study Variables | No. of Items | Factor Loadings Range | Eigen Values | % of Variance Explained | % of Cumulative Variance |
|---|---|---|---|---|---|
| PSC Resilience | 5 | 0.608–0.821 | 4.968 | 29.224 | 29.224 |
| Risk Treatment | 3 | 0.767–0.912 | 2.036 | 11.975 | 41.199 |
| Risk Assessment | 3 | 0.733–0.876 | 1.700 | 10.002 | 51.201 |
| Risk Monitoring | 3 | 0.703–0.885 | 1.508 | 8.872 | 60.073 |
| Risk Identification | 3 | 0.693–0.860 | 1.411 | 8.301 | 68.374 |
| Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.775, Bartlett's Test of Sphericity (app. Chi-square = 1645.787, df = 136, and sig. = 0.000), Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization | | | | | |

# 5.5.4 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) was performed using AMOS 26 to rigorously evaluate the measurement model's fit. The analysis yielded excellent model fit indices: $\chi^2 = 145.809$ with 107 degrees of freedom ($\chi^2/df = 1.363$, $p = 0.811$), RMSEA = 0.042, SRMR = 0.056, GFI = 0.931, AGFI = 0.901, CFI = 0.975, RFI = 0.91 and TLI = 0.968. These results collectively demonstrated that the proposed measurement model fits the data well, with all indices meeting recommended thresholds for good model fit (Fig. 3).

The reliability and validity of the measurement model were confirmed through comprehensive analysis (Table 20). As presented in Table 20, all constructs demonstrated CR values and Cronbach's alpha coefficients exceeding 0.70, confirming satisfactory internal consistency across all measured dimensions. These results provide strong evidence for the reliability of the measurement instrument. Additionally, convergent validity was assessed through examination of both factor loadings and average variance extracted (AVE) values.

All five constructs (RI, RA, RT, RM, and PSCR) exhibited AVE values above 0.50, along with significant inter-correlations ($p < 0.001$), supporting their convergent validity. For discriminant validity, the study applied Fornell and Larcker's criterion, comparing inter-construct correlations against the square roots of AVEs. The results showed that all correlations were indeed lower than the corresponding AVE square roots, as displayed in the table, thereby verifying discriminant validity among the factors. These results collectively demonstrated the strong validity characteristics of the measurement model.

Table 20
Reliability and Validity of the Measurement Models with Their Respective Factors of the Study Variables (n = 228), April 2025

| Factor | RI | RA | RT | RM | PSCR | α-value | CR | AVE |
|---|---|---|---|---|---|---|---|---|
| 1. RI | **0.714** | | | | | 0.750 | 0.755 | 0.510 |
| 2. RA | .317*** | **0.771** | | | | 0.810 | 0.813 | 0.595 |
| 3. RT | .232** | .313*** | **0.849** | | | 0.870 | 0.883 | 0.721 |
| 4. RM | .264** | .179* | .288*** | **0.755** | | 0.735 | 0.793 | 0.569 |
| 5. PSCR | .465*** | .480*** | .360*** | .278** | **0.721** | 0.804 | 0.782 | 0.520 |
| Note(s): *** p < 0.001, diagonal bold numbers represent the square root of average variance extracted (AVE) for each factor, α = Cronbach alpha, CR=Composite reliability. | | | | | | | | |
| **Structural Path Analysis and Hypothesis** | | | | | | | | |

The structural model (path analysis) was developed using adjusted measurement models. The model demonstrated good fit, as indicated by the following fit indices: CMIN = 150.9, DF = 112 (CMIN/DF = 1.347, p = .875), SRMR = 0.0625, RMSEA = 0.039, GFI = 0.992, AGFI = 0.903, RFI = 0.915, CFI = 0.975 and TLI = 0.970. Additionally, all standardized regression weights were statistically significant (p < .001), confirming that the proposed model aligns well with the sample data. These results support the validity of the structural model and its underlying theoretical framework. With $R^2$ = 0.61, Pharmaceutical Supply Chain Risk Management explained 61% variances in Supply Chain Resilience. The outcomes of testing the structural model were summarized in (Fig. 4 **and** Table 21**)**.

### The Hypothesis Test Results

H: Supply Chain Risk Management Practices including (Risk Identification, Risk Assessment, Risk Treatment and Risk Monitoring) had a positive effect on Pharmaceutical Supply Chain Resilience of Public Health Facilities.

The path analysis results revealed a statistically significant positive relationship between supply chain risk management and pharmaceutical supply chain resilience, with an unstandardized estimate of β = 0.804 (t-value = 4.850, p < 0.001). This indicates that effective Supply chain risk management practices substantially contribute to enhancing resilience in pharmaceutical supply chains. In simpler terms, if supply chain risk management (SCRM) improves by one unit while all other factors remain unchanged, pharmaceutical supply chain resilience increases by 0.804 units. The analysis further revealed that all SCRM constructs demonstrated strong predictive power, with standardized regression weights exceeding 0.614. This indicates substantial effect sizes for each construct's relationship with overall SCRM performance. Among all predictor variables, Risk Assessment demonstrated the strongest predictive influence, showing the highest standardized regression weight (β = 0.59, p < 0.001). Increasing the Risk Assessment (RA) by one unit for example, by ensuring that the facility prioritizes its main supply

chain risks and correctly follows supply chain risk evaluation procedures improves Supply Chain Risk Management (SCRM) by 0.59 units (Fig. 4 **and** Table 21).

Table 21
Unstandardized Regression Estimates of The Study Variables For The Data Collected From Public Health Facilities In Four Wollega Zones, Ethiopia (n = 228), April 2025

| Path | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|
| RI ← SCRM | .860 | .188 | 4.569 | *** |
| RA ← SCRM | 1.000 | Reference | | |
| RT ← SCRM | .833 | .178 | 4.685 | *** |
| RM ← SCRM | .614 | .173 | 3.559 | *** |
| PSCR ← SCRM | .804 | .166 | 4.850 | *** |
| RI4 ← RI | .820 | .111 | 7.363 | *** |
| RI2 ← RI | 1.000 | Reference | | |
| RI1 ← RI | .840 | .098 | 8.578 | *** |
| RA3 ← RA | .795 | .084 | 9.470 | *** |
| RA2 ← RA | 1.000 | Reference | | |
| RA1 ← RA | .987 | .087 | 11.310 | *** |
| RT5 ← RT | .645 | .058 | 11.108 | *** |
| RT3 ← RT | .985 | .049 | 20.065 | *** |
| RT2 ← RT | 1.000 | Reference | | |
| RM4 ← RM | .597 | .090 | 6.625 | *** |
| RM2 ← RM | 1.000 | Reference | | |
| RM1 ← RM | .986 | .119 | 8.272 | *** |
| SRC_1 ← PSCR | .971 | .113 | 8.575 | *** |
| SAR_1 ← PSCR | .922 | .138 | 6.682 | *** |
| SRR_1 ← PSCR | .942 | .128 | 7.334 | *** |
| SRV_1 ← PSCR | .869 | .121 | 7.183 | *** |
| SRF_1 ← PSCR | 1.000 | Reference | | |
| Note: S.E. = Standard error, C.R. = critical ratio, ***p-value < 0.001 | | | | |

# 2.6 Qualitative Findings

This study explored the key risks in the pharmaceutical supply chain of public health facilities, the challenges in implementing Supply Chain Risk Management, and the effect of SCRM on supply chain resilience. Through in-depth face-to-face interviews with key informants including facility administrators, decision-makers, and supply chain officers the research gathered insights from professionals aged 30 to 45 with at least two years of experience in pharmaceutical supply chain management. The findings aimed to identify critical risks, assess barriers to SCRM adoption and evaluate strategies to strengthen supply chain resilience in public health settings.

# 2.6.1 Key Risks encountered in the Pharmaceutical Supply Chain of public health facilities

To assess the risks encountered by PSC of public health facilities, in-depth face-to-face interviews were carried out. Key informants highlighted several concerns, and the collected data was thematically analyzed by grouping the responses according to their characteristics. The findings were then summarized as follows:

### Demand Related Risks

Demand-related risks in our pharmaceutical supply chain primarily stem from unpredictable surges in medication needs, often triggered by events like disease outbreaks (e.g., malaria), and coupled with inadequate forecasting tools. This volatility frequently leads to critical stock outs. The consequences are severe: immediate treatment delays for patients, worsening clinical outcomes, and significantly increased pressure on healthcare staff. Beyond clinical impacts, recurring shortages erode patient trust and damage our facility's reputation. Critically, our current approach is reactive; we lack the robust predictive capabilities and concrete contingency plans needed to proactively manage these inevitable demand fluctuations and ensure reliable access to essential medicines. A 34-year-old Supply Chain Officer at a hospital, with 4 years of experience in this position stated: "**…***demand-related risks are frequent in our facility. For instance, a sudden malaria outbreak recently caused a surge in antimalarial drug demand, disrupting our supply chain and causing critical stock outs. We struggle to forecast accurately during outbreaks, leaving usual stock levels insufficient. Suppliers often can't respond fast enough to these spikes. This affects not only malaria drugs but other essential medicines, risking patients' lives. Consequently, many patients faced treatment delays, worsening their conditions and increasing staff burden."*

One hospital administrator supporting this idea is 39 years of age and has 3 years of experience in their current position"*… beyond just medicines, such demand fluctuations impact our entire operations. When we run out of key drugs, patient trust declines, and our facility's reputation suffers. We need better predictive tools and contingency plans to manage these risks proactively."*

### Supply Related Risks

Supply-related risks in the PSC, particularly inefficient logistics (e.g., poor transport, warehousing, customs delays, or fragmented networks), directly disrupt medicine deliveries. This causes delays and inconsistent availability at healthcare facilities, leading to stock outs and irregular supply. Consequently, healthcare providers struggle to deliver consistent patient care, risking treatment interruptions. This unreliability fundamentally undermines the PSC's goal: getting the right medicine to the right place at the right time. A 40-year-old Supply Chain Officer at the health center, with 5 years of experience in the role said:"*… we face major supply inefficiencies, particularly poor logistics causing frequent delays in essential medicine deliveries. These stem from transport bottlenecks, supplier shortages, or bureaucratic procurement. Significantly increased lead times for critical drugs severely impact patient care. This especially harms emergency/chronic patients, worsening health outcomes through preventable delay."*

The idea was supported by a 30-year-old Hospital Clinical Director with 3 years' experience in the role,"*… when essential medicines arrive late, it disrupts our entire operations. Doctors are forced to ration available stocks or prescribe alternatives, which may not be as effective. This not only compromises treatment quality but also increases patient frustration and distrust in the healthcare system."*

### Infrastructure Related Risks

Infrastructure deficiencies pose severe, multifaceted risks to pharmaceutical supply chains. Electricity outages disrupt critical operations: cold storage units fail, compromising temperature-sensitive medicines (e.g., vaccines, biologics, insulin) that require strict climate control. Inadequate cold chain infrastructure from refrigerated warehouses to temperature-monitored transport further threatens product integrity, potentially degrading efficacy or safety before drugs reach patients. Simultaneously, poor transportation networks (damaged roads, limited fleet capacity, and remote inaccessibility) cause delays and physical damage to goods. Together, these failures create a cascade effect: medicines spoil or become unstable, supply timelines unravel, and availability plummets. Ultimately, patients face stock outs of vital treatments or receive compromised products, directly endangering health outcomes and eroding trust in the healthcare system. A 35-year-old Hospital Supply Chain Officer with 4 years' experience in the role expressed his views on this matter"*…frequent electricity outages severely threaten our pharmaceutical supply chain, directly compromising temperature-sensitive medicines like vaccines, insulin, and biologics due to unreliable refrigeration. Inadequate cold chain storage, worsened by power-related equipment damage, creates constant risks of spoilage, expiry, and costly waste. When refrigerators fail, medicines lose potency, forcing us to discard them and causing preventable stock outs."*

The idea was supported by a 39-year-old Facility Administrator with 6 years' experience in this role*"… a broken infrastructure doesn't just disrupt operations it dismantles the entire pharmaceutical lifeline, from manufacturer to patient. Fixing these gaps isn't optional; it's the difference between life and death for those relying on these medicines."*

# 2.6.2 Challenges for implementing SCRM to Strengthen Pharmaceutical Supply Chain Resilience

There are many challenges that hinder implementing SCRM to enhance SC resilience. These factors are Lack of awareness and prioritization, weak and fragmented systems and limited financial and human resources. It was described by key informants as follows:

### Lack of awareness and prioritization

Implementing effective SCRM in our facility faces two critical barriers: lack of staff awareness and institutional de-prioritization. Staff across departments view SCRM as an abstract concept disconnected from daily operations rather than a vital safeguard against drug shortages or patient harm. This awareness gap was exacerbated by leadership's systematic de-prioritization of risk mitigation such as resolving recurring stock outs or cold chain failures in favor of urgent operational pressures. According to one Facility Administrator, aged 36 with 3 years of experience in this position *"…implementing effective SCRM faces major challenges: staff awareness gaps and institutional de-prioritization. Procurement and operational teams often view SCRM as abstract rather than a vital safeguard against drug shortages or patient harm. Leadership compounds this by sidelining systematic risk solutions (e.g., recurring stock outs, cold chain failures) for immediate operational demands. For instance, a stock-tracking dashboard was dismissed as "non-urgent," though its absence directly undermines patient care when supplies deplete. This neglect perpetuates reactive fragility. Resilience will remain compromised until SCRM is recognized as integral to quality care not an administrative add-on."*

### Weak and fragmented systems

A significant factor hindering SCRM implementation is the absence of formalized risk management policies. Without standardized frameworks for risk assessment, contingency protocols, or clearly defined roles, SCRM practices become reactive and fragmented across departments. Staff lack consistent tools to systematically identify or mitigate threats like demand surges or logistics failures a vulnerability compounded by insufficient training. This policy void forces reliance on ad hoc responses, undermining proactive resilience. A 38-year-old Supply Chain Officer at the hospital, with 5 years' experience in the position, provided this elaboration on the factor as *"… in our efforts to institutionalize Supply Chain Risk Management within our facility, we are confronted with a fundamental structural challenge: weak and fragmented systems. Presently, there exists no standardized policy framework or operational guidelines to govern SCRM implementation across public healthcare facilities. This critical gap forces facilities to adopt ad-hoc, reactive approaches addressing supply chain risks only when crises emerge, rather than through systematic prevention and preparedness."*

A 40-year-old Facility Administrator with 3 years' experience in the role also supported the idea. *"…as frontline administrator, I witness daily how the lack of a standardized SCRM framework cripples our operations. The current system operates in silos pharmacy teams track expiries manually, procurement*

*works with outdated supplier lists, and clinical staff remains unaware of impending shortages until crisis hits. This fragmentation means minor risks snowball into emergencies. For example, last quarter, our hospital nearly suspended pediatric surgeries because anesthesia vials expired unnoticed. No protocol required cross-checking pharmacy logs with surgical schedules. Such preventable near-misses stem from two critical gaps: policy paralysis and accountability gaps."*

**Limited financial and human resources**

Acute shortages of financial and human resources critically undermine SCRM implementation in pharmaceutical supply chains. Financially, facilities lack funds for predictive tools, supplier diversification, or cold-chain maintenance, forcing reactive decisions like emergency spot purchases. Simultaneously, staffing gaps leave no dedicated risk experts, overburdening operational teams who lack capacity for proactive risk mapping or contingency planning. A 32-year-old Facility Administrator with 4 years' experience stated his perspective on this issue,"*… as a facility administrator, I witness how financial and human resource gaps create a vicious cycle of vulnerability. Budgets cover only routine procurement, excluding risk mitigation like backup generators or emergency supplier contracts. Human resource shortages are equally severe: our single pharmacist juggles dispensing and stock management, leaving no capacity for proactive risk assessment. With no dedicated supply chain staff, unfilled positions, and zero training funds, we remain trapped in reactive crisis response unable to prevent disruptions."*

# 2.6.3 The Effect of SCRM on Resilience in Public Health Facilities

Effective implementation of SCRM had significant effect on pharmaceutical supply Chain resilience. The suggestions of key informants were described as follows. A 30-year-old Hospital Chief Executive Officer with 3 years' experience in the role commented on this issue "*…implementing SCRM has fundamentally transformed our medicine supply system. We've moved from constant crisis management to proactive prevention. By establishing multiple approved suppliers for essential medicines, we've created a safety net against shortages. Our digital tracking system (Dagu2) now alerts us to potential stock issues before they become critical, allowing us to plan what to order."*

The idea received additional support from a 34-year-old System Bottleneck-Focused Reform member with 2 years' experience in the role. He elaborated his idea as "*…SCRM implementation has given us the tools to overcome many challenges. The backup power systems we installed for our medicine storage areas have been invaluable during frequent power outages. We've developed strong partnerships with nearby facilities to share resources during emergencies. Having flexible funding available for urgent medicine purchases has allowed us to respond quickly to unexpected disease outbreaks in our community. Our staff now approach supply chain issues with a prevention mindset rather than just reacting to crises. These all aspects contributed to resilience of PSC."*

Most key informants characterized their current SCRM practices as unstructured and inadequate. They indicated that while basic systems exist, significant gaps persist in three critical areas: early risk identification, implementation of effective mitigation strategies, and rapid response to disruptions. Key challenges including limited awareness, insufficient budget allocations, constrained human resources, and the absence of formal guidelines collectively hinder the supply chain's ability to proactively address issues such as supplier bottlenecks, sudden demand fluctuations, and critical infrastructure failures.

# Discussion

The study examined PSC risks and the relationship between Supply Chain Risk Management and Supply Chain Resilience within public health facilities. It aimed to evaluate the SCRM in public health facilities and its impact on enhancing Supply Chain resilience. Effective supply chain risk management processes improve supply chain resilience. Key practices such as risk identification, assessment, mitigation, and monitoring along with flexibility, collaboration, and redundancy, strengthen resilience(23).

This study demonstrate that pharmaceutical supply chains in public health facilities face multiple significant risks, as evidenced by high grand mean scores across all categories: demand-related (3.66), supply-related (3.91), regulatory/bureaucratic (3.89), infrastructure (3.96), macro/catastrophic (3.92), and financial risks (3.88).Notably, infrastructure and macro/catastrophic risks emerged as the most critical concerns closely followed by supply-related and financial risks. With all categories scoring above 3.5 on the Likert scale, these findings highlight the pervasive nature of supply chain risks and emphasize the urgent need for integrated risk management strategies to strengthen pharmaceutical supply chain resilience in public healthcare systems. Key informants strongly supported these quantitative findings, particularly emphasizing three critical risk areas: demand inaccuracies, supply chain disruptions, and infrastructure weaknesses. They reported that distorted demand information frequently leads to incorrect orders, while poorly functioning supply system cause persistent stock outs. Most notably, they highlighted how frequent IT system failures severely undermine inventory management.

The current study closely mirror those of the Arizona State University research on building supply chain resilience in the Arizona healthcare system during COVID-19 .The findings reveal that pandemic-induced disruptions notably medication shortages (affecting 60% of elective surgeries), supplier delays (76%), and inflated costs (62%) have eclipsed traditional disaster risks as the most acute threats. The convergence of strained supply chains (70% external delays), spiking demand, and financial pressures exposes a fragile system where operational vulnerabilities amplify external shocks. This suggests resilience efforts must prioritize real-time supply monitoring and financial buffers over conventional disaster preparedness alone(35).

The study's findings on the Iranian pharmaceutical supply chain revealed almost similar risks. The findings highlighted that Iran's pharmaceutical supply chain faces greater threats from external risks particularly financial, political, and regulatory factors than internal operational weaknesses. The high weighting of economic instability (0.5542) and policy volatility (0.5171) reveals a sector highly vulnerable

to macroeconomic shocks and government decisions, while strategic gaps in R&D (0.3247) and supplier reliability (0.2907) compound these challenges. This risk profile suggests that while internal improvements can help, building resilience requires addressing external dependencies through measures like local production capacity, policy stabilization, and financial hedging to mitigate systemic vulnerabilities(36).

The results of this study support the findings on pharmaceutical supply chain risks in Moroccan hospitals. That study identified critical risk categories, including process inefficiencies, demand fluctuations, supplier disruptions, environmental factors, market volatility, and financial uncertainties, which were systematically cataloged in a detailed risk, register documenting descriptions, classifications, and root causes(37).

The findings indicate that public health facilities have adopted good SCRM practices, though implementation varies across risk management phases; with most respondents (54.4%) confirming standardized risk identification processes categorized by frequency (mean = 3.86). For risk assessment, 52.2% acknowledged quantification based on severity, likelihood, and detectability, while 49.1% affirmed proper evaluation procedures, though risk prioritization showed room for improvement (only 3.5% disagreement, mean = 3.87). Risk treatment appeared effective, with 60.1% reporting enhanced contract controls and 26.8% strongly endorsing supply insurance (mean = 3.96). Monitoring was particularly strong, as 26.8% strongly agreed on systematic integration of past lessons into updated protocols (mean = 4.01).

The finding of this is in line with study conducted in Kenya to assess Supplier Risk Management Practices and Performance of Supply Chain in the Health Sector. The findings revealed moderate adoption of SCRM practices, with 50.8% of facilities effectively identifying risks, though supplier assessments show room for improvement (54.2% combined agreement). Collaborative approaches demonstrate stronger engagement, as 62.8% participate in supplier training and 58.3% in joint risk workshops. Notably, dual sourcing emerges as a preferred mitigation strategy (84.8% endorsement), suggesting facilities increasingly value supply diversification despite implementation challenges. These patterns indicate progressing - but uneven - SCRM maturity, where reactive collaboration outpaces proactive risk assessment(28).

The study also assessed five key dimensions of resilience across key dimensions, though with notable variations. Facilities demonstrate particular strength in visibility (4.07) and collaboration (4.14), evidenced by real-time shipment tracking (64%) and frequent data exchange (38.2% strongly agree). Redundancy (3.98) is well-established, with 66.2% maintaining backup suppliers, while flexibility (3.95) shows robust product diversification (67.5%). The minimal disagreement (2.2%) on trust indicates collaborative potential remains underutilized given moderate forecasting effectiveness (48.2%). Overall, while resilience of facility appears strong, optimizing execution SCRM metrics could further strengthen the Pharmaceutical supply chain of the health facilities.

The path analysis findings demonstrate that SCRM significantly enhances supply chain resilience, as evidenced by its impact on key resilience components. Specifically, SCRM contributed variances of 0.69 for flexibility, 0.62 for visibility, 0.67 for redundancy, 0.61 for agility, and 0.63 for collaboration. Among these, flexibility exhibited the strongest influence (β = 0.69), indicating that adopting practices which strengthen flexibility can substantially improve overall supply chain resilience.

The findings show that all SCRM predictive constructs demand focused attention to strengthen supply chain resilience in healthcare facilities. Path analysis revealed that enhancing key risk management practices including risk identification, assessment, treatment, and monitoring leads to corresponding improvements in overall SCRM .Accordingly, the explained variances of the four constructs of SCRM practices were, 0.56, 0.59, 0.49, and 0.38 for RI, RA, RT and RM respectively. The results demonstrated that risk assessment (RA) practices exert the strongest influence on supply chain resilience, with a standardized coefficient (β) of 0.59. This indicates that for every unit improvement in RA, supply chain risk management increases by 59%. Consequently, prioritizing and strengthening risk assessment procedures yields the most substantial enhancement to overall supply chain resilience capabilities.

The path analysis further confirm a strong, statistically significant relationship between SCRM practices and Supply Chain Resilience, with a substantial positive correlation (β = 0.78). This robust finding demonstrated that effective implementation of SCRM practices directly enhances supply chain resilience outcomes.

The statistical analyses confirm a highly significant positive relationship ($p < 0.001$) between SCRM practices and supply chain resilience. The coefficient of determination ($R^2 = 0.61$) indicates that 61% of the observed variation in supply chain resilience can be attributed to SCRM practices. This substantial explanatory power highlights SCRM as a key driver of resilience, while acknowledging that additional external factors may also influence outcomes.

A study conducted on French pharmaceutical manufacturers supported this study result. It stated that supply chain risk management practices - particularly risk identification, assessment, mitigation and control - significantly enhanced supply chain resilience, their effectiveness can be compromised during major disruptions like COVID-19. Notably, risk mitigation emerged as the most influential factor in building resilience, suggesting companies should prioritize these strategies, while the pandemic's disruptive effects revealed vulnerabilities in traditional SCRM approaches, highlighting the need for more robust risk management frameworks that maintain effectiveness during large-scale crises. These results demonstrated both the value of proactive SCRM implementation and the importance of developing resilient systems capable of withstanding unprecedented disruptions(38).

In spite of methodological differences, a comprehensive review on SCRM to mitigate health care supply chain disruptions in U.S.A corroborates with recent findings, showing that effective supply chain risk management including risk identification, assessment, mitigation, and treatment significantly enhances supply chain resilience in healthcare. Proactive SCRM helps identify vulnerabilities, implement

safeguards, and strengthen operational efficiency, ultimately supporting a more resilient healthcare ecosystem and improved patient safety(39).

Another study conducted by Al-Ayed and Al-Tit in Saudi Arabia examined the relationships between supply chains risk management demonstrated SCRM's dual impact on resilience: directly (β = 0.350) and via IoT mediation (β = 0.142). Their results showed SCRM drives both operational improvements and digital adoption (β = 0.452→0.315), revealing its dual role as protective mechanism and innovation enabler for supply chain resilience(26).

Despite there is difference in sample size (n = 92); the study conducted in Zimbabwe Pharmaceuticals retailers on the effects of supply chain risk management strategies on resilience to economic risks supported the current study. It findings stated that risk identification (β = 0.136, p = 0.010), risk planning (β = 0.191, p = 0.028), and risk avoidance (β = 0.575, p < 0.001) all have statistically significant positive impacts, with risk avoidance showing the strongest effect, while risk pooling (β = 0.021, p = 0.073) has a marginal influence. The results demonstrate that implementing structured risk identification, strategic planning, and proactive avoidance measures significantly enhances economic resilience, providing critical insights for businesses operating in volatile markets(40).This findings again aligned with a study conducted on health supply chain risks in Ghana during the COVID-19 pandemic, which revealed that while supply chain disruptions negatively affected healthcare delivery, effective supply chain risk management practices significantly mitigated these adverse effects. The analysis demonstrated SCRM's positive moderating role (β = 0.341, CR = 4.871), indicating that hospitals with robust risk management strategies were better equipped to counteract supply chain vulnerabilities and sustain service quality. This suggests that SCRM not only reduces operational risks but also enhances healthcare delivery by strengthening resilience against disruptions(41).

The findings of this study agree with the study conducted in Nairobi on Pharmaceutical firms. The study demonstrated a strong positive relationship between supply chain risk management and supply chain resilience. The analysis revealed a significant correlation coefficient of 0.724, indicating that improvements in SCRM lead to a substantial enhancement in SCR(42).

Key informants affirm that while robust SCRM strengthens pharmaceutical supply chain resilience, its implementation faces critical challenges including lack of awareness, inadequate policies, insufficient trained personnel, and funding constraints. They identified prevalent risks across demand fluctuations, supplier reliability, and infrastructure limitations, revealing a concerning gap between SCRM's recognized importance and actual operational capacity in health facilities. These findings highlight the need for targeted interventions addressing policy frameworks, workforce training, and resource allocation to bridge this implementation gap and secure pharmaceutical supply chains.

This study aligns with qualitative research on four Norwegian firms (pharmaceutical, food distribution, home-delivery, and fish farming), which found that proactive risk management integrating identification, assessment, and mitigation strengthens preparedness and crisis response. Firms confirmed that robust

initial risk assessment directly improves supply chain resilience during disruptions(43).Another study performed in Hospitals in Pakistan supported the recent study's findings(44).

This study aligns also with qualitative findings from Ethiopian pharmaceutical companies, which highlight key barriers to effective SCRM implementation. These include the absence of a dedicated risk mitigation team, lack of standardized frameworks for risk identification and management, and insufficient employee awareness of supply chain risks(15).

The practical implications are that effective SCRM implementation strengthens Pharmaceutical supply chains. Health facilities should adopt end-to-end risk management frameworks, while policymakers must integrate SCRM into national strategies with investments in digital tools and training. Together, these measures enable a shift from reactive to proactive approaches, ensuring medicine availability and protecting vulnerable populations amid growing uncertainties.

## Limitations of the study and Direction for future study

This study had several limitations that should be acknowledged. First, its cross-sectional study design restricts the ability to establish causal relationships or track the evolution of supply chain risk management practices over time; longitudinal studies could offer deeper insights into these dynamics. Second, the reliance on surveys and interviews introduced the limitation of self-reporting bias, as these methods are prone to inaccuracies stemming from participants' potential misremembering of details, or unintentional misinterpretation of questions. Such biases could lead to discrepancies between reported data and actual experiences, thereby affecting the reliability and validity of the findings. Additionally, rather than comparing SCRM implementation across health facilities, the study adopted a generalized perspective, which may overlook variability in practices. Future research should explicitly compare facilities with and without SCRM systems to assess their impact on resilience. Finally, a review of existing literature revealed limited studies specifically examining SCRM's impact on healthcare supply chain resilience, with most publications only superficially addressing the topic. This gap underscores the need for more in-depth research on pharmaceutical supply chain risk management in healthcare settings.

## Conclusions

The findings of this study highlighted the critical pharmaceutical supply chain risks within public health facilities. Demand-related, supply-related, regulatory, infrastructure, macroeconomic, and financial risks pose significant threats, with infrastructure and catastrophic risks being the most severe. These risks disrupt medicine availability, emphasizing the urgent need for integrated risk management strategies.

The analysis confirms a strong, definitive relationship between supply chain risk management practices and resilience outcomes. Among these practices, risk assessment stands out as the most influential driver of resilience, followed by mitigation and monitoring efforts. Facilities exhibit notable capabilities in key resilience areas such as transparency, stakeholder collaboration, backup systems, and adaptive

capacity. However, agility despite being prioritized lags behind other dimensions, revealing inconsistencies between strategic planning and on-the-ground execution.

Persistent challenges, including fragmented institutional awareness, underdeveloped policies, workforce skill shortages, and resource limitations, hinder the full operationalization of risk management frameworks. These challenges highlight a persistent gap between institutional awareness of risk management's importance and the practical execution of these strategies. Collectively, the findings stress that strengthening end-to-end risk management processes is vital for building resilient pharmaceutical supply chains in public health facilities. By systematically addressing these gaps, health facilities can enhance their ability to withstand disruptions, maintain reliable access to essential medicines, and protect public health in an era of growing uncertainty.

# Recommendations

Pharmaceutical supply chain management aims to deliver high-quality, cost-effective products efficiently by optimizing internal operations, supplier coordination, and demand responsiveness. To strengthen pharmaceutical supply chain resilience in public health facilities, policymakers and health administrators should prioritize the establishment of standardized, context-specific risk assessment frameworks that systematically evaluate infrastructure vulnerabilities, macroeconomic instability, demand and supply-related disruptions. Concurrently, targeted workforce training programs should be implemented to address skill gaps in risk prioritization, agile response strategies, and digital tool utilization, ensuring personnel are equipped to translate risk awareness into operational action. National health policies must institutionalize supply chain risk management by mandating its integration into public health strategies, supported by dedicated funding for critical infrastructure upgrades such as IT systems and backup storage facilities

Collaboration between health facilities, suppliers, and regulators should be formalized through transparent partnerships and shared accountability mechanisms, fostering collective resilience. Dual sourcing agreements must be expanded to buffer against supply shocks, while cross-facility knowledge-sharing platforms should disseminate lessons from past disruptions to standardize best practices. To fill the gap between strategic agility and operational execution, health systems should adopt dynamic inventory management systems and flexible procurement contracts, backed by contingency funding to address unforeseen crises. Regular audits of SCRM performance metrics will help identify bottlenecks and refine implementation processes.

Finally, to drive effective implementation of SCRM, relevant government authorities including the Ministry of Health, Regional Health Bureaus, and Zonal Health Departments must adopt a proactive stance. This involves maintaining ongoing collaboration with public health facility leaders to identify and address systemic barriers hindering the adoption of SCRM practices.

# Abbreviations

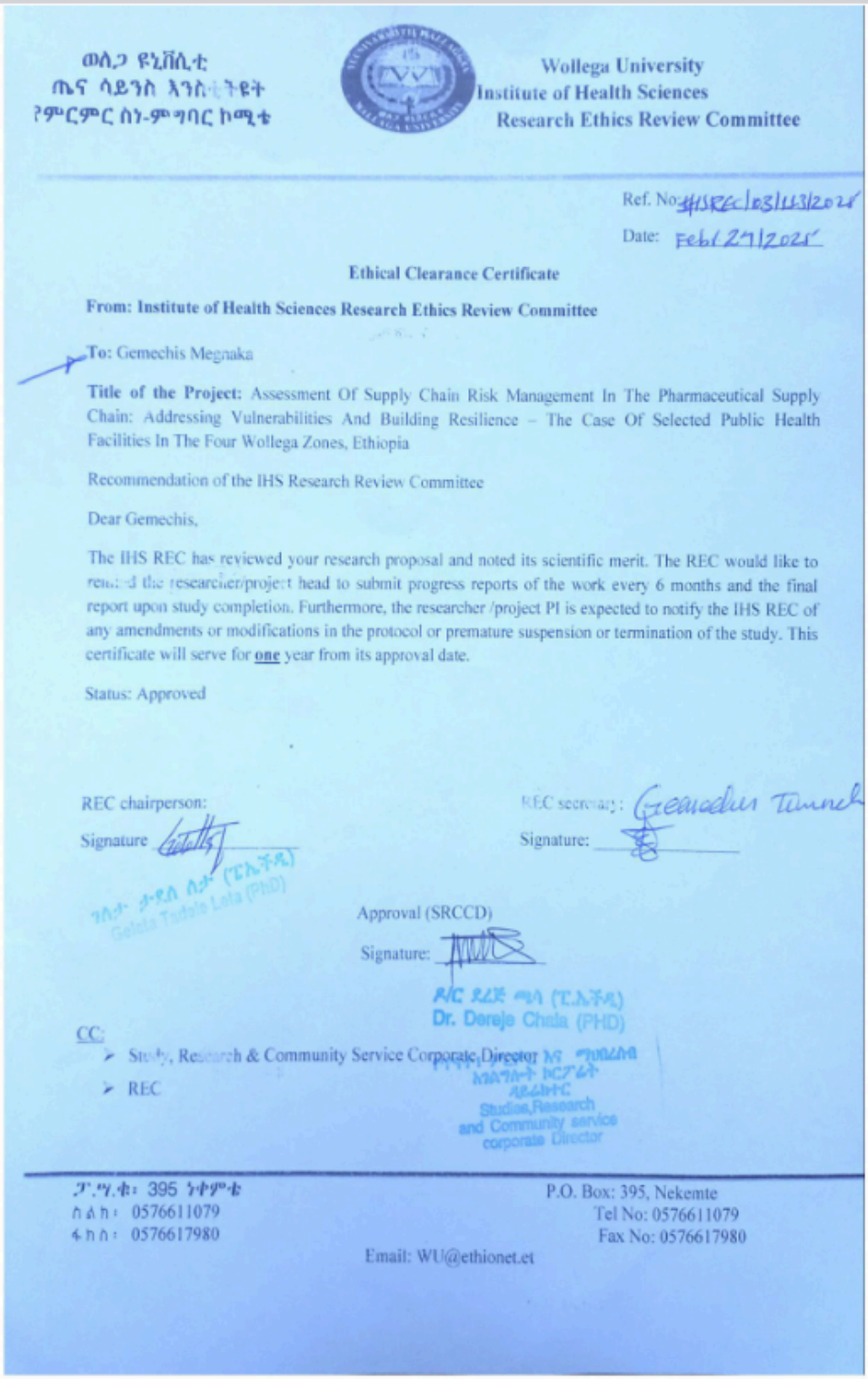
### Lists of Abbreviations /Acronyms

| | |
|---|---|
| **AMOS** | Analysis of Moment Structure |
| **AVE** | Average Variance Extracted |
| **CFA** | Confirmatory Factor Analysis |
| **COVID-1** | Coronavirus disease 2019 |
| **EFA** | Exploratory Factor Analysis |
| **LIAT** | Logistics Indicators Assessment Tool |
| **PSC** | Pharmaceutical Supply Chain |
| **PSCM** | Pharmaceutical Supply Chain Management |
| **SCA** | Supply Chain Agility |
| **SCM** | Supply chain management |
| **SCR** | Supply Chain Resilience |
| **SEM** | Structural Equation Modeling |
| **SPSS** | Statistical Package for Social Science |
| **SRCM** | Supply Chain Risk Management |
| **USAID** | United States Agency for International Development |

# Declarations

### Ethical Approval

Ethical approval for this study was obtained from the Institutional Research Ethical Committee of Wollega University (**Reference Number: IHS REC/03/113/2025.**This study was conducted in accordance with the Declaration of Helsinki. Following the approval, official letters of cooperation were sent to selected health facilities to obtain their consent for the study. Before beginning data collection at the facilities, permission was obtained from the head of the facility after presenting the cooperation letter. Prior to data collection, the study's objectives were explained to the participants, and verbal consent was obtained from them. Participants were assured that their information would remain confidential and that the study would adhere to ethical standards, using the data solely for research purposes. To maintain confidentiality, participants' names and departmental affiliations were not recorded on the questionnaires; instead, a coding system was used. The letter is attached below.



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Wollega University
Institute of Health Sciences
Research Ethics Review Committee

Ref. No: IHSREC/03/1143/2024
Date: Feb/27/2024

**Ethical Clearance Certificate**

**From: Institute of Health Sciences Research Ethics Review Committee**

**To:** Gemechis Megnaka

**Title of the Project:** Assessment Of Supply Chain Risk Management In The Pharmaceutical Supply Chain: Addressing Vulnerabilities And Building Resilience – The Case Of Selected Public Health Facilities In The Four Wollega Zones, Ethiopia

Recommendation of the IHS Research Review Committee

Dear Gemechis,

The IHS REC has reviewed your research proposal and noted its scientific merit. The REC would like to remind the researcher/project head to submit progress reports of the work every 6 months and the final report upon study completion. Furthermore, the researcher /project PI is expected to notify the IHS REC of any amendments or modifications in the protocol or premature suspension or termination of the study. This certificate will serve for **one** year from its approval date.

Status: Approved

REC chairperson:
Signature
ገለታ ታዲሰ ለታ (ፒ.ኤችዲ)
Geleta Tadele Leta (PhD)

REC secretary: Gemechis Tamene
Signature:

Approval (SRCCD)
Signature:
ዶ/ር ደረጄ ጫላ (ፒ.ኤችዲ)
Dr. Dereje Chala (PhD)

CC:
- Study, Research & Community Service Corporate Director
- REC

የጥናት፣ ምርምርና ማህበረሰብ አገልግሎት ኮርፖሬት ዳይሬክተር
Studies,Research and Community service corporate Director

ፖ.ሣ.ቁ፡ 395 ነቀምቴ
ስልክ፡ 0576611079
ፋክስ፡ 0576617980

P.O. Box: 395, Nekemte
Tel No: 0576611079
Fax No: 0576617980

Email: WU@ethionet.et

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# Information sheet and consent form

## Information sheet

### Introduction:

Good day. My name is **Gemechis Megnaka Hunde**; my colleague

I am a student at Wallaga University in the School of Pharmacy, specializing in Pharmaceutical Supply Chain Management. I am currently working on my MSc thesis titled "T**he Effect of Pharmaceutical Supply Chain Risk Management on Building Resilience in Public Health Facilities across Four Wollega Zones, Ethiopia: A Mixed- Method Approach.**"I am seeking information about the SCRM and SC Resilience within this context, as well as the relationships among these three variables in my study. All methods were carried out in accordance with the Declaration of Helsinki.

**Purpose:**

The main objective of this study is assessing the Effect of Pharmaceutical Supply Chain Risk Management on Building Resilience in Public Health Facilities across Four Wollega Zones, Ethiopia: A Mixed Method Approach

With your permission, I would like to ask you a series of questions about the relationships among supply chain risk management (SCRM) and resilience within your agency. Additionally, I would like to review relevant documents related to SCRM implementation, the identification of vulnerabilities, and strategies for building resilience in your facility.

**Risk:** By participating in this data collection, you may need to invest your time; however, you will not encounter any significant risks in this process.

**Benefits:** While you will not receive immediate compensation or benefits for your participation, the findings of this study will contribute valuable insights for developing recommendations regarding SCRM and SC Resilience within the facility.

**Confidentiality:** Individual staff performance will not be evaluated, and no personal identifiers will be collected. The data will be analyzed in aggregate, ensuring no personal manipulation, and a coding system will be used to identify the facilities.

**Right to Refuse or Withdraw:** You have the full right to refuse participation in this research. Your decision will not impact your action by any means in the facility or in the community.

**Person to Contact:** If you want to know more information, you can contact me by: Gemechis Megnaka Hunde

Phone number: **09-10-88-20-81**

**E-mail:**megnakagemechis@gmail.com

1. **Consent Form**

Previously I have tried to clear out the purpose of the study, the procedure of data collection, information the researcher need to collect for this study purpose.

Do you have any questions?

Can we continue? Yes No _____

Unit title of person asked for this survey Name of unit/:

Job title:

Experience of the respondent:

***Informed consent was obtained from all individual participants included in the study.***

## Consent for Publication

-Not applicable.

## Availability of data and materials

**-**Not Applicable

## Competing Interests

- The authors declare that they have no competing interests.


## Funding

-No funding was received for conducting this study.


## Authors' contributions

**G.M:** Conceptualization, Methodology, Data collection, Data Curation, Formal analysis, Investigation, Writing Original Draft, Writing Review & Editing, corresponding author.

**T.D:** Methodology, Data collection, Validation, Formal analysis, Writing Review & Editing.

**H.G:** Data analysis, Data Curation, Writing Review & Editing.

**D.Z:** Data collection, Writing Review & Editing, Supervision.

**T.A:** Supervision, Proof reading, Writing – Review & Editing.


## Acknowledgements

**-**Not Applicable

### Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to the sensitive nature of the research involving human participants and public health facilities, and because the consent obtained from participants did not include permission for public data sharing. Furthermore, disclosure of the raw data could compromise the privacy and confidentiality of the health facilities and the respondents. However, de-identified data are available from the corresponding author (Gemechis Megnaka Hunde) upon reasonable request.

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# Figures

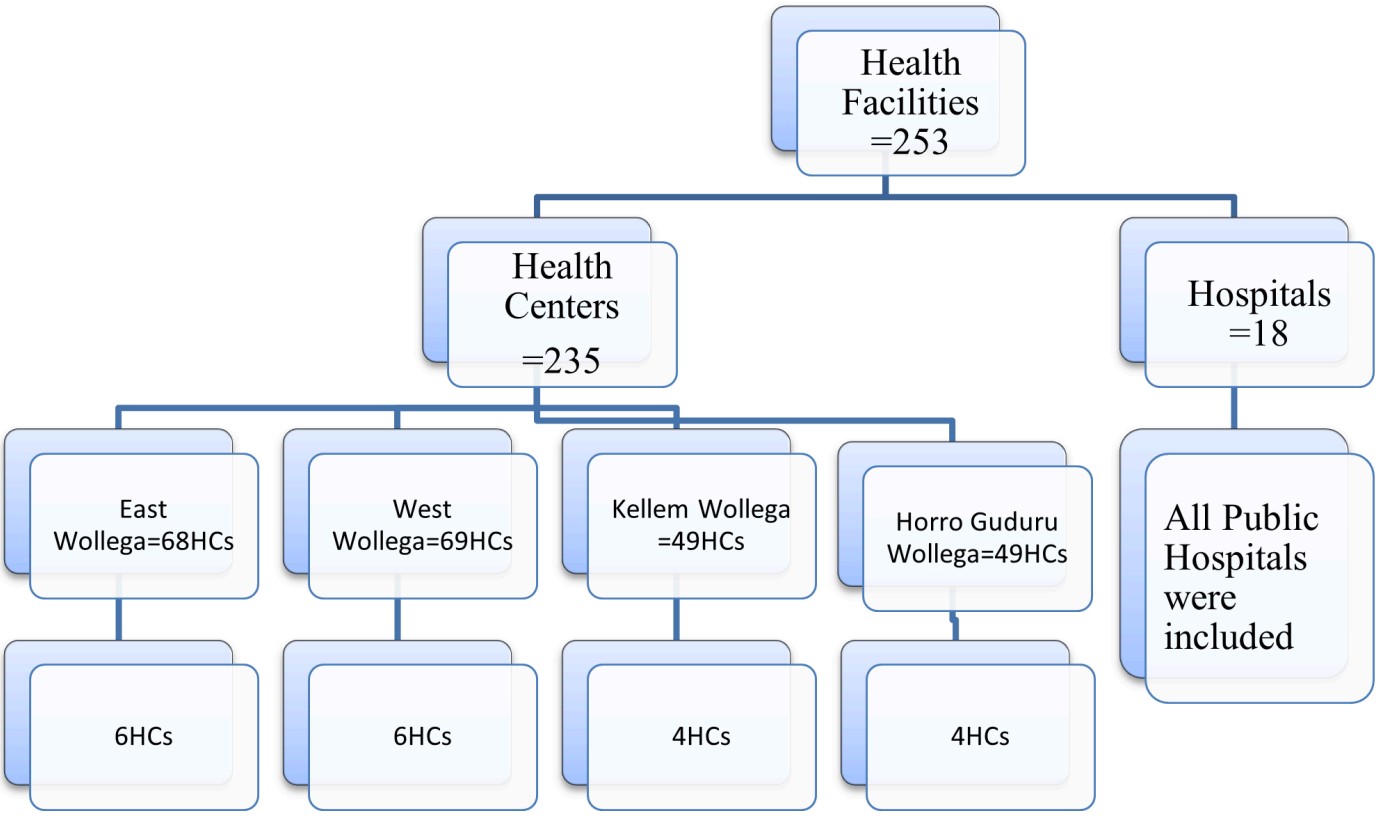
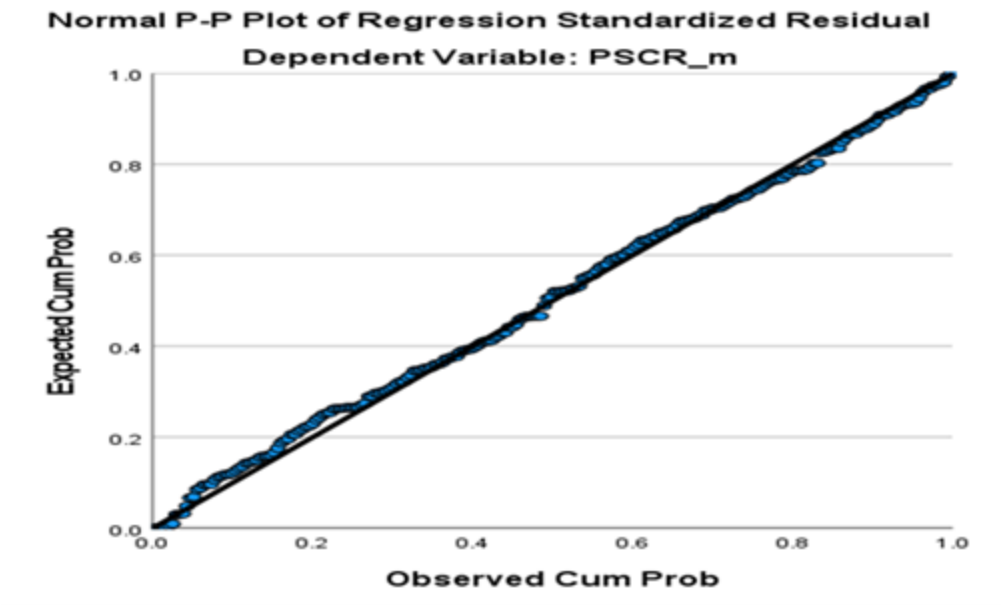



**Figure 1**

Classification of Health Facilities in the Four Wollega Zones and Its Sampling Technique (18).




## Figure 2

Normal P-P Plot Standardized Residuals for Linearity Test (n=228), April 2025

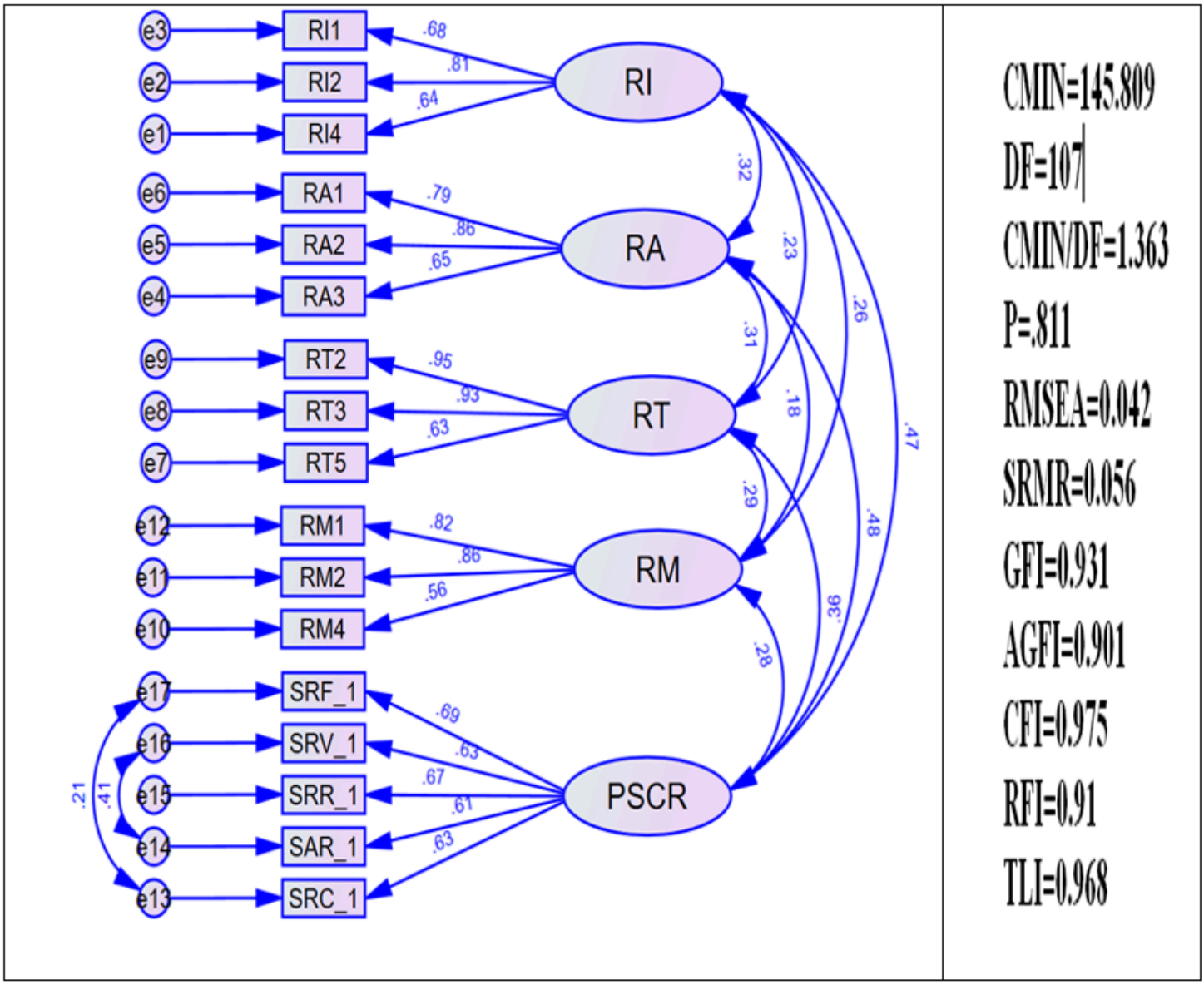



**Figure 3**

Confirmatory Factor Analysis of The Study Variables For The Data Collected From Public Health Facilities of The Four Wollega Zones , Ethiopia ( n=228), April 2025

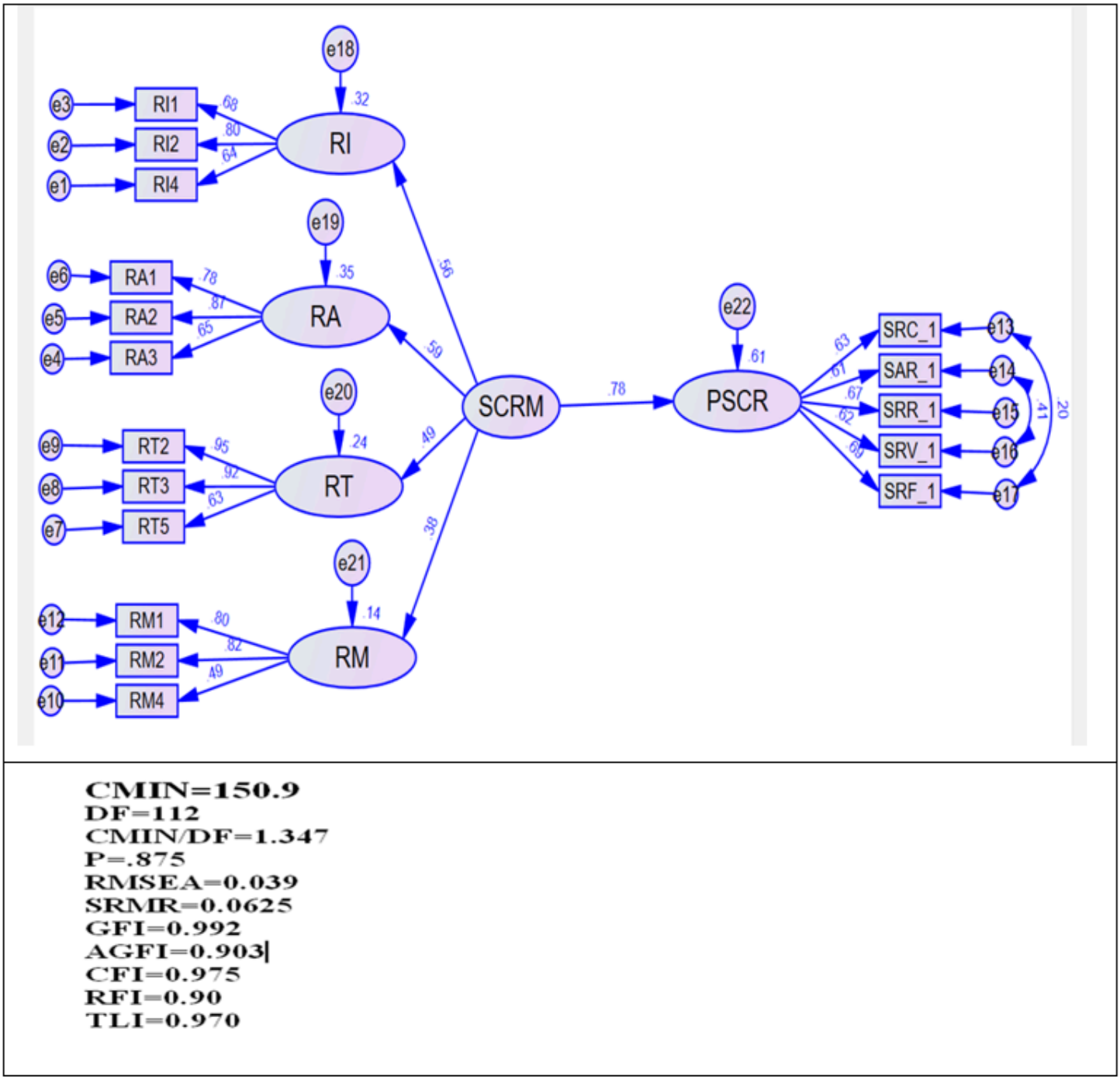



**Figure 4**

Hypothesized Structural Path Analysis of the Study Variables (n=228), April 2025

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFile1.docx