RESEARCH PAPER

Assessing the Digitalization Barriers within African Cold Chains for Resilience and Food Security Enhancement: Best-Worst MCDM Approach

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Received: 14th June, 2026; Revised: 20th July 2026; Accepted: 20th August, 2026; Available Online: 05th September 2026

ABSTRACT
African Continent plans on embracing digital transformation as a key enabler for economic growth and supply chain resiliency. Although the continent recorded progress within digital penetration in the form of internet usage, the cold chains within the continent still lack the needful technological infrastructures for providing end-to-end visibility to thrive disruptions and to overcome post-harvest food losses. Digital capabilities within the cold chains can be facilitated through the implementation of data-driven, real-time monitoring and visibility systems, which in turn foster resilience building through transformation of data into real-time predictive insights for informed decisions. Hence, this study aims at identifying and prioritizing a comprehensive set of barriers for digital competency building through cloud, big data analytics, the Internet of Things (IoT), machine learning, robotics, Artificial Intelligence (AI) etc., within the African Cold Chains in order to combat disruptions and in turn reduce post-harvest food losses for economic prosperity of people who are solely dependent on Agriculture for their living. Consequently, the study deploys the Best-Worst MCDM Approach (BWM) for conducting an in-depth comprehensive analysis of barriers towards digital competency building within the African Cold Chains for fostering resilience and food security capabilities.

Index Terms—Barrier Analysis, Best-Worst MCDM Approach (BWM), Cold Chains, Digital Transformation, Food Security, Resilience

How to cite this article: Gurrala KR, Oyenuga M and Gonela S., Assessing the Digitalization Barriers within African Cold Chains for Resilience and Food Security Enhancement: Best-Worst MCDM Approach. Int J Drug Deliv Technol. 2026;16(87s): 1608-1618; DOI: 10.25258/ijddt.16.87s.171
Source of support: Nil.
Conflict of interest: None

I. INTRODUCTION

Food Loss and Waste (FLW) amplifies Food Insecurity across the Globe, as around one-third of the global food produced for human consumption i.e., 1.3 billion tons or one trillion dollars' worth of food gets lost in the form of post-harvest losses before even reaching the customer or in the form of wastes at the retail and consumer level. Hence, to promote the achievement of SDG goal 12.3 aimed at cutting down the FLW to half by the year 2030 [1]. Additionally, FLW management stands crucial within developing nations such as Sub-Saharan Africa (SSA), where post-harvest food losses account for around 37% (i.e., four billion dollars' worth) of the total food produced every year, with an ability to feed at least 48 million people [2].

Moreover, according to a report published by the World Food Program USA (2022), FLW's figures differ between developed and developing nations, as developed nations account for food waste of around 31% at the retail and consumer level, whereas around one third of the food produced gets lost during and after harvest within the developing nations. Further, poor storage conditions, lack of advanced technologies, manpower related issues, and transportation related challenges stand out as the primary reasons for the post-harvest losses within developing nations [3].

In this pursuit Cold Chains, with inherent capabilities to preserve and safe-guard the shelf-life of the temperature-sensitive foods, stand out as sustainable solutions to curb the post-harvest losses within developing nations. However, highly unreliable, outdated, poorly maintained cold chains produce contrary results i.e., rise in operations costs and environmental harm, resulting in severe economic, social, and environmental damage, further pushing around 6.5 million additional African citizens to suffer from hunger and malnutrition every year [4, 5].

Besides, cold chains are also exposed to multiple risks within developing nations such as faulty storage equipment, lack of uniform infrastructures, energy intensive refrigeration, prolonged power outages, food-borne illnesses, product exposures to heat, product contamination, improper handling, improper packing, etc. [6].

Consequently, cold chain digitalization offers potential solutions to day-to-day problems faced within the African cold chains [7, 8]. Besides, in a continent where over 60% of the total population relies on Agriculture for living [9],

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it is highly desirable to accelerate the digitalization efforts within the cold chains where data stands predominant towards solving the problem of post-harvest losses.

However, the cold chains within Africa face multiple barriers to digitalization due to huge capability gaps in terms of infrastructure and skills in order to facilitate absorption of the new technologies, integration of the new technologies with the existing infrastructures, and retrofitting of the new technologies, leading to the dearth of needful technological infrastructures facilitating end-to-end visibility to thrive disruptions and to overcome post-harvest food losses [10, 11].

Hence, this study aims at identifying and prioritizing a comprehensive set of barriers for digital competency building through RFID, the Internet of Things (IoT), data loggers, digital controls, digital twins, big data analytics, etc., within the African Cold Chains in order to combat disruptions and in turn reduce post-harvest food losses for economic prosperity of people who are solely dependent on Agriculture for their living. Additionally, the barrier prioritization within the study aims at highlighting the key digitalization barriers through deployment of the Best-Worst MCDM approach, to enable the policy makers and key stakeholders to develop apt strategies for overcoming the key barriers highlighted, towards improving the digital competencies within African Cold Chains.

Furthermore, the study intends to address the gap towards successful adoption and deployment of advanced digital trends within the African Cold Chains for resilience and food security enhancement. In this pursuit, the study seeks to find answers to the following questions:

• What are the key barriers for successful digital transformation within the cold chains?

• What barriers need to be addressed on priority, based on the prominence ranking of the barriers?

The next section provides a glimpse into the research associated with highlighting the digitalization barriers within African Cold Chains.

II. RELATED STUDIES

Cold Chain Digitalization has tremendous potential to enhance the performance of Cold Chains within developing nations, as it fosters Advanced Digital Capabilities (ADC) convened through the amalgamation of information, computing, communication, and connectivity technologies, facilitating real-time monitoring and visibility within the cold chains, and additionally promoting data transformation into real-time predictive insights for making informed decisions for risk mitigation and resilience enhancement [12, 11].

Additionally, digital supply chain solutions use advanced technologies such as blockchain, big data analytics, RFID, robotics, sensors, artificial intelligence (AI), cloud computing, machine learning, the Internet of Things (IoT), and the Industrial Internet of Things (IIoT) to increase visibility, optimize operations, and help make better decisions. Modern technology makes it possible to track, monitor, and manage food products in more inventive ways, which reduces waste across the supply chain [11, 13]. Furthermore, digitalization aids with the formulation of mitigation strategies to lower food waste throughout the supply chain by facilitating precise demand forecasting and inventory management, real-time monitoring and traceability, just-in-time delivery and route optimization, dynamic pricing and promotions based on food quality, and waste tracking and analytics at every stage of the supply chain [14, 15]. Therefore, digital technologies provide supply chains with an opportunity to improve food security by lowering food losses in post-harvest distribution, processing, and storage activities.

Although cold chain digitalization stands highly promising, the technology infusion into cold chains operating within developing nations such as Sub-Saharan Africa faces multiple barriers. Table I below underlines the research studies undertaken in this pursuit and thus provides a comprehensive list of digitalization barriers identified by the research scholars. Nonetheless, it is evident from the list of barriers presented within Table I that most of the research studies concentrated on identifying barriers pertaining to a specific category (i.e., Technological, Social, Economic, Organizational etc.).

Table I: Cold Chain Digitalization Barriers

Barrier Code	Barriers Description	References
B-1	Compatibility Problems (Infrastructural incompatibilities between technologies, incompatibilities with existing infrastructures, and compatibility between partners with different business sizes)	[20, 21, 22]
B-2	Data Heterogeneity and Data Management Complexity	[20, 23, 28]
B-3	Data Privacy & Security Concerns	[20, 22, 23,24, 25, 26, 34]
B-4	Lack of access to the needful Technological Infrastructures	[10, 20, 23, 25, 26, 28, 29]
B-5	Lack of proper technological standards & Unified regulatory frameworks for compliance	[10, 20, 22, 23, 24, 25, 28, 30, 32, 34]
B-6	Low speed communication networks and network connectivity and bandwidth issues	Khumalo et al., 2022; 26, 34]

B-7	Nature of the Technology (Openness of the platform and technological complexity)	[20]
B-8	Scalability Problems	[22, 34]
B-9	Technology Immaturity or Readiness	[24, 25, 27, 29]
B-10	High Capital Investments and Financial Constraints	[10, 20, 22, 23, 25, 26, 27, 29, 31, 34,]
B-11	Lack of Govt support & rewards/incentives for adoption	[25, 32]
B-12	Lack of Awareness/information about Technologies and their perceived Benefits	[21, 23,24, 25, 26, 31, 34]
B-13	Lack of collaboration and trust between Cold Chain Stakeholders	[20, 23, 24, 25, 30, 31, 34, 36]
B-14	Lack of data ownership	[20, 34]
B-15	Lack of Knowledge and Technical Expertise	[10, 20, 22, 23, 25, 26, 28, 34,]
B-16	Nature of the Food (Type and form of food being handled)	[20]
B-17	Negative Perceptions and Behavioural Intentions	[20, 25, 26, 34]
B-18	Poor Leadership and Management Support	[25, 35]
B-19	Resistance to Change or Organizational Inertia	[25, 33]

III. RESEARCH FRAMEWORK

Fig. 1 below portrays the proposed framework for the study. The study was planned in two phases. The Phase I concentrates on identification of cold chain digitalization barriers from the literature and categorization of the barriers based on expert inputs through online focus groups with experts from Academia (Supply Chain Experts and Digitalization Experts), and experts from Cold Chain Industry within Africa, followed by Phase II wherein, Best-Worst MCDM approach was employed to analyse and rank the prominence of the barriers within individual categories and across all three categories.

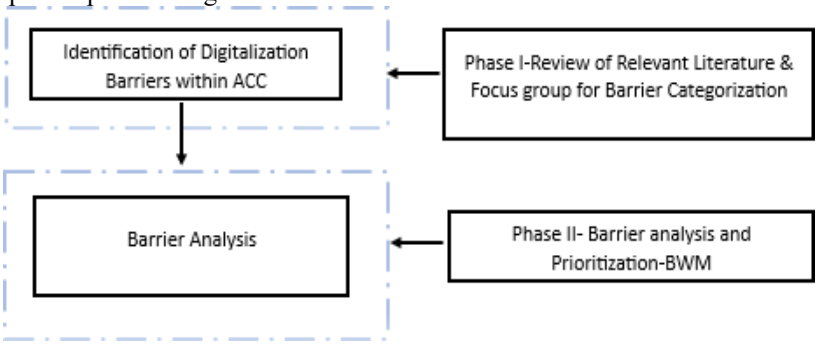


Fig. 1. Research Framework

The analysis of barriers for technology deployment within cold chains is a Multi Criteria Decision Making (MCDM) problem, as it involves determination of relative weights for the criteria in order to define the prominence order for the barriers. Additionally, by offering a methodical and structured framework for decision-making, MCDM methods empower decision-makers to base their decisions on clear and well-defined decision rules. In this pursuit, the current study employs the Best-Worst MCDM (BWM) approach proposed by Rezaei (2015) [16], as it stands out as a popular method for prominence ranking [17, 18]. Moreover, the method out-performs the Analytical Hierarchical Programming (AHP) method, in terms of several statistical evaluation criteria, including conformance, consistency ratio, minimal violation, and total deviation. The framework for the Best-Worst MCDM approach is illustrated within Fig. 2 below [19, 17, 18].

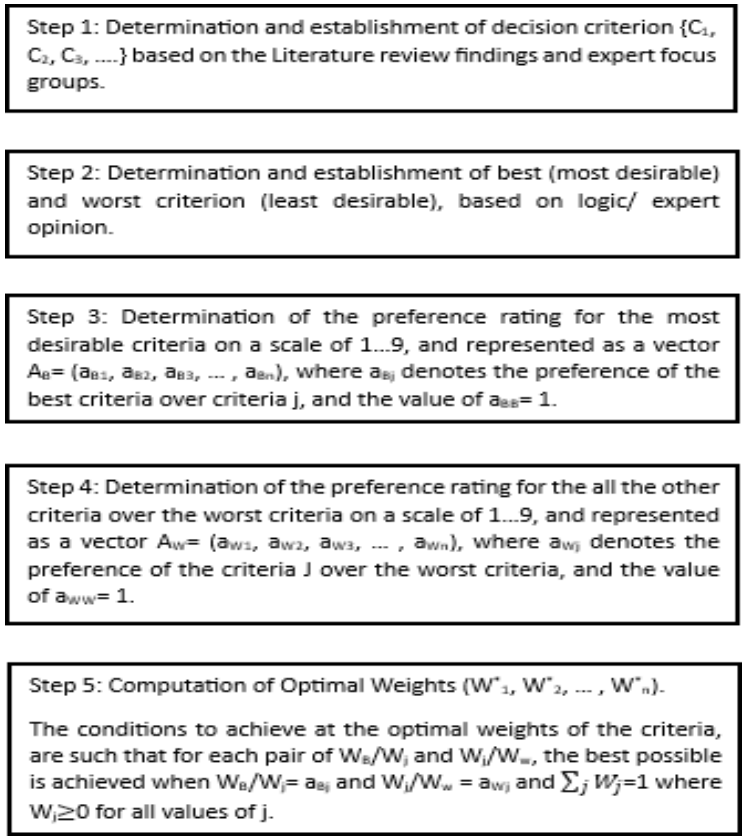


Fig. 2. Framework for the Best-Worst MCDM Approach

The following section would disclose the results achieved from the analysis of digitalization barriers within African Cold Chains.

IV. BARRIER ANALYSIS

The study of relevant literature on barriers for Cold Chain Digitalization helped us arrive at a comprehensive list of 19 barriers (as listed within Table I) for review using the online focus group with the experts. Based on the focus group discussions, the experts agreed on "Technological", "Economical", and "Social/Organizational", as meaningful categories for barrier classification. The output of the focus group discussions is as depicted within Table II below (i.e., classification of barriers into the specified categories—Step 1 of BWM).

Table II: Barrier Categorization

Barrier Code	Barrier Category	Barriers Description
B-1	Technological	Compatibility Problems (Infrastructural incompatibilities between technologies, incompatibilities with existing infrastructures, and compatibility between partners with different business sizes)
B-2		Data Heterogeneity and Data Management Complexity
B-3		Data Privacy & Security Concerns
B-4		Lack of access to the needful Technological Infrastructures
B-5		Lack of proper technological standards & Unified regulatory frameworks for compliance
B-6		Low speed communication networks and network connectivity and bandwidth issues
B-7		Nature of the Technology (Openness of the platform and technological complexity)
B-8		Scalability Problems
B-9		Technology Immaturity or Readiness
B-10	Economical	High Capital Investments and Financial Constraints
B-11		Lack of Govt support & rewards/incentives for adoption

B-12	Social/Organizational	Lack of Awareness/information about Technologies and their perceived Benefits
B-13		Lack of collaboration and trust between Cold Chain Stakeholders
B-14		Lack of data ownership
B-15		Lack of Knowledge and Technical Expertise
B-16		Nature of the Food (Type and form of food being handled)
B-17		Negative Perceptions and Behavioural Intentions
B-18		Poor Leadership and Management Support
B-19		Resistance to Change or Organizational Inertia

A. Technological Barriers

The deployment of advanced technologies within cold chains faced multiple hurdles on the technology front. One of the challenges that cold chains faced predominantly was compatibility, i.e. the cold chains faced problems regarding incompatibilities between technologies, incompatibilities with existing infrastructures, and incompatibility between partners with different business sizes [20, 21, 22]. Additionally, the data collected from multiple sources and from multiple stakeholders resulted in Data Heterogeneity & Data Management Complexity problems [23, 19, 22]. Nonetheless, with the magnitude of data collected, Data Privacy and Security was also at stake [20, 24, 11, 23, 25, 26, 27, 22].

Equally, the developing nations still lack access to the needful infrastructures for advanced technology deployment [10, 20, 23, 25, 28, 27, 29]. Besides, lack of technological standards and unified regulatory frameworks for compliance, also stand detrimental to technology implementation and integration [10, 20, 24, 11, 23, 25, 30, 26, 28, 22, 29].

In addition, lack of high-speed communication networks within developing nations to leverage data for prompt decision making, stands contradictory to the whole idea of implementing new technologies for timely decision making [31, 26, 27]. Furthermore, advanced technologies are characterized by inherent technological immaturity and readiness issues leading to problems with regards to openness of the platforms for specific applications, innate complexities and scalability concerns [20, 24, 25, 32, 26, 22, 29].

B. Economical Barriers

One of the major hindrances for advanced digital capability integration into cold chains is the lack of government support in the form of rewards and incentives and lack of financial capabilities to acquire and implement new technologies [10, 20, 11, 23, 31, 25, 30, 32, 26, 27, 22, 29].

C. Social/Organizational Barriers

In addition, the Social/Organizational barriers also play a significant role in inhibiting technology adoption within cold chains, as they stem from the lack of knowledge and technological expertise, lack of awareness of the new technologies and their benefits, lack of proper leadership and management to guide the change processes for technology implementation by overcoming the organizational inertia for changes, negative perceptions about the new technologies, lack of collaboration and trust between the stakeholders resulting in data ownership problems, and finally a need for customized blend of new technologies based on the type of food handled by the cold chains [33, 34, 10, 20, 21, 35, 24, 23, 25, 26, 28, 36, 27, 22].

To sum up, the barriers work together to prevent the smooth adoption and successful implementation of cutting-edge technological developments into cold chains.

V. EXPERT FEEDBACK

An online survey using the Google Forms was sent out to experts from the Academia (Supply Chain Experts and Digitalization Experts) and Industry (Cold Chain logistic Service Providers from Africa) in order to gain insights on the ranking of each of the barrier identified through the literature study on a scale of 0 to 10, wherein 0 indicates the least rating value for the barrier and on the other hand 10 indicates the strongest rating value for the barrier.

Further, to capture a substantial majority of opinions and exclude distant responses, opinions falling outside the $\pm 2\sigma$ limit of the average of total responses are ignored. Thus, after ignoring remote data, the average rating points for each barrier were obtained. Barriers were ranked both ways within each category overall based on the means of respondents' ratings under (means of all $\pm 2\sigma$) values, where σ denotes the standard deviation of the sample. Table III-Appendix summarizes the survey responses and statistical values derived from the survey responses for further analysis.

Likewise, the table also portrays the in-category and global rankings for the barriers, fostering the identification of the strongest and weakest barriers (Step 2 of BWM). Besides, the best criterion (Step 3 of BWM) and worst criterion (Step 4 of BWM) were respectively determined by comparing the mean values (within $\pm 2\sigma$) of polled responses for each of the barriers to the strongest and weakest barriers within each of the categories respectively.

VI. DETERMINATION OF PROMINENCE OF BARRIERS WITHIN THE TECHNOLOGICAL CATEGORY THROUGH BWM

Consequently, the relative preference values were individually evaluated for each of the barriers, by calculating the ratio values with respect to the best

criterion value and worst criterion value within the Technological category. Further, the relative preference values were calibrated on a scale of 1-9 to convene step 5 of BWM (i.e., determination of optimal criteria weights). Table IV -Appendix depicts the calibrated preferences for the barriers for the Technological Category (i.e., best to others and others to worst).

In consequence, the optimal weights for each of the criteria (i.e., barrier) within the Technological category were computed with the aid of BWM solver and MS Excel. Moreover, Fig. 3 below depicts the graphical representation of the optimal barrier weights based on BWM computations (Step 5 of BWM).

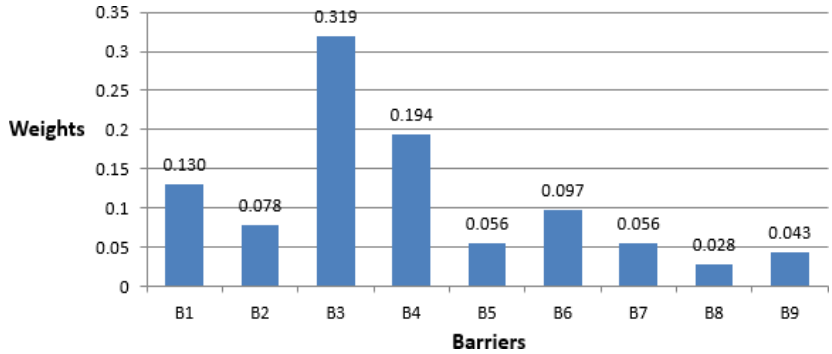


Fig. 3. Optimal Weights for Barriers—Technological Category

Moreover, the input-based CR (Consistency Ratio) and the associated threshold values obtained from the analysis were "0" and "0.3662" indicating that the pair-wise comparison consistency level is acceptable, as input-based CR value is less than the associated threshold value.

VII. DETERMINATION OF PROMINENCE OF BARRIERS WITHIN THE SOCIAL/ORGANIZATIONAL CATEGORY THROUGH BWM

Similarly, Table V-Appendix presents the calibrated preferences for the barriers within the Social/Organizational category (i.e., best to others and others to worst).

Accordingly, the optimal weights for each of the criteria (i.e., barrier) within the Social/Organizational category were computed with the aid of BWM solver and MS Excel. Moreover, Fig. 4 below depicts the graphical representation of the optimal barrier weights based on BWM computations (Step 5 of BWM).

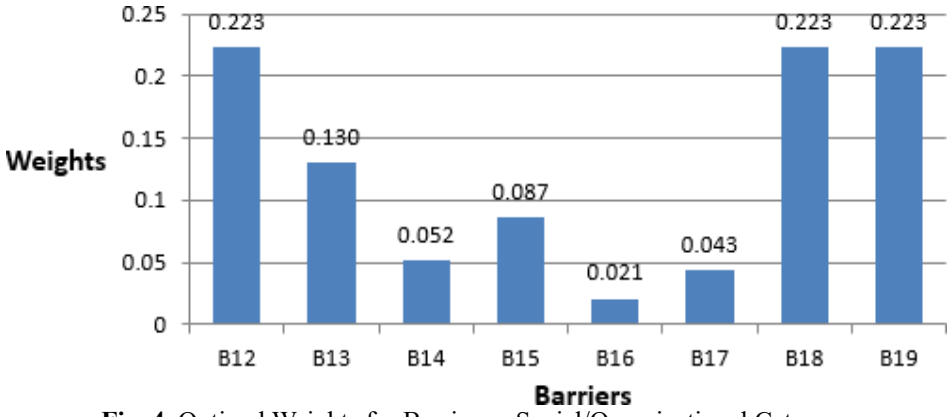


Fig. 4. Optimal Weights for Barriers—Social/Organizational Category

Besides, the input-based CR (Consistency Ratio) and the associated threshold values obtained from the analysis were "0.152778" and "0.362" indicating that the pair-wise comparison consistency level is acceptable, as input-based CR value is less than the associated threshold value.

VIII. DETERMINATION OF PROMINENCE OF BARRIERS AS A CATEGORY OVER OTHER CATEGORIES THROUGH BWM

In addition, the BWM was used to determine the prominence of one category over another, based on the average scores of "M" values of all the barriers within each of the categories. Thus, Table VI-Appendix demonstrates the calibrated preferences for the barriers as a category over others.

As a result, the optimal weights of one category over others was computed with the aid of BWM solver and MS Excel. Moreover, Fig. 5 below depicts the graphical representation of the optimal weights for categories based on BWM computations (Step 5 of BWM). Also, the input-based CR (Consistency Ratio) and the associated threshold

values obtained from the analysis were “0.097222” and “0.1359” indicating that the pair-wise comparison consistency level is acceptable, as input-based CR value is less than the associated threshold value.

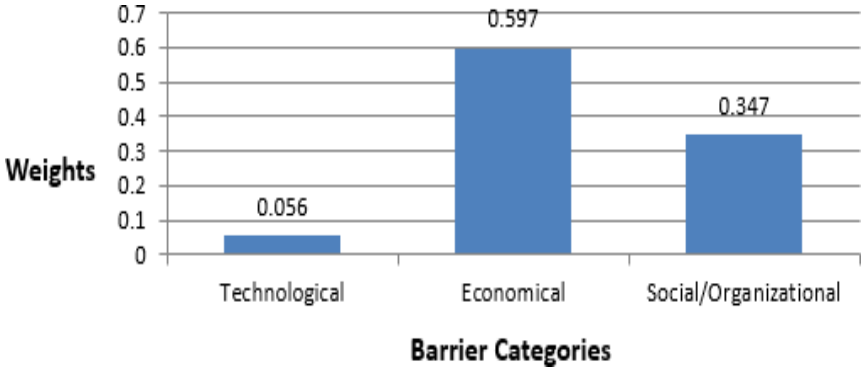


Fig. 5. Optimal Weights for Categories

IX. RESULTS AND DISCUSSION

Table III depicts the in-category and global rankings for the digitalization barriers within African Cold Chains and additionally Fig. 6 below portrays the prominence ranking of barriers across all categories. Additionally, the BWM study ranked the barriers in the order of priority as, B12 (Lack of Awareness/Information about the technologies and their perceived benefits) > B19 (Resistance to Change and Organizational Inertia) > B3 (Data Privacy & Security Concerns) > B11 (Lack of Government Support/Incentives for Technology adoption) > B18 (Poor Leadership and Management Support) > B13 (Lack of Collaboration and Trust between Cold Chain Stakeholders) > B4 (Lack of access to needful Technological Infrastructures) > B15 (Lack of Knowledge and Technical Expertise) > B1 (Compatibility Problems) > B6 (Low Speed Communication Networks, Network Connectivity and Bandwidth issues) > B14 (Lack of Data Ownership) > B2 (Data Heterogeneity and Data Management Complexity) > B10 (High Capital Investments and Financial Constraints) > B5 (Lack of proper Technological Standards and Unified Regulatory Frameworks for Compliance) > B17 (Negative Perceptions and Behavioral Intentions) > B7 (Nature of Technology) > B9 (Technology Immaturity and Readiness) > B8 (Scalability Problems) > B16 (Nature of Food).

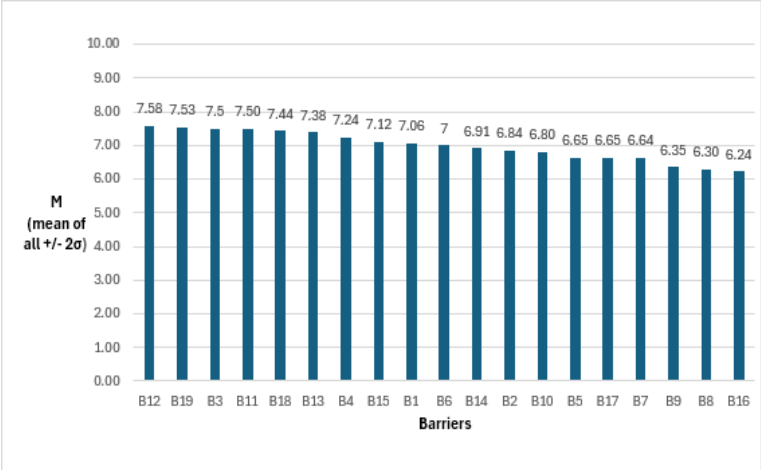


Fig. 6. Prominence Ranking of Barriers across all categories

The ranking clearly demonstrated the importance of developing awareness about the available technologies and their benefits in order to foster change with full-fledged support from the management and government agencies to fill the knowledge gaps and to aid with providing incentives/needful infrastructures respectively, to convene technology implementations at a faster pace.

X. CONCLUSION AND FUTURE IMPLICATIONS

The study provided insights into the importance of technology deployment within cold chains for economic prosperity of majority of African Households who rely on Agriculture for their livelihoods. It also highlighted the gap between current cold chain infrastructures and futuristic structures for extensive food preservation.

The study also explored the relevant literature to identify a list of key barriers for advanced technology deployment

within the African Cold Chains. Further, the study also identified the key barriers that need to be addressed on priority to ensure resilience and food security within cold chains through a detailed and stepwise analysis of data obtained from the literature and expert feedback using a Best-Worst MCDM Modelling approach.

In addition, the study furnished a prominence ranking for the barriers deploying the BWM approach, to facilitate decision makers in formulating apt strategies/policies for mitigation of the essential barriers that hinder the deployment of key digital technologies for resilience and food security enhancement within the African Cold Chains.

However, the study featured a few limitations, as it is based on an analysis of only 19 barriers discovered through literature review and expert focus groups. Additionally, the data for the study was obtained through an expert survey, and statistical measurements were used to identify barrier relationships. Moreover, the study was based solely on 35 responses. Hence, future studies might concentrate on involving larger sample sizes, identifying barriers within similar developing nations, validating the results achieved using other MCDM methods, and finally investigating interdependencies among barriers towards generalization of the results.

XI. CONFLICT OF INTEREST

The authors declare no conflict of interest.

XII. AUTHOR CONTRIBUTIONS

Prof. Kavitha Reddy Gurrala conceptualized the study, conducted the literature review, and led the writing of the manuscript. Dr. Oyenuga Michael and Dr. Saradhi Gonela contributed to the data collection, expert survey design, and analysis. All authors reviewed and approved the final version.

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Appendix:

TABLE III: BARRIER RANKING

Cat.	Code	N	Max	Min	Mean	σ	Mode	Freq	Med	2σ	M+2σ	M-2σ	M	Rank(Cat)	Rank(Global)
Technological	B1	35	10	2	6.8	1.7	8	9	7	3.4	10.2	3.4	7.06	3	G
	B2	35	9	2	6.5	1.7	7	12	7	3.3	9.8	3.2	6.84	5	12
	B3	35	10	1	7.3	2.0	8	9	8	4.1	11.4	3.3	7.5	1	4
	B4	35	10	1	7.1	2.1	6	8	7	4.2	11.3	2.8	7.24	2	7
	B5	35	10	2	6.5	2.0	6	10	6	4.0	10.5	2.5	6.65	6	15
	B6	35	10	1	6.8	2.4	8	7	7	4.9	11.7	1.9	7	4	10
	B7	35	10	3	6.6	1.5	7	10	7	3.0	9.6	3.7	6.64	7	16
	B8	35	10	2	6.3	1.8	6	10	6	3.6	9.8	2.7	6.30	9	18
	B9	35	8	2	6.2	1.6	8	11	6	3.1	9.4	3.1	6.35	8	17
Economical	B10	35	10	3	7.7	1.6	8	11	8	3.1	10.8	4.6	6.80	2	13
	B11	35	10	3	7.9	1.5	8	11	8	2.9	10.9	5.0	7.50	1	3
Social	B12	35	10	3	7.3	1.7	7	10	7	3.5	10.8	3.9	7.58	1	1
	B13	35	10	2	7.2	1.8	6	9	7	3.6	10.8	3.7	7.38	4	6
	B14	35	10	3	6.8	1.6	7	10	7	3.3	10.1	3.5	6.91	6	11
	B15	35	10	3	7.0	1.8	7	10	7	3.6	10.6	3.4	7.12	5	8
	B16	35	10	1	6.1	2.1	5	10	6	4.2	10.3	1.9	6.24	8	19
	B17	35	10	1	6.5	1.8	6	12	7	3.5	10.0	2.9	6.65	7	14
	B18	35	10	1	7.3	1.9	7	8	7	3.8	11.0	3.5	7.44	3	5
	B19	35	10	3	7.4	1.6	7	10	7	3.3	10.7	4.1	7.53	2	2

TABLE IV: CALIBRATED PREFERENCE VALUES OF B & W (TECHNOLOGICAL CATEGORY)

Barrier Code	Mean Rating Value (M)	Ranking (M)	Ratio Best to Others (B)	Calibrated B (1-9)	Ratio Others to Worst (W)	Calibrated W (1-9)
B1	7.06	3	1.062232	3	1.120192	6
B2	6.84	5	1.09589	5	1.085787	5
B3	7.5	1 (best)	1	1	1.189904	9
B4	7.24	2	1.036585	2	1.147907	8
B5	6.65	6	1.128319	7	1.054581	3
B6	7.0	4	1.071429	4	1.110577	6
B7	6.64	7	1.130137	7	1.052885	3

Barrier Code	Mean Rating Value (M)	Ranking (M)	Ratio Best to Others (B)	Calibrated B (1-9)	Ratio Others to Worst (W)	Calibrated W (1-9)
B8	6.30	9 (Worst)	1.189904	9	1	1
B9	6.35	8	1.180556	9	1.007919	1

TABLE V: CALIBRATED PREFERENCE VALUES OF B & W (SOCIAL/ORGANIZATIONAL CATEGORY)

Barrier Code	Mean Rating Value (M)	Ranking According to M	Ratio of Best to Others (B)	Calibrated Value of B on a Scale of 1-G	Ratio of Others to Worst (W)	Calibrated Value of W on a Scale of 1-G
B12	7.58	1 (Best)	1	1	1.21498	9
B13	7.38	4	1.026198	2	1.183962	8
B14	6.91	6	1.096067	5	1.108491	4
B15	7.12	5	1.064363	3	1.141509	6
B16	6.24	8 (Worst)	1.21498	9	1	1
B17	6.65	7	1.139716	6	1.066038	3
B18	7.44	3	1.018086	1	1.193396	9
B1G	7.53	2	1.006155	1	1.207547	9

TABLE VI: CALIBRATED PREFERENCE FOR BARRIERS AS A CATEGORY OVER OTHERS

Category Name	Average of Rating Value (A)	Ranking According to A	Ratio of Best to Others (B)	Calibrated Value of B on a Scale of 1-G	Ratio of Others to Worst (W)	Calibrated Value of W on a Scale of 1-G
Technological	6.84	3 (Worst)	1.045642	9	1	1
Economical	7.15	1 (Best)	1	1	1.045642	9
Social/Organizational	7.04	2	1.01594	2	1.029236	8