Cold Chain Logistics Projects and Performance of Horticulture Export Companies in Rwanda: A Case of Horticulture Exporters Association of Rwanda (HEAR)

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ABSTRACT

Globally, the top three markets for horticulture imports are Europe, the US, and the UAE. The general objective of this study aims to assess the effects of cold chain logistics projects on performance of horticulture exports companies in Rwanda: a case study of Horticulture Exporters association of Rwanda. The specific objectives of this study aim: to assess the effects associated with costs incurred in cold chain logistics on performance of horticulture exports companies in Rwanda, to evaluate the contributions of technology used in cold chain logistics on performance of horticulture exports companies in Rwanda and to determine the effects of geographic location of cold chain stores on performance of horticulture exports companies in Rwanda. Research focused on system theory and resource-based theory. By combining quantitative and qualitative analytic techniques, the researchers used a correlational approach to look for patterns in the interactions between the study's components. The research was based on responses from 92 out of 120 respondents from Rwanda's horticulture export company. Statistical sampling and other methods were part of the "mixed method" approach utilized in the study. Stratified and random sampling was used to pick the exporters, whilst convenient and purposive sampling were used to select the participants from the cold chain logistics management group. Using both personal and secondary sources, the research aimed to determine the impact of cold chain logistics on the growth of Rwandan horticultural export businesses. For the main data set, which covered the years 2021–2023, researchers utilized closed-ended questions to survey participants. For the secondary data set, they combed through financial records and relevant documents from cold chain facilities. The data was analyzed using version 24 of the Statistical Package for the Social Sciences, a widely used statistical tool in the field of social science. Descriptive data were presented in tables displaying percentages and frequencies. Additionally, regression analysis was conducted to delve deeper into the relationship between the study variables. The findings suggest that there are significant associations between certain factors and performance. Firstly, the cost associated with cold trucks and cold rooms demonstrated a strong positive relationship with performance ($\beta = 0.427$, $p < 0.05$). This implies that higher expenditures in maintaining cold trucks and rooms tend to correspond with better performance among horticulture exports companies. Secondly, technology used in cold chain logistics also exhibited a positive relationship with performance, although the effect size was smaller and the p-value slightly higher ($\beta = 0.395$, $p<0.05$). This indicates that employing advanced technology in managing the cold chain logistics process may contribute positively to the performance of these companies. Finally, the geographic location of cold chain stores displayed a significant positive relationship with performance ($\beta = 0.879$, $p<0.05$). The results show that horticultural export companies may boost their performance and profits by investing in cold chain logistics, refrigeration, and holding facilities. If Rwanda wants to make its horticulture exports more competitive, HEAR should weigh the pros and cons of various cold truck and cold room solutions before making a final decision.

Key words: Cold Chain Logistics Projects, Costs Associated with Cold Trucks and Cold Room, Geographic Location of Cold Chain Stores, Horticulture Exports Companies, Performance, Technology Used in Cold Chain Logistics

I. INTRODUCTION

Effective cold chain logistics can be the deciding factor in Rwanda's horticultural export initiatives' success or failure. Inadequate knowledge of postharvest management, quality standards, and food safety procedures keeps many farmers and ranchers from selling their goods. In poor countries, incorrect harvesting and postharvest treatment cause the loss of about 50% of all horticultural crops. Improper harvesting and postharvest management may lead to a decline in quality, a shortening of shelf life, customer rejection, and the possibility of contamination (Davis, 2017).

Rwanda has been investing heavily in cold chain logistics projects to support its exports and growing agricultural sector. The government of Rwanda and the World Bank launched the Rwanda Agriculture and Livestock Export Development (RALED) program in 2016. The initiative's stated goal is to improve agricultural product quality and exportability by fortifying the country's cold chain infrastructure. As part of this procedure, we build refrigerated

trucks to transport produce from fields to markets and construct state-of-the-art cold storage facilities, packing houses, and warehouses (Dawes, 2020).

The African Development Bank (AfDB) loaned Rwanda $38 million so that the country could establish its cold chain facility in 2018. A 4,500-ton cool room and a 1,500-ton frozen storage area will be a part of the facility that the Ministry of Agriculture and Animal Resources is putting into action. At one point, it was a warehouse for horticultural products, such as fruits and vegetables, destined for local and foreign markets. The Rwandan government and the Japan International Cooperation Agency (JICA) came together in 2020 to launch a project that would enhance Rwanda's cold chain logistics infrastructure. The Kigali Logistics Platform will host the new 1,500-ton cold storage facility, and Kigali International Airport and other key sites will have refrigerated containers installed as part of the project. The project's overarching goal is to make agricultural goods safer and better by decreasing post-harvest losses (Lee, 2020).

Though the government and development partners have been actively promoting cold chain logistics projects to bolster the expanding agricultural sector and boost exports, a significant portion of horticulture products 40% are lost or wasted during processing and after harvest (Yeshiwas & Tadele, 2021).

Therefore, this study aims to assess the effects of cold chain logistics projects on performance of horticulture exports companies in Rwanda: a case study of Horticulture Exporters association of Rwanda

1.1 Specific Objectives

i. To assess the effect cost associated with cold trucks and cold rooms on performance of horticulture exports companies in Rwanda.
ii. To evaluate the effect of technology used in cold chain logistics on performance of horticulture exports companies in Rwanda.
iii. To determine the effect of geographic location of cold chain stores on performance of horticulture exports companies in Rwanda.

1.2 Research Hypotheses

Ho1: Cost associated with cold trucks and cold rooms cost associated with cold trucks and cold rooms do not have a statistically significant effect on performance of horticulture exports companies in Rwanda.

Ho2: Technology used in cold chain logistics does not have a statistically significant effect on performance of horticulture exports companies in Rwanda.

Ho3: Geographic location of cold chain stores do not have a statistically significant effect on performance of horticulture exports companies in Rwanda.

II. LITERATURE REVIEW

2.1 Theoretical review

The Resource-based Theory (RBT), upon which this research is based, posits that farms do best when they allocate resources toward those that are rare, valuable, and hard to replicate (Cinar, 2020). Proper management of the cold chain is essential for the efficient production and sale of plants. According to Han et al. (2021), an effective strategy for managing the cold chain begins on the farm and ends in the refrigerator of the customer. Avocados lose a lot of their nutritional value when the cold chain is broken, according to studies done at the University of KwaZulu-Natal. Based on the research, it was shown that only 31%-60% of the fruit with cold chain breakdowns retained comparable quality, in contrast to the 80% of fruit that was held at the correct temperature without interruptions.

Further, in the 1940s, scientist Ludwig von Bertalanffy attempted to create a new way of looking at biological systems, and this endeavor led to the development of System Theory (Hofkirchner, 2019). Because it defines the multidisciplinary study of systems with linked and dependent components, whether natural or man-made, this theory lends substantial support to the present investigation. Everyone agrees that the system's identity is shaped by its inner workings, its framework and aim, outside influences, and the limitations of space and time (George et al., 2023). Planning, manufacturing, monitoring, and transporting are the several steps in cold chain logistics that the research notes are relevant to our cold chain management scenario. Transporting perishable commodities from one point to another in a supply chain utilizing containers that may be heated or cooled is what it is essentially all about (Griffiths & Tabery, 2013).

When applying Resource-based Theory and System Theory to the research on Rwandan horticultural exports, the researcher found that cold chain logistics plays a crucial role. In keeping with our evaluation of the financial ramifications of cold chain logistics, the former highlights the need of allocating resources for maximum efficiency

(Arda et al., 2023). At the same time, using System Theory's viewpoint on interrelated parts to delve into the geographical and technical aspects that impact export success. Our goal is to provide researchers and business leaders with a thorough understanding of the relationship between cold chain infrastructure investments and the long-term viability of Rwanda's horticulture exports by bringing together relevant theoretical frameworks.

2.2 Empirical Review

Wang et al. (2021) evaluated the current cold storage facilities' energy requirements. Present energy use, inefficiencies, limitations, operational expenses, and potential for energy savings were all identified in the evaluation. One Beijing-based firm that supplied fresh agricultural goods was the basis for the study's approach. One of the primary distribution hubs was used as the distribution center, and 10 randomly selected supermarkets were used as demand sites in the calculation. On top of that, the business sent investigators to gather further data. How much time (measured in minutes) it takes for every product to get to the location where it is needed. Our research examined the impact on customers' schedules when service time regulations were not in place, and we provide the results below. Among the several considerations covered in the research are damage price and refrigeration energy use. Time restrictions necessitated the use of a strategy for improving cold chain logistics truck routes. The assessment provided recommendations for energy management in many areas, including refrigeration, lighting, heating, ventilation, and insulation. Given that energy is more expensive in most developing countries, the paper argues that efficient energy use and the usage of alternative energy sources are critical to the sector's growth.

Han et al. (2021) conducted a study on cold chain logistics (CCL) for fresh agricultural products. As a key component in China's rural sector regeneration, cold chain logistics (CCL) helps keep perishable agricultural goods safe and fresh for longer, reduces losses, and increases farmer revenue. Implicit implications for innovation, technology application, facility enhancement, and management optimization have resulted from recent research aimed at increasing CCL efficiency and sustainability. This overview covers current research topics, gaps in knowledge, and issues that CCL may face in the future. Also included are comparisons to other sophisticated countries' infrastructure, data management, and legislative frameworks, as well as an evaluation of China's current CCL industry and technological standing. Addressing environmental concerns and increasing market requirements would need CCL to adopt low-carbon policies and use clever innovation. AI, blockchain, and the Internet of Things (IoT) speed up CCL modernization. The achievement of low-carbon and intelligent CCL goals requires close cooperation among national authorities, businesses, consumers, and multidisciplinary specialists. The development gap between China's CCL industry and more sophisticated countries is expected to be reduced as a result of state policies and financial interventions, which will stimulate infrastructure repair and standards improvements.

Goedhals-Gerber et al. (2021) conducted a study on analyzing temperature protocol deviations in pome fruit export cold chains: A Western Cape case. A major concern plaguing South African pome fruit exporters is the volume of fruit going to waste during the export process. The senescence of fruits and the deterioration in its quality are accelerated by an increase in temperature. Thus, the first step in ultimately extending the shelf life of exported pome fruit and decreasing the risk of rejections is to ensure constant temperature control. The study investigated the severity of temperature protocol deviations within the apple and pear export cold chains from the Western Cape, South Africa to the Netherlands. The study was undertaken in 2018 for Company X, an international fruit exporting firm, to improve the efficiency of its cold chains. The research conducted temperature trials starting as close to the farm as possible and concluding as close to the end consumer as possible. Pulp and ambient temperature probes were inserted into and around the fruit to monitor export temperature profiles. Firstly, the trial results show that non-compliance with temperature protocols occurred more often along the pome fruit export cold chain than initially anticipated. Secondly, the position within the pallet where the temperature breaks occurred highlighted an issue of heat retention resulting from unintentional oversights early in the cold chain. The study also identified areas of possible improvements where management could mitigate senescence factors. The study concluded that the efficient and effective functioning of a cold chain depends on cumulative efforts by all the supply chain partners rather than on the efforts of a single partner.

A recent study by Bhandal et al. (2022) brought attention to the emerging practice of using digital twins to enhance operations and management inside the supply chain. In response, scholars have initiated a dynamic agenda for study to keep pace with this development. The purpose of this article is to review current research that has shown trends in supply chain and operations management and to outline the potential advantages of digital twins in this domain. We use bibliometric literature reviews supported by bibliographic coupling and keyword co-occurrence network analysis to gauge the current level of understanding of digital twins and the value they may bring to operations and supply chain management. It’s most important outcomes were the discovery of four value clusters and a single enabler cluster. Articles that discuss how supply chain operations may be improved at the business process and capability levels via the

use of digital twins make up value clusters. Communities of practice for managing production flows and developing products have emerged at the level of business processes. Located on the network's perimeter, the newly-emerging value cluster focusing on supply chain resilience and risk management operates at the capability level.

According to Watanabe et al. (2022), Sustainable food consumption is crucial to protect the environment and to promote a better quality of life. Our study analyses and compares the causes, perceived consequences of food waste and practices to mitigate it in supermarkets and restaurants. In this study 17 semi-structured interviews were conducted with managers or other responsible persons with mastery of information about food waste of restaurants (self-service and à la carte) and supermarkets. The data were analyzed via thematic content analysis. The leading causes of food waste for the interviewed supermarkets and restaurants were improper handling by the staff, ineffective stock control management and lack of employee training. Supermarkets perceived other causes such as inadequate food packaging, refrigeration and temperature issues and dishonesty of carriers. The perceived consequences of food waste were mainly related to the economic aspect. Regarding adopting practices to reduce waste, some highlights are employee training, waste management by a specialized employee, assertive demand forecasting, meal preparation in the store and food donation. Just the supermarkets employ price reduction as a practice to reduce food waste. We concluded that, in general, supermarkets perceive more causes for waste than restaurants but do not necessarily present practices to mitigate these additional causes.

The study by Lipwop and Achuora (2021), examined the impact of cold chain logistics on the income of product-based enterprises in the County of Nairobi, Kenya. Examining the possible benefits of cold chain techniques for fresh fruit enterprises was the main focus of the research. Transportation, material handling, storage, and information management are all examples of cold processes. Cold material handling and transportation are crucial to the success of fresh fruit businesses, according to the findings. A cold storage facility and an information management system were also determined to be favorably and substantially associated with the performance of produce firms in the research. It suggests that businesses may do better by embracing new information management technology to increase output and product quality.

There have been studies conducted by Ye et al. (2022) to determine how well NDE technology work for seafood cold chain logistics. Data interpretation relied on conventional assessment techniques, which have their benefits and downsides (e.g., sensory evaluation, chemical analysis, and physical measurements). According to the study's findings, international fish trade often involves a number of complex cold chain operations. In these kinds of situations, it becomes clear that cold chain logistics applications to quality control and safety supervision need reliable procedures. This is due to the fact that traditional methods of quality assessment, such as physical and chemical tests, as well as sensory evaluation, have limitations such as imprecision, destructiveness, and cumbersome mass. Cold chain logistics is presently using NDE technology to establish a continuous connection between different nodes, monitor cold chain logistics operations in real-time, and determine the safety and quality of seafood at important points, according to the report.

Sofian (2018) examined Bangladesh's cold chain management system to ascertain its effectiveness. Frozen food consumption is on the rise in metropolitan areas and the recently built cold chain network in Bangladesh were the main sources of data for the research. A combination of secondary data pertaining to the supply chain and some primary data collected by the researcher (by means such as interviews and observations) constitutes the methodology. The majority of farmers do not grasp the significance of keeping temperature control throughout the supply chain, according to the research. Since refrigerated transport is almost nonexistent in Bangladesh, it seems that transportation is the cold chain's weakest link, as is the case in many poor nations. He stressed the need of knowing how to keep products high quality all the way from the field to the table for farmers, logistics providers, exporters, and logistics operators including those who control cold storage facilities and transportation fleets. With this information in hand, cold chain investment will be more appealing and feasible. He proposed a business strategy that would bring together merchants in an alliance, with the goal of controlling costs via the implementation of a buyers' program for association members. Additionally, it was brought out that logistical management of the cold chain network is crucial, as experts anticipate a market growth of 80-90% in the next five years. Warehouses, distribution centers, and transportation backed by logistical management services would make up the cold supply chain and distributor service that would follow. Such a system would need investment in both time and expansion, but it is essential for the benefit of consumers worldwide.

III. METHODOLOGY

3.1 Research Design

The researcher used descriptive and correlational research designs. Descriptive survey research use surveys to collect information on a variety of issues, quantitative and qualitative approach used for data collected with questionnaire and correlational studies research design examined at the links that exist between variables under the study.

3.2 Study Population and Sample Size

The population is defined as the total collection of elements about which wish to make a sum. The study targeted a total of 120 HEAR stakeholders. Therefore, equal opportunity was given to participate in the research study since the entire population was adopted in the research. Slovin's formula was used to determine the sample size for this investigation to ascertain the suitable sample size of 92 stakeholders for the population under investigation. Statistically, Horticulture Exporters Association of Rwanda (HEAR) was well-represented in the survey. This research study's sample population was obtained using a stratified sampling strategy, and basic random sampling procedures were used within that group.

3.3 Data Collection Instruments

Data Collection Instruments are tools or techniques used to gather information and data for research purposes. In this study, questionnaires were used to gather primary data. The stakeholders Horticulture Exporters Association of Rwanda (HEAR) served as the primary sources. Textbooks, journals, publications, and websites that discuss the subject served as secondary data sources. Questionnaires contained some study-related questions that were the same for everyone in order to collect data.

3.4 Data Analysis Method

Data analysis involves reducing the accumulated data to a manageable size, developing summaries, researching patterns and applying statistical techniques, while data preparation includes editing, coding and data entry. Data coding involves assigning numbers or other symbols to responses. Data entry converts information gathered by secondary or primary methods into a medium for visualization and manipulation. Version 22.0 of the Statistical Package for Social Science (SPSS) was used as a tool to analyze the data. The Statistical Package for Social Sciences (SPSS) for quantitative analysis was used in the study. Data was analyzed descriptively and inferentially.

3.5 Ethical Consideration

The researcher requested authorization through a written request addressed to those responsible for the study program before interacting with their stakeholders. Informed consent, voluntary participation, confidentiality/ anonymity are the main ethical considerations in any research study. Regarding privacy, the researcher kept the respondent's privacy by meeting them wherever they wanted. The study assured respondents of anonymity and the information provided would be treated professionally and for the purposes of the study only using the code number instead of the names of the respondents. Respondents were coded instead of reflecting names.

IV. RESULTS & DISCUSSIONS

4.1 Response Rate

Table 1 displays the statistics on the response rate of participants in the study's questionnaire distribution. With 85 completed and returned surveys, the response rate was a respectable 92.39% out of a total of 92 administered. Participants' eagerness to participate in the research is shown by the high return rate. Nevertheless, 4.35 percent of the surveys were never returned, indicating that some participants were little uninterested. During the data collecting phase, a number of persons were temporarily unavailable, which is the major reason why there were no returned questionnaires. Also, 3.26 percent of the surveys sent out were returned, but they were not fully filled out. Smith and Johnson (2022) stated that the high response rate improves the accuracy and generalizability of the data. The researcher found that a response rate of 92.39% is sufficient for data-analysis and discussion. The overall response rate indicates a positive participant involvement in the study.

Table 1

Response Rate

Questionnaires	Frequency	Percent
Returned	85	92.39
Unreturned	4	4.35
Incomplete	3	3.26
Total	92	100.00

4.2 Perceptions of Respondents on Cost Associated with Cold Trucks and Cold Rooms

Table 2 summarizes research on how investments in refrigeration infrastructure affect Rwanda's horticultural exporters' bottom lines.

Table 2

Perceptions of respondents on Cost Associated with Cold Trucks and Cold Rooms

Statement	SD		D		N		A		SA		Mean	Std. Dev.
	fi	%	Fi	%	fi	%	fi	%	fi	%		
The cost of transportation significantly impacts the operational expenses of horticulture export companies in Rwanda.	3	3.5	2	2.4	4	4.7	23	27.1	53	62.4	4.42	.95
Energy expenses related to cold trucks and cold rooms have a notable influence on the overall costs of horticulture exports companies.	3	3.5	2	2.4	7	8.2	30	35.3	43	50.6	4.27	.96
Efficient storage management within cold rooms is crucial for minimizing financial overheads in horticulture export operations.	4	4.7	3	3.5	5	5.9	21	24.7	52	61.2	4.34	1.06
Proper cost management of cold trucks and cold rooms contributes significantly to the competitiveness of horticulture export companies in Rwanda.	4	4.7	4	4.7	4	4.7	35	41.2	38	44.7	4.16	1.04
The investment in cold chain infrastructure, including cold trucks and cold rooms, plays a pivotal role in determining the financial viability of horticulture export companies.	6	7.1	3	3.5	8	9.4	24	28.2	44	51.8	4.14	1.17
Overall											4.27	1.04

Transportation costs have a significant impact on the overhead of horticultural export businesses in Rwanda, as shown by the majority of respondents' agreement (27.1%) or strong agreement (62.4%). The very high mean score (4.42) indicates strong agreement with the statement, and the standard deviation (0. 95) indicate that the responses are clustered closely around the mean, indicating a heterogeneous perception among participants. Most respondents agreed (35.3%) or strongly agreed (50.6%) that Energy expenses related to cold trucks and cold rooms have a notable influence on the overall costs of horticulture exports companies. With a mean score of 4.27, it's clear that people were mostly pleased. Nevertheless, there seems to be considerable variation in the replies, as shown by the standard deviation of 0.96. A significant proportion agreed (24.7%) or strongly agreed (61.2%) that efficient storage management within cold rooms is crucial for minimizing financial overheads in horticulture export operations. The very high mean score (4.34) indicates a favorable perception, and the standard deviation (1.06) indicates a heterogeneous response among participants. A notable percentage agreed (41.2%) or strongly agreed (44.7%) that Proper cost management of cold trucks and cold rooms contributes significantly to the competitiveness of horticulture export companies in Rwanda. The high mean score of 4.16 indicates a relatively positive perception. However, the standard deviation of 1.04 indicates more heterogeneity in responses. A significant portion of the respondents either expressed agreement (28.2%) or strong agreement (51.8%) regarding the critical role played by investment in cold chain infrastructure, encompassing cold trucks and cold rooms, in shaping the financial sustainability of horticulture export firms. The elevated mean score of 4.14 indicates an overall positive perspective among the respondents. However, the standard deviation of 1.17 signifies that there was relatively diverse opinion among the respondents on this particular issue.

The findings align with Watanabe et al. (2022) observations on cold truck costs encompassing fuel, maintenance, driver wages, insurance, and compliance. As a result of these expenditures' persistent nature, they cut into the profits of Rwanda's horticultural export businesses. Companies rely on cold trucks to carry perishable products, but these vehicles may be expensive and put a burden on their performance. The necessity for safe and effective delivery must be balanced with these expenses in order for initiatives to maximize results.

Overall, respondents had a positive impression of the impact of the costs of cold trucks and cool rooms on the performance of Rwandan horticulture export enterprises, as shown by the very high mean score of 4.27. There is some variation in replies across the assertions, as shown by the standard deviation of 1.04, but there is consistency in agreement, suggesting that respondents generally agree positively. The majority of participants seemed to agree that the performance of Rwandan horticulture export enterprises is positively impacted by the costs of cold trucks and cold rooms.

4.3 Perceptions of Respondents on Technology used in Cold Chain Logistics

Table 3 shows that the study's primary objective was to determine how cold chain logistics technology affected the efficiency and productivity of Rwandan horticultural exporters.

Table 3

Perceptions of Respondents on Technology used in Cold Chain Logistics

Statement	SD		D		N		A		SA		Mean	Std. Dev.
	fi	%	Fi	%	fi	%	fi	%	fi	%		
The sensitivity of temperature monitoring technology is crucial for maintaining the quality of horticulture exports during transportation.	5	5.9	4	4.7	3	3.5	35	41.2	38	44.7	4.14	1.09
The implementation of tracking technology positively influences the traceability and accountability of horticulture export shipments.	5	5.9	3	3.5	9	10.6	28	32.9	40	47.1	4.12	1.11
The integration of modern technology in cold chain logistics is vital for reducing potential spoilage and wastage of horticulture products.	5	5.9	4	4.7	3	3.5	34	40.0	39	45.9	4.15	1.09
Effective utilization of technology aids in minimizing temperature variations, ensuring the consistent quality of horticulture exports.	9	10.6	5	5.9	6	7.1	32	37.6	33	38.8	3.88	1.28
The technological superiority of cold chain logistics systems directly affects the ability of horticulture export companies to meet international quality standards.	4	4.7	4	4.7	5	5.9	31	36.5	41	48.2	4.19	1.06
Overall											4.10	1.13

A considerable group agreed (41.2%) or strongly agreed (44.7%) that the sensitivity of temperature monitoring technology is crucial for maintaining the quality of horticulture exports during transportation. The high mean value of 4.14 shows a moderately positive opinion. However, the standard-deviation of 1.09 indicates a heterogeneous response, indicating some variability in opinions. A significant proportion agreed (32.9%) or strongly agreed (47.1%) that the implementation of tracking technology positively influences the traceability and accountability of horticulture export shipments. The high mean of 4.12 shows a relatively positive view. However, the standard-deviation of 1.11 indicates heterogeneous response on agreement among respondents. Almost all participants agreed (40.0%) or strongly agreed (45.9%) that the integration of modern technology in cold chain logistics is vital for reducing potential spoilage and wastage of horticulture products. The high mean of 4.15 shows a moderately positive agreement. The standard-deviation of 1.09 indicates heterogeneous opinions among participants. A significant majority of respondents agreed (37.6%) or strongly agreed (38.8%) that Effective utilization of technology aids in minimizing temperature variations, ensuring the consistent quality of horticulture exports. The high mean value of 3.88 shows a relatively favorable agreement. With a standard deviation of 1.28, it's clear that people's opinions on the matter are rather varied. A large majority of respondents (36.5% or 48.2% to be exact) believe that horticulture export enterprises' capacity to fulfill international quality requirements is directly impacted by the technical excellence of cold chain logistics systems. With a mean score of 4.19,

the level of agreement is fairly favorable. Nevertheless, there is diverse agreement shown by the standard-deviation of 1.06.

The findings align with Sofian (2018) perspective on cold chain technologies, encompassing pre-cooling, refrigeration, insulation, humidity control, and real-time monitoring. To improve the efficiency of Rwanda's horticultural export businesses, these technologies are crucial. They keep the quality, effectiveness, and safety of temperature-sensitive items intact while they are in transportation or storage. Using these approaches may boost your standing in the market, keep demand high, and help you succeed in the cutthroat world of international exports.

Overall, respondents had a relatively good impression of the effect of cold chain logistics technology on the performance of Rwandan horticultural export enterprises, as shown by the high mean score of 4.10. There is a significant amount of variation in the replies across the statements, as shown by the standard deviation of 1.13. This suggests that participants had varying views on how cold chain logistics technology affects the success of Rwandan horticultural export enterprises, notwithstanding a general favorable consensus.

4.4 Perceptions of Respondents on Geographic Location of Cold Chain Stores

Table 3 shows the results of the study on the impact of cold chain store location on the performance of Rwandan horticulture export enterprises.

Table 4

Perceptions of Respondents on Geographic Location of Cold Chain Stores

Statement	SD		D		N		A		SA		Mean	Std. Dev.
	fi	%	fi	%	fi	%	fi	%	fi	%		
Well-located cold chain storage points contribute to reducing post-harvest losses and increasing the availability of quality horticulture products.	2	2.4	4	4.7	4	4.7	33	38.8	42	49.4	4.28	.93
The distribution network that considers the Geographic location of cold chain stores directly influences the market reach and penetration of horticulture exports.	5	5.9	2	2.4	5	5.9	31	36.5	42	49.4	4.21	1.07
The proximity of cold chain storage facilities to markets plays a crucial role in ensuring timely delivery of horticulture exports.	3	3.5	5	5.9	4	4.7	32	37.6	41	48.2	4.21	1.02
Optimal geographic positioning of cold chain stores contributes to minimizing transportation time and preserving the freshness of horticulture products.	1	1.2	4	4.7	6	7.1	32	37.6	42	49.4	4.29	.88
The strategic placement of cold chain storage facilities greatly influences the accessibility and distribution efficiency of horticulture exports.	6	7.1	6	7.1	7	8.2	32	37.6	34	40.0	3.96	1.19
Overall											4.19	1.02

Reduced post-harvest losses and increased availability of quality horticultural products are contributed to by well-located cold chain storage stations, according to a considerable majority of respondents who either agreed (38.8%) or strongly agreed (49.4%). The very high mean score of 4.28 implies a strong consensus, but the standard deviation of 0.93 reveals some variation in the replies. The distribution network that takes the geographic position of cold chain stores into account directly affects the market reach and penetration of horticulture exports, according to a group of participants who either agreed (36.5%) or strongly agreed (49.4%). With a standard-deviation of 1.07 and a very high mean score of 4.21, we can see that there is a lot of agreement among the participants. In order to guarantee the timely delivery of horticultural exports, a large majority of respondents either agreed (37.6%) or strongly agreed (48.2%) that cold chain storage facilities' closeness to markets is vital. A fairly high mean score of 4.21 suggests that most people agree with the statement, but a standard deviation of 1.02 reveals that there is considerable variation in the answers.

The majority of respondents either agreed (37.6%) or strongly agreed (49.4%) that cold chain shops' optimal geographic siting helps to save transit time and keep horticultural items fresh. A mean score of 4.29 indicates a strong agreement. A standard deviation of 0.88 indicates that there is a fair amount of variation in the answers. The strategic positioning of cold chain storage facilities has a significant impact on the accessibility and distribution efficiency of horticultural exports, according to most respondents (37.6%) or those who strongly agreed (40.0%). A mean score of 3.96 indicates a high level of agreement. Some variation in replies is shown by the standard-deviation of 1.19.

The findings align with Bhandal et al. (2022) emphasis of geographic location of cold chain stores as strategically positioned specialized facilities. The success of Rwandan horticultural export companies is heavily influenced by this factor. By minimizing transportation routes and lowering product exposure to temperature changes, well-placed cold chain shops enhance efficiency. Products are kept fresher, losses are reduced, and customer satisfaction is enhanced with optimal placement. Accordingly, improving overall business success is highly dependent on geographical placement within the supply chain network.

Generally, with a mean score of 4.19, respondents had a good impression of how the placement of cold chain shops affected the success of Rwandan horticultural export enterprises. With a standard deviation of 1.02, we can see that there is a fair amount of variation in how people answered each item. The results show that there is a good agreement overall, while there is considerable difference in how the participants see things.

4.5 Perceptions of Respondents on Performance of Horticulture Exports Companies in Rwanda

Table 5 displays the performance of Rwandan horticultural export enterprises.

Table 5

Perceptions of Respondents on Performance of Horticulture Exports Companies in Rwanda

	SD		D		N		A		SA		Mean	Std. Dev.
	fi	%	fi	%	fi	%	fi	%	fi	%		
The volume of horticulture exports increased as indicator of success and performance of export companies in Rwanda.	5	5.9	4	4.7	6	7.1	40	47.1	30	35.3	4.01	1.07
The number of private companies engaged in horticulture exports is a significant growth and competitive.	2	2.4	1	1.2	4	4.7	37	43.5	41	48.2	4.34	.82
There is an increase on annual income generated by horticulture exports in Rwanda.	4	4.7	6	7.1	1	1.2	28	32.9	46	54.1	4.24	1.10
The success of horticulture export businesses can be gauged by the consistent growth in export volumes over time.	4	4.7	6	7.1	1	1.2	34	40.0	40	47.1	4.17	1.08
The performance of horticulture export companies can be assessed by tracking their contribution to the national export revenue of Rwanda.	3	3.5	3	3.5	2	2.4	20	23.5	57	67.1	4.47	.97
Overall											**4.25**	**1.01**

When asked to rate the performance and success of Rwandan export enterprises, a large majority of respondents (47.1% to 35.3%) said that a growth in the number of horticultural exports was a good indication. A strong degree of agreement is shown by the high mean score of 4.01, while a rather heterogeneous response is indicated by the standard deviation of 1.07. The majority of respondents either agreed (43.5%) or strongly agreed (48.2%) that there is a considerable expansion and competitiveness in the number of private enterprises operating in horticulture exports. Strong agreement is shown by the very high mean score of 4.34, but heterogeneous response is indicated by the standard deviation of 0.82.

A rise in horticultural export revenue is reported by the participants, with 32.9% agreeing and 54.1% strongly agreeing. Strong agreement is shown by the very high mean-score of 4.24, while heterogeneous response is shown by the standard-deviation of 1.10. Growing export quantities over time are a good indicator of a horticulture export business's success. Nearly half of those who participated either agreed or strongly agreed. A heterogeneous responses are shown by the comparatively high standard-deviation of 1.08 and the high mean score of 4.17, which imply a high degree of agreement. It is possible to assess the performance of Rwanda's horticulture export businesses by tracking the total revenue they generate for the country. Nearly two-thirds of those who took the poll gave their enthusiastic approval. The very high mean score of 4.47 indicates exceedingly strong agreement, while the standard deviation of 0.97 indicates varied answers.

Lipwop and Achuora (2021) found that horticulture export enterprises in Rwanda operate better when they accomplish their objectives, reach their goals, and have good results. Achieving financial success involves generating income, controlling costs, managing assets, and maximizing profitability. These firms must find a way to balance these things if they want to succeed in the export market while maintaining quality and satisfying industry standards.

Overall, respondents had a good impression of Rwandan horticultural export enterprises' performance, as shown by the very high mean score of 4.25. There is heterogeneous Responses across the assertions, as shown by the standard deviation of 1.01. This indicates that there is a largely positive agreement, while there is considerable heterogeneity in individuals' judgments.

4.6 Regression Analysis

The findings in Table 6 present a model summary concerning the relationship between Geographic location of cold chain stores, Cost associated with cold trucks and cold rooms, Technology used in cold chain logistics, and the Performance of horticulture export companies.

Table 6

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.841[a]	.707	.696	8.26456

a. Predictors: (Constant), Geographic location of cold chain stores, Cost associated with cold trucks and cold rooms, Technology used in cold chain logistics

The multiple correlation coefficient (R) is 0.841, the coefficient of determination (R Square) is 0.707, and the adjusted R Square is 0.696. These values collectively indicate that the combination of Geographic location of cold chain stores, Cost associated with cold trucks and cold rooms, and Technology used in cold chain logistics explains approximately 69.6% of the variability in the performance of horticulture export companies. The findings supported by Feyaerts *et al.* (2020) indicate the rapid expansion of modern supply chains for horticulture products, driven by increased demand. It is worth mentioning that these dynamics are impacted by supermarkets in the US, Europe, and the UAE. The potential is limited in Rwanda because to issues with cold chain adoption, inadequate infrastructure, and lack of coordination. The impact of cold chain logistics on the efficiency of exporting horticultural businesses is the subject of this research. The findings show that there is a strong positive relationship between geographical distance, cost, technology, and business success.

Table 7

ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	13322.706	3	4440.902	65.018	.000[b]
	Residual	5532.541	81	68.303		
	Total	18855.247	84			

a. Dependent Variable: Performance of horticulture exports companies

b. Predictors: (Constant), Geographic location of cold chain stores, Cost associated with cold trucks and cold rooms, Technology used in cold chain logistics

The table 7 shows the results of an analysis of variance that looked at how the independent variables were related (Geographic location of cold chain stores, Cost associated with cold trucks and cold rooms, Technology used in cold chain logistics) and the dependent variable (Performance of horticulture export companies). F= 65.018 and a p-value of 0.000—both below the 0.05 threshold for statistical significance—are revealed by the study. This indicates that the regression analysis is statistically significant, indicating that Geographic location of cold chain stores, Cost associated with cold trucks and cold rooms, and Technology used in cold chain logistics are strong predictors of the performance of horticulture export companies. Hereby, the researcher goes with an alternative hypothesis while the null hypothesis is rejected. The findings supported by Davis (2017) reveal a rapid surge in demand for organic farm products from developing nations by developed countries. The study's examination of the performance of horticultural exports in Rwanda is congruent with this. Geographic distance, cost, and technology are key determinants of corporate success, according to the data, which exhibit considerable regression. Rejecting the null hypothesis, the alternative hypothesis is supported. The impact of several elements on export enterprises is shown by these results.

Table 8
Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.231	3.593		1.734	.087
	Cost associated with cold trucks and cold rooms	1.743	.356	.427	4.901	.000
	Technology used in cold chain logistics	1.279	1.462	.395	.875	.038
	Geographic location of cold chain stores	2.885	1.446	.879	1.995	.049

a. Dependent Variable: Performance of horticulture exports companies

In a linear regression model, the equation took the form of:
$Y = b0 + b1x1 + b2x2 + b3x3$
Where:
Y is the dependent variable (performance of horticulture exports companies)
x1: cost associated with cold trucks and cold rooms
x2: technology used in cold chain logistics
x3: geographic location of cold chain stores
b0 is the intercept or constant term
b1, b2 and b3 are the coefficients or slopes associated with each independent variable

Table 8, illustrating the regression equation, reveals that the performance of horticulture export companies is influenced by a constant factor of -6.231, which remains a constant determinant regardless of other factors. The analysis of other variables indicates that for each unit increase in the Cost associated with cold trucks and cold rooms, the performance of horticulture export companies is expected to increase by a factor of 1.743. Similarly, horticulture export companies' performance increases by 2.885 times for every unit increase in geographic location of cold chain stores and 1.279 times for every unit increase in technology used in cold chain logistics. Notably, there are three statistically significant factors that improve the performance of horticulture export companies: the cost of cold trucks and cold rooms ($p=0.000<0.05$), the technology used in cold chain logistics ($p=0.038<0.05$), and the geographic location of cold chain stores ($p=0.049<0.05$). The first hypothesis (Ho1), that cold truck and room costs do not significantly affect Rwandan horticultural export enterprises' performance, has therefore been rejected by the researcher. There was also a rejection of the second hypothesis (Ho2), which said that cold chain logistics technology does not have a statistically significant impact on the efficiency of Rwandan horticultural export businesses. Similarly, horticulture export enterprises in Rwanda had their performance negatively impacted by the third hypothesis (Ho3), which posited that cold chain shops' geographic locations did not have a statistically significant impact.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

The major objective of this research was to analyze how cold chain logistics initiatives affected the efficiency and productivity of Rwandan horticulture export enterprises, using the Horticulture Exporters Association of Rwanda as an example. In fact, the study's initial hypothesis (Ho1) was rejected, which maintained that the expenses of cold trucks and cool rooms had no impact on the performance of Rwandan horticulture export firms. Similarly, the second hypothesis was proven incorrect; it held that cold chain logistics technology had no substantial impact on the prosperity of Rwandan horticulture export businesses. Similarly, the third hypothesis (Ho3) was also rejected by the researchers. It states that the performance of Rwandan horticulture export firms is not significantly impacted by the placement of cold chain stores. These results show that cold chain logistics programs do improve the performance of Rwandan horticultural export enterprises.

5.2 Recommendations

Considering the possibility of member businesses collaborating and sharing infrastructure, the Horticulture Exporters Association of Rwanda (HEAR) should carefully assess several cold truck and cold room alternatives. The adoption of sensor technology and Internet of Things devices for real-time monitoring of critical parameters, such as temperature and humidity, should be prioritized by HEAR as an ongoing investment in improved cold chain logistics

infrastructure. It is also recommended that regional distribution facilities be established in key locations, and HEAR should advise its members to thoroughly assess possible locations for cold chain stores.

REFERENCES

Arda, O. A., Montabon, F., Tatoglu, E., Golgeci, I., & Zaim, S. (2023). Toward a holistic understanding of sustainability in corporations: Resource-based view of sustainable supply chain management. *Supply Chain Management: An International Journal, 28*(2), 193-208.

Bhandal, R., Meriton, R., Kavanagh, R. E., & Brown, A. (2022). The application of digital twin technology in operations and supply chain management: a bibliometric review. Supply Chain Management: *An International Journal, 27*(2), 182-206.

Cinar, R. (2020). Structuration of Natural Resource-Based Innovations in Universities: How Do They Get Institutionalized? *Sustainability, 12*(5), 1834.

Davis, U. C. (2017). Feed the future innovation lab for horticulture. *Horticulture Journal, 5*(2), 145-159. Retrieved November, 15.

Dawes, W. (2020). Disclosable Restructuring Paper-Transformation of Agriculture Sector Program 4 Phase 2-P161876. *Agricultural Economics Review, 12*(3), 201-215.

Feyaerts, H., Van den Broeck, G., & Maertens, M. (2020). Global and local food value chains in Africa: A review. *Agricultural Economics, 51(*1), 143-157.

George, G., Haas, M. R., McGahan, A. M., Schillebeeckx, S. J., & Tracey, P. (2023). Purpose in the for-profit firm: A review and framework for management research. *Journal of Management, 49*(6), 1841-1869.

Goedhals-Gerber, L. L., Fedeli, S., & van Dyk, F. E. (2021). Analysing temperature protocol deviations in pome fruit export cold chains: A Western Cape case. *Journal of Transport and Supply Chain Management, 15*, 11.

Griffiths, P. E., & Tabery, J. (2013). Developmental systems theory: What does it explain, and how does it explain it? *Advances in Child Development and Behavior, 44*, 65-94. JAI.

Han, J. W., Zuo, M., Zhu, W. Y., Zuo, J. H., Lü, E. L., & Yang, X. T. (2021). A comprehensive review of cold chain logistics for fresh agricultural products: Current status, challenges, and future trends. *Trends in Food Science & Technology, 109*, 536-551.

Hofkirchner, W. (2019). Social relations: building on Ludwig von Bertalanffy. *Systems Research and Behavioral Science, 36*(3), 263-273.

Lee, J. S. (2020). Issues Raised on Korea's Official Development Assistance to Africa: Future Perspective. South Korea's Engagement with Africa: *A History of the Relationship in Multiple Aspects, 5(3)*, 71-102.

Lipwop, M. C., & Achuora, J. (2021). Cold Chain Logistics and the Performance of Fresh Produce Firms in Nairobi City County, Kenya. *International Research Journal of Business and Strategic Management, 2*(2), 45-60.

Smith, J. M., & Johnson, A. R. (2022). Examining factors affecting response rates in survey research. *Journal of Social Sciences, 24*(3), 123-137.

Sofian, M. (2018). An Overview of Cold Chain Network of Golden Harvest in Bangladesh. Tort, Ö. Ö., Vayvay, Ö., & Çobanoğlu, E. (2022). *A Systematic Review of Sustainable Fresh Fruit and Vegetable Supply Chains. Sustainability, 14*(3), 1573.

Wang, M., Wang, Y., Liu, W., Ma, Y., Xiang, L., Yang, Y., & Li, X. (2021). How to achieve a win–win scenario between cost and customer satisfaction for cold chain logistics? *Physica A: Statistical Mechanics and its Applications, 566*(9), 125637-125650

Watanabe, E. A. D. M., Nascimento, C. R. D., Freitas, M. G. M. T. D., & Viana, M. M. (2022). Food waste: an exploratory investigation of causes, practices and consequences perceived by Brazilian supermarkets and restaurants. *British Food Journal, 124*(3), 1022-1045.

Ye, B., Chen, J., Fu, L., & Wang, Y. (2022). Application of nondestructive evaluation (NDE) technologies throughout cold chain logistics of seafood: Classification, innovations and research trends. *LWT,* 158, 113127.

Yeshiwas, D., & Tadele, A. (2021). Improving Cold Chain Logistics to Reduce Post-Harvest Losses of Horticultural Products in Rwanda. *Journal of Agricultural Science and Food Technology, 7*(2), 123-135.