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# Challenges and Opportunities in Implementing Digital Solutions in Cold Chain Logistics in Oman

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## Abstract

The Sultanate of Oman, with its evolving cold chain logistics arena, finds itself balancing between emerging technological advancements and its established operational frameworks (Brown & Al-Harthy, 2019). Considering Oman's pivotal role in international commerce, deciphering the impact of digital innovations in its cold chain logistics is of paramount importance (Khan & Al-Saidi, 2020). This research endeavors to dissect the impediments and opportunities linked to the infusion of digital methodologies within Oman's temperature-sensitive logistics. Guiding this exploration are three specific objectives: (1) Exploring the digital readiness and challenges of Oman's cold chain: Conversations with industry players, logistics aficionados, and cold chain specialists will reveal the existing digital backdrop and its associated challenges. A meticulous analysis of current logistics records will elucidate the potential and implications of digital enhancements. (2) Highlighting apt digital strategies and their resonance in the Omani landscape: A rigorous literature exploration, paired with dialogues with experts, will unveil cutting-edge digital tools, their worldwide applications, and their suitability for Oman's distinctive cold chain environment. (3)Crafting a roadmap for the digital transformation of Oman's cold chain operations: Questionnaires targeting logistics experts and stakeholder interactions will gauge the current state of digital assimilation, understanding, and necessities. These insights will craft a foundation for pragmatic guidelines and advice for effective digital adoption. This scholarly endeavor aims to amplify understanding regarding the digital horizon in Oman's cold chain domain. Its insights aspire to enlighten logistics experts, decision-makers, and industry stakeholders, ensuring Oman carves its niche in the realm of digital-forward cold chain logistics.

## Keywords
Cold Chain Logistics, Digital Solutions, Oman Logistics, Supply Chain Vulnerabilities, Technology.

# 1. Introduction

The Sultanate of Oman, strategically positioned at the crossroads of major trade routes, is increasingly recognizing the pivotal role of cold chain logistics in its economic landscape. This sector, crucial for the efficient and safe transportation of temperature-sensitive goods, faces a pressing need for modernization amidst a rapidly evolving global market. The motivation for this research stems from the urgent requirement to embrace digital solutions in Oman's cold chain logistics, a move critical for enhancing operational efficiency, market competitiveness, and sustainable growth. The significance of this research lies in its potential to guide strategic decision-making and policy formulation, directly impacting the nation's logistical prowess and economic resilience.

However, the path towards digital transformation in Oman's cold chain logistics is fraught with challenges. These include technological inadequacies, infrastructural limitations, and a lack of clear strategic direction, all of which impede the adoption of advanced digital solutions. Furthermore, the existing digital divide, resistance to change, and economic considerations pose significant barriers to the seamless integration of innovative technologies. These problems underscore the need for a comprehensive understanding of the current state of digital readiness, the identification of gaps, and the exploration of feasible digital strategies tailored to Oman's unique context.

This research aims to address these challenges by providing an in-depth analysis of the current landscape of Oman's cold chain logistics. It seeks to uncover the underlying issues hindering digital adoption, evaluate the readiness for digital transformation, and propose actionable strategies that align with the nation's economic and technological framework. The study also endeavors to identify opportunities that digital solutions can unlock, such as enhanced supply chain visibility, improved operational efficiency, and better alignment with global sustainability goals.

Through this exploration, the research aspires to offer a comprehensive roadmap for the digitalization of Oman's cold chain logistics. It is poised to contribute significantly to the body of knowledge in logistics and supply chain management, particularly in the context of emerging economies. The findings and recommendations of this study are anticipated to be instrumental for logistics experts, policymakers, industry stakeholders, and academia in navigating the complexities of digital transformation in the logistics sector.

In essence, this research is not just an academic exercise but a critical endeavor aimed at catalyzing the growth and development of Oman's cold chain logistics, ensuring it remains competitive and relevant in the global arena.

**Objectives**

1. Exploring the digital readiness and challenges of Oman's cold chain.
2. Highlighting apt digital strategies and their resonance in the Omani landscape.
3. Crafting a roadmap for the digital transformation of Oman's cold chain operations:

# 2. Literature Review

The are quite several challenges that countries face in the implementation of digital solutions in Cold Chain Logistics. Oman is not an exception. This section provides an in-depth literature discussion covering the digital readiness of Oman’s cold chain logistics, digital strategies in Oman’s Cold chain logistics and digital planning in the Cold Chain Logistics. The next section reflects on the digital readiness of Oman’s cold chain logistics.

## 2.1. Digital Readiness of Oman’s Cold Chain Logistics

According to Wang (2022), technological advancement and the internet have fueled e-commerce and logistics in different sectors. The digital readiness of cold chain logistics in Oman revolves around digital tracking systems, implementing digital solutions, technologies and tools in the cold chain logistics, and the level of investment to achieve digital transformation.

The digital readiness of Oman's cold chain logistics is an important aspect to consider, especially in the context of the COVID-19 pandemic (Abdulkadir, 2023). The outbreak of COVID-19 has disrupted many supply chains, including the cold chain, which requires specific conditions and faces unique challenges (Faris,et al., 2022). Digital transformation has emerged as a valuable solution for improving the resilience of the cold chain during the pandemic (Balan, 2022). By leveraging digital technology, such as big data analytics and digitalization, the cold chain can enhance its preparedness and agility, leading to improved productivity and operational outcomes. However, it is important to note that the success of digitization in the cold chain sector is influenced by factors such as the availability

of infrastructure, technological economic growth, and the empowerment of society (Ashrafet al., 2023). Therefore, assessing the digital readiness of Oman's cold chain logistics is crucial for ensuring its effectiveness and ability to adapt to future disruptions.

The technological advancement technologies and tools enable easier monitoring and tracking of goods in transit. Lam and Tang (2023) state that real-time monitoring and tracking helps assess components like temperature, humidity, and vibration. These monitoring efforts are crucial in determining the actual remaining shelf life of the perishable products and also helps in cold chain decision making (Lam & Tang, 2023). The scholars also recommend that firms should adopt technologies efficient in capturing data across the cold chain to make the operations more efficient and effective. Further, the real-time tracking and monitoring technologies promote cold supply chain visibility, transparency, improved customer satisfaction levels, and eradicates efficiencies and losses across the cold chain.

Thus, implementing various digital solutions to cold chain logistics is a crucial component of readiness. Schiffmann et al. (2023) highlight that even though the digital solutions in the cold chain logistics promise immense benefits to the company and its stakeholders, the policymakers and decision-makers should adopt a strategic approach during the implementation process. For instance, the firm should make strategic decisions based on the business objectives and goals on the initial investment required, the forecasted return on investment, the business efficiencies, and the value-added to the customers (Schiffmann et al., 2023). Besides, implementing digital solutions should come after making accurate cost-benefit predictions which helps inform sustainable and strategic decision-making which aligns with business objectives (Wang, 2022).

Han (2021) states that digitalized tools and technologies are crucial in cold chain logistics because they promote efficiencies and effectiveness. For instance, the Internet of Things (IoT) technologies have the capabilities of tracking and monitoring temperature fluctuations across the cold supply chain. Han (2021) adds that some cold chain logistics firms have deployed sensors across transport modes like trucks, rail freight, or air cargo to monitor and track product temperatures. Similarly, these technologized tools are integrated with GPS and RFID tracking tools to track the present cargo positions (Han, 2021). The RFID systems utilizes the RFID readers strategically positioned to relay information to the logistics company in real-time using GPS.

Therefore, in response to Schiffmann et al.'s (2023) viewpoint of aligning the digital implementation process with the business strategies and objectives using the Cost-Benefit Analysis (CBA) framework, cold chain logistics providers (CCLPs) can determine the level of investment in these modern technologies. Further, the digital transformation investment levels using the CBA framework informs policymakers and other decision-makers in the cold chain logistics sector to make a balanced and strategic investment approach when choosing and selecting the digital tools (Schiffmann et al., 2023). The scholars also suggest that investors should use an advanced modelling and simulation approach to assess the CBA and only invest when the ROI payback time for digitization is accurate and the benefits outweigh the costs of investments (Schiffmann et al., 2023). The next section provides insight into digital strategies in cold chain logistics.

## 2.2. Digital Strategies in Cold Chain Logistics

Digital strategies in cold chain logistics have been the focus of several studies. Simulation has been identified as a valuable tool for decision-making in the implementation of digital technologies in the food supply chain, providing accurate predictions of cost-benefit and helping organizations make strategic decisions (Ben, Hicks et al ., 2023) In addition, Blockchain adoption has been found to have both positive and negative effects on supply chain performance, depending on factors such as transportation fees and coordination mechanisms (Kniphfer 2023). Further to that resilience strategies, including crisis simulation and digitalization, have been recommended to ensure the sustainable functioning of cold supply chains during disruptions such as the COVID-19 pandemic. The use of Internet of Things (IoT) and blockchain technologies has shown promise in real-time monitoring and control of cold chain logistics, improving transportation efficiency and ensuring the quality and safety of agricultural products (Amin 2022).

Adopting digitized solutions in Oman's cold chain logistics is crucial because they eradicate disruptions and enhances transparency and supply chain efficiencies. Understanding the digital strategies in Oman's cold chain logistics calls for deeply assessing the strategies and approaches logistics industry use when adopting these technologies, the process of budget allocations, the adoption rates of specific tools, and the role of partnerships and collaborations in upholding cold chain digitization (Zhang, Lan & Liang, 2018).

According to Tadesse et al. (2021), cold chain logistic companies should strategically optimize business processes and increase their revenue when they go the digital path. Also, since embracing technologies help meet key supply chain objectives like costs, quality, speed, risk reduction, sustainability, and flexibility, there is an increasing need to adopt a mixed tailored approach to the business models. Tadesse et al. (2021) add that the readiness and willingness of businesses to adopt technologies to their cold chain logistics systems are impacted by workers resistance because of job loss fears, and the expected ROI. The strategies should align with business objectives and solve the erupting challenges by having technological prioritizations and making informed decisions on which part of the supply chain to digitize (Tadesse et al., 2021).

Sharma et al. (2021) while studying the inhibitors of cold supply chains in UAE identified that fragmented cold supply chains, lack of top-level management commitment, higher capital and operational costs, and inadequate information system infrastructure. The scholars assert that an organization's readiness to cold chain logistics is evident in its top management's commitment to effective resource allocation and budgets when prioritizing the right technological tool (Sharma et al., 2021). An organization's readiness to cold chain logistics is evident in its top management's commitment to effective resource allocation and budgets when prioritizing the right technological tool (Anna, 2020). The prioritization of manpower readiness factors, including top management support and commitment for digitalization, is crucial for building competencies in the logistics sector (Anchal, 2021) Additionally, the large company in the multi-case study was best positioned to adopt blockchain due to its robust change management structure, indicating the importance of organizational readiness (Kitti, 2022) Furthermore, the pandemic has brought cold chain logistics to the forefront, highlighting the need for efficient management of vaccine supply, logistics, and distribution. Overall, organizational readiness, as demonstrated by top management's commitment to resource allocation and budgets, plays a significant role in the successful implementation of cold chain logistics and the adoption of technological tools.

Consequently, resource allocations and top-level management commitment to digitizing the cold chain logistics in Oman also determine the adoption rates of different digital tools. Yang, Fu, and Zhang (2021) discovered that technological intelligence and supply chain cooperation are the major factors when adopting the different supply chain IoT, Blockchains, sensors, GPS, and RFID. Further, the scholars hold that these digitized tools produced large volumes of data which helps firms enhance competitiveness and create value according to their needs, budget allocations, and preferences (Yang, Fu & Zhang, 2021). Further, Yang, Fu, and Zhang (2021) state that supply chain cooperation levels involve firms within the supply chain working together to achieve more cold chain logistics effectiveness and best practices. Since Sharma et al. (2021) had identified that poor collaboration among supply chain stakeholders is a major inhibitor to supply chain effectiveness, there is a great need for these stakeholders to form long-lasting relationships in a bid to accelerate digital transformation efforts. Yang, Fu, and Zhang (2021) claim that an advanced technological intelligence with high supply chain cooperation is a crucial opportunity for cold chain logistic industries to achieve digitization effectiveness. The next section outlines digital planning across cold chian logistics.

## Digital Planning Across Cold Chain Logistics

Digital planning across cold chain logistics has gained significant attention and importance, especially during the COVID-19 pandemic. The use of digital technologies such as Digital Supply Chain Twins (DSCT), robotic process automation (RPA), and digital transformation has been explored to improve the efficiency, reliability, and sustainability of cold chain operations. DSCT can enable sustainable network planning and predictive planning within logistics systems, while RPA applications can automate repetitive tasks and streamline operations in the cold chain industry (Liyuan, 2023). Simulation models have been used to predict the benefits and costs of digitalizing cold distribution chains, providing decision-makers with more accurate predictions of the cost-benefit of increased sensorization in supply chains (Lam et al.,2023). Additionally, the integration of Internet of Things (IoT) and digital twins in a cold chain logistics mechanism can enhance reliability, traceability, and risk analysis, ensuring the quality of vaccine delivery and preventing disruptions in the cold chain. These digital technologies and approaches contribute to the resilience, efficiency, and sustainability of cold chain logistics in the digital age.

Yang, Fu, and Zhang (2021) discovered that supply chain firms should start from reviewing the need for having the technologies by linking the drivers and processes before developing adoption strategies based on the current supply chain situations. Thereafter, the firm can make informed decisions for different digitalization levels and extent (Yang, Fu & Zhang, 2021). Similarly, Wang, Ghadge, and Aktas (2023) use a case study of food supply chain, a component of cold chain logistics to highlight the steps taken by logistics organizations to plan for digital transformation. They state that the roadmap to digital transformation is divided into two main stages; initiation and implementation (Wang,

Ghadge & Aktas, 2023). During initiation, cold chain logistic organizations set objective based on key principles like compatibility, and data governance. The firms also implement a robust technological architecture that analyzes the tools' application and perception layers. Finally, the implementation stage involves putting the digitized tools to practice to help solve the challenges identified during the initiation phase (Wang, Ghadge & Aktas, 2023). Furthermore, these scholars highlight that the transformation timeline depend on the complexities of the challenges in place, the type of technologized tool identified, and the power structures within the organization (Wang, Ghadge & Aktas, 2023). Therefore, they suggest that the timeframe from the initiation phase to the implementation stage should be realistic and flexible to accommodate the changing landscapes revolving around technology implementation.
Consequently, Yang, Fu, and Zhang (2021) reveal that different drivers influences adoption activities, levels, and supply chain impacts differently. For instance, the external drivers comprising of customers, suppliers, supply chain partners, and competitors significantly impacts the adoption activities which resultantly shifts the adoption levels toward a higher supply chain cooperation degree (Yang, Fu & Zhang, 2021). Malik et al. (2022) also insist that stakeholders are vital part of the supply chain because they influence the decisions and strategies developed towards improving supply chains. Thus, the cold chain logistic sector should align the crafted roadmap with the actual digital transformation progress and evaluate the progress using metrics like ROI, adoption rates, stakeholder satisfaction rates, and the overall impacts on the business (Chaudhuri et al., 2018). Firms should deploy continuous evaluation and monitoring strategies after the implementation process to assess the strengths and weaknesses of RFIDs, GPS, Big Data Analytics, sensors, Artificial intelligence, and Machine Learning in cold chain logistics (Chaudhuri et al., 2018). Base on the literature discussion the next section presents the conceptual model of the study.

**Conceptual model diagram**

The conceptual model diagram present the study independent variables( digital readiness, digital strategies and digital planning planning) with the mediator (stakeholder engagement) and dependent variable (digital transformation) (Figure 1 and Table 1).

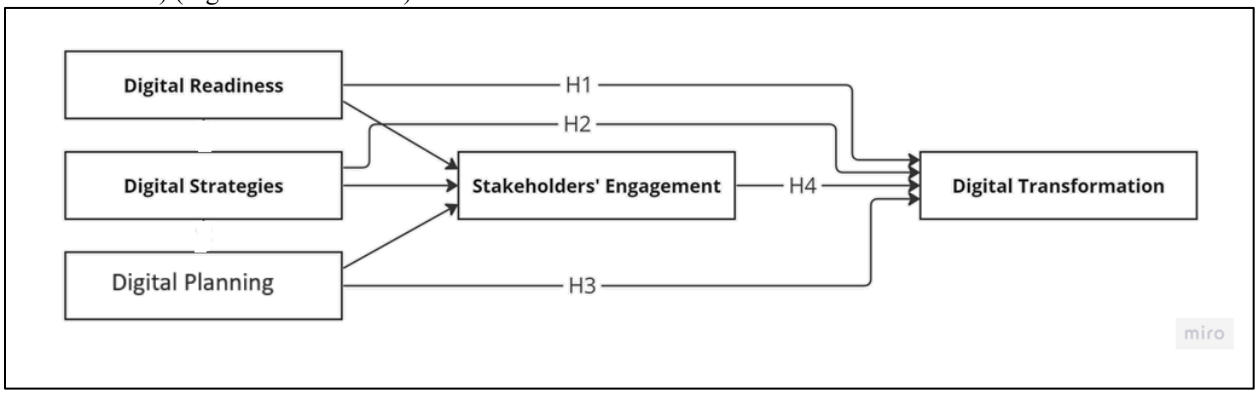


Figure 1. Conceptual model diagram

Table 1. Independent Variables and their measurements,

| **H1 Digital Readiness of Oman's Cold Chain Logistics** | | |
|---|---|---|
| *Measurements* | | Author / Theory |
| DR1 | digital tracking and monitoring systems. | Lam and Tang (2023)<br>Functional theory – Expounding how digital tracking and monitoring in the cold chain enhances real-time visibility and upholding transparency, efficiencies, and better performances from a structural aspect. |
| DR2 | implementation digital solutions. | Schiffmann et al., 2023<br>Structural theory – explaining the structural aspects of implementing digital solutions in cold chain logistics using strategic approaches and organizational readiness. |
| DR3 | digital tools and technologies (e.g., IoT sensors, RFID, GPS) | Han (2021)<br>Structural and Technological Theories – the author explains the transformative potentials of IoT and other digitized technologies in maintaining and upholding the cold chain logistics efficiencies and effectiveness. |

| | | |
|---|---|---|
| DR4 | Level of investment in digital transformation. | Schiffmann et al. (2023)<br>Interdisciplinary developmental theory – the author uses economic and strategic dimension approaches to assess the digital readiness using a balanced and strategic investment approach based on CBA. |
| **H2 Digital Strategies in Oman's Cold Chain Logistics.** | | |
| *Measurements* | | Author / Theory |
| DS1 | digital strategies or approaches employed | Tadesse et al. (2021)<br>Structural theory – the author touches on the business' strategy and functionalism by highlighting the factors to consider when deploying the digital tools in cold chain logistics. |
| DS2 | Allocation of budget | Sharma et al. (2021)<br>Economic theory – the relationship between budget allocation, top management commitment, and financial conditions. |
| DS3 | Adoption rate of specific digital tools | Yang, Fu, and Zhang (2021)<br>Structural Theory – the authors view the adoption rate from a structural metric and technology viewpoints. |
| DS4 | partnerships or collaborations | Yang, Fu, and Zhang (2021)<br><br>Social theory – the benefits of industry-wide collaborations when implementing and utilizing cold chain logistics digitized tools and platforms. |
| **H3 Digital planning.** | | |
| *Measurements* | | Author / Theory |
| CR1 | digital transformation roadmap. | Wang, Ghadge, and Aktas (2023)<br>Diffusion of Innovation (DOI) Theory – explaining how new ideas, technologies, and processes get adopted and diffused by individuals or organizations. |
| CR2 | Timeframe | Wang, Ghadge, and Aktas, (2023)<br>Conceptual theory – handling timeframes and the aspects of implementing digital solutions. |
| CR3 | stakeholders in the development and implementation of the roadmap. | Malik et al. (2022)<br>Stakeholder theory – the role of stakeholders in the development and implementation of digital transformation roadmap. |
| CR4 | crafted roadmap and the actual digital transformation progress. | Chaudhuri et al. (2018)<br>Structural theory – continuous monitoring of cold chain logistic progress. |

## 3. Methods

The study applied pragmatism research methodology which involves the collection of numerical data to understand a phenomenon. This was followed by descriptive and exploratory research designs and quantitative and qualitative approaches to data analysis. The study utilized PLS-SEM regression in the development, assessment, and validation of the model. Hypothesis testing was applied to understand the direct, indirect and moderation effects of the variables of interest. Thematic analysis was used in thematic analysis in the analysis of in-depth interviews.

### 3.1 Research Design

The study uses a mixed research design entailing mixed research design to effectively investigate the challenges and opportunities in implementing digital solutions in cold chain logistics in Oman. The comprehensive mixed design utilized a literature review discussion to support the results and recommendations of the study. (Apuke, 2017).

### 3.2 Population and Sample

The study population was derived from supply chain professionals and will derive information from logistics professionals, cold chain professionals, supply chain policymakers, and related stakeholders. The questionnaire was distributed using the snow sampling technique that utilizes social networks to identify suitable participants for the

study. The sampling technique allowed us to collect data from experts in logistics and supply chain, hence improving the study response rate. This study targets a sample of 290 from 286 responses, which is a 98.6% response rate, The interviews utilized focus group discussions comprising 15 logistics and supply chains from the Ministry of Transport, Communications and Information Technology, Transom Oman (aviation sector) and The Ministry of Agriculture, Fisheries and Water Resources, Oman. The response rate Using Krecie and Morgan precalculated statistical tables the study sample of 286 was established which represents a population of 500000.

## 4. Data Collection, Analysis and Presentation

Kabir (2016) opines that once data is collected from the field, the researcher must clean it before checking their completeness, accuracy, and consistency. Google Forms and Smart PLS 4 are essential data analysis and presentation tools. Qualitative results were analysed based on the focus group discussion meeting which was prepared by the moderators of the meeting. The results are then presented visually using tables, charts, and graphs to illustrate key findings and features. The next section presents the interview question results.

## 5. Results

### 5.1 Interview results

The interviews revealed the following opportunities:

- Digital solutions provide real-time tracking and monitoring capabilities, enhancing visibility and transparency throughout the cold chain. This heightened level of transparency not only improves the understanding of the process but also facilitates more effective management of temperature-sensitive products, reducing the risk of spoilage or damage during transit.

- The incorporation of automation and digital optimization within cold chain operations has the potential to yield significant efficiency gains. This, in turn, leads to a reduction in operational costs. The advanced demand forecasting and inventory management capabilities afforded by these technologies enable companies to minimize wastage and allocate resources more efficiently.

- The adoption of digital solutions opens doors to an expanded market for Omani cold chain products. Through the improvement of both quality and reliability within the cold chain services, Omani products can become more competitive in the global marketplace, particularly within the Gulf Cooperation Council (GCC) region.
- Ensuring the integrity of temperature-sensitive goods during their journey in the supply chain is instrumental in achieving higher levels of customer satisfaction. Meeting consumer demands for products that are fresher and safer not only fosters satisfaction but also strengthens brand loyalty and enhances market positioning.
- Digitalization has the potential to contribute to environmental sustainability objectives. By optimizing routing and reducing energy consumption, digital solutions can lead to a decrease in carbon emissions. This alignment with global sustainability goals not only resonates with eco-conscious consumers but may also result in potential reductions in operational costs.

- The adoption of digital solutions may serve as a catalyst for fostering partnerships and collaborations with technology providers, research institutions, and international organizations. Such collaborative endeavors facilitate knowledge exchange, drive innovation, and create opportunities for joint ventures within the cold chain sector.

- Government incentives and support mechanisms for the digitalization of logistics further incentivize the adoption of these technologies. The potential emergence of public-private partnerships can expedite innovation and enhance the overall competitiveness of Oman's cold chain logistics industry within the academic discourse.

The interviews have also highlighted the following challenges:

- Currently, there is a limited number of companies working in the telecommunications sector who could act as possible candidates to implement digital solutions in the cold supply chain in Oman. This includes digital solutions companies, maintenance, hardware vendors and software development companies.

- Similarly, respondents raised the point that current telecommunication service providers (Omantel and Ooredoo Oman) have a poor network coverage in many areas. Especially those related to fisheries and remote

farming areas. This represents a big obstacle for implementing digital solutions, noting that these solutions heavily depend on network coverage.

- Although there are many development initiatives form the government, most Omani fishermen are still following the artisanal fishing. This fact represents several challenges; 1) Digital illiteracy rate is considerably high amongst fishermen. 2) Majority are poor and can't afford purchasing and installing the required equipment. 3) Low level of awareness about the potential benefits and rewards that could be obtained if such systems are implemented. 4) Resistance to change and the desire for quick and simple earning.

- Some referred to the fishing and farming sectors as "spoiled sectors" because many laws and regulations were announced a very long time ago (some as 2004), but have not been implemented, or no penalties were imposed. This is mainly due to the government trying to give people in these sectors more time for development and prosperity away from tight regulations and penalties. Respondents believe this perspective is a real challenge for any digital developments in the future.

- Respondents also believe that the current local market is not yet ready for such developments. This is due to the size and of supply and demand as well as the limited diversity of cold chain products in the market. Initiating a digital implementation would either not be practical or not economically rewarding.

- There are also challenges related to the cold chain infrastructure itself. On many occasions, fish caught, and harvested fruits/vegetables lose their quality before being loaded to the transporting reefers. The issue here is beyond digital as it's necessary to fully develop the cold chain and then move towards shifting it digitally. The next section reflects on the quantitative data analysis.

The next section presents Quantitative data analysis of the study

## 5.2 Quantitative data analysis

The study calculated the construct reliability and validity to ascertain using the Cronbach's alpha, composite reliability and average variance extracted (AVE) (Table 2).

Table 2. Construct reliability and validity

| | *Cronbach's alpha* | *Composite reliability (rho_a)* | *Composite reliability (rho_c)* | *Average variance extracted (AVE)* |
|---|---|---|---|---|
| *Digital Planning* | 0.852 | 0.872 | 0.898 | 0.689 |
| *Digital Transformation* | 0.912 | 0.921 | 0.939 | 0.794 |
| *Digital readiness* | 0.857 | 0.873 | 0.903 | 0.699 |
| *Digital strategies* | 0.854 | 0.865 | 0.903 | 0.701 |
| *Stakeholder Engagement* | 0.883 | 0.891 | 0.918 | 0.738 |

Cronbach's alpha- Higher values, closer to 1, suggest better reliability, Composite reliability (rho_a and rho_c, values closer to 1 indicate a higher level of reliability, Average Variance Extracted (AVE, Higher AVE values (closer to 1) suggest good convergent validity. The table reflects strong internal consistency and reliability across all constructs, with high values for Cronbach's alpha and composite reliability. Using the Rule of the Thumb, the study results were above the benchmark of (0.7), hence the study proceeded to calculate the discriminant validity. This information is crucial for ensuring the robustness of your research findings. The study went on to establish the discriminant validity of the data (Table 3).

Table 3. Discriminant validity Heterotrait-monotrait ratio (HTMT) – Matrix

| | *Digital Planning* | *Digital Transformation* | *Digital readiness* | *Digital strategies* |
|---|---|---|---|---|
| *Digital Planning* | | | | |
| *Digital Transformation* | 0.555 | | | |
| *Digital readiness* | 0.328 | 0.323 | | |
| *Digital strategies* | 0.693 | 0.706 | 0.453 | |
| *Stakeholder Engagement* | 0.579 | 0.806 | 0.233 | 0.673 |

In discriminant validity assessment, these values should be significantly lower than 1. A commonly accepted threshold is 0.85. Discriminant validity, the general guideline is that the HTMT value for any pair of constructs should be less than 0.85. If the HTMT value is greater than 0.85, it suggests a lack of discriminant validity between the constructs.all the values are below 0.85, indicating satisfactory discriminant validity (Table 4).

Table 4. Outer loadings Outer loadings

| | *Digital Planning* | *Digital Transformation* | *Digital readiness* | *Digital strategies* | *Stakeholder Engagement* |
|---|---|---|---|---|---|
| *DP1* | 0.774 | | | | |
| *DP2* | 0.774 | | | | |
| *DP3* | 0.884 | | | | |
| *DP4* | 0.883 | | | | |
| *DR1* | | | 0.828 | | |
| *DR2* | | | 0.883 | | |
| *DR3* | | | 0.873 | | |
| *DR4* | | | 0.755 | | |
| *DS1* | | | | 0.762 | |
| *DS2* | | | | 0.916 | |
| *DS3* | | | | 0.916 | |
| *DS4* | | | | 0.736 | |
| *DT1* | | 0.947 | | | |
| *DT2* | | 0.832 | | | |
| *DT3* | | 0.831 | | | |
| *DT4* | | 0.947 | | | |
| *SE1* | | | | | 0.833 |
| *SE2* | | | | | 0.827 |
| *SE3* | | | | | 0.887 |
| *SE4* | | | | | 0.887 |

The general rule of thumb for outer loadings is that they should ideally be 0.7 or higher to indicate a strong relationship between the indicator and its corresponding latent construct. Looking at your results, most of the outer loadings surpass this threshold, suggesting a robust measurement model (Figure 2).

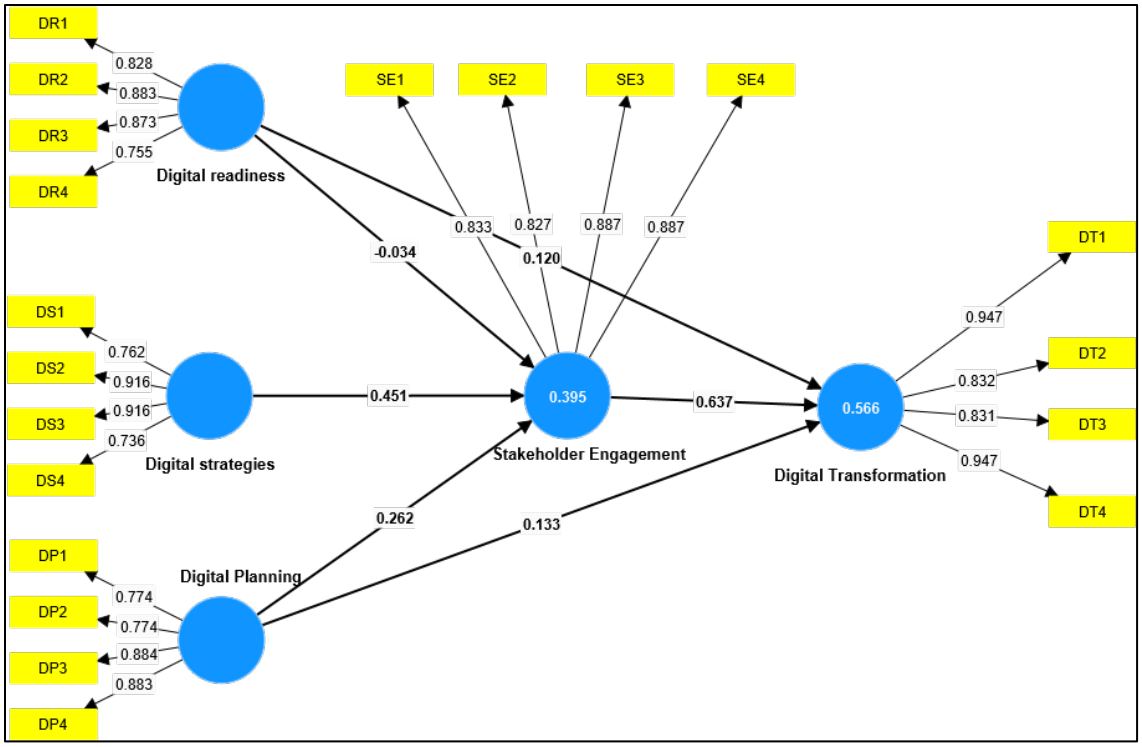


Figure 2. SmartPLS model

The model reveals a strong link between strategic factors like digital strategies (DS), digital planning (DP), and stakeholder engagement (SE) to overall digital transformation (DT). Outer loadings between these constructs range from 0.827 to 0.947, exceeding the 0.7 rule of thumb for construct validity. This suggests a significant influence of these elements on the success of the transformation.

- Focus on strategic alignment: Ensure DS and DP directly support your DT goals, as indicated by the high outer loadings.
- Prioritize stakeholder engagement: Active involvement of stakeholders, as reflected in the strong outer loadings, is crucial for successful adoption and overcoming challenges.
- Investigate the digital readiness gap: Further analysis is needed to understand the reasons behind the weak DR connection and identify potential barriers to bridge. Reassessing readiness strategies might be necessary. Based on preceding results of construct reliability and validity, discriminant validity and the outer loading of the study indicator. The study went on to establish the direct and indirect relationships of the model.

## Direct relationship

Table 5. Mean, STDEV, T values, p values

| | *Original sample (O)* | *Sample mean (M)* | *Standard deviation (STDEV)* | *T statistics (\|O/STDEV\|)* | *P values* |
|---|---|---|---|---|---|
| *Digital Planning -> Digital Transformation* | 0.133 | 0.133 | 0.058 | 2.310 | 0.021 |
| *Digital Planning -> Stakeholder Engagement* | 0.262 | 0.263 | 0.071 | 3.669 | 0.000 |
| *Digital readiness -> Digital Transformation* | 0.120 | 0.122 | 0.040 | 2.984 | 0.003 |
| *Digital readiness -> Stakeholder Engagement* | -0.034 | -0.031 | 0.058 | 0.594 | 0.552 |
| *Digital strategies -> Stakeholder Engagement* | 0.451 | 0.451 | 0.077 | 5.824 | 0.000 |
| *Stakeholder Engagement -> Digital Transformation* | 0.637 | 0.635 | 0.052 | 12.309 | 0.000 |

The analysis of hypothesis testing, focusing on the statistical significance through p-values and t-values, underscores the impactful role of digital planning and strategies in catalyzing digital transformation within Oman's cold chain logistics sector (Table 5). The notable significance between Digital Planning and Digital Transformation, alongside Digital Strategies and Stakeholder Engagement, with p-values of 0.021 and 0.000 respectively, aligns with the literature that emphasizes the criticality of integrating digital tools and technologies for enhancing operational efficiencies (Han, 2021; Lam & Tang, 2023). This concurrence with the scholarly assertion by Lam and Tang (2023) on the importance of real-time monitoring technologies further validates our findings, underscoring the transformative potential of digital readiness on enhancing the cold chain's responsiveness and efficiency. Moreover, our findings on the statistical significance of Digital Planning with Stakeholder Engagement and Digital Readiness with Digital Transformation, with p-values of 0.000 and 0.003 respectively, resonate with the perspectives shared by Schiffmann et al. (2023). These authors advocate for a strategic approach in implementing digital solutions, emphasizing the necessity of aligning digital investments with business objectives to accrue tangible benefits and value addition. This correlation not only supports the theoretical underpinnings of implementing digital solutions but also highlights the empirical evidence on the benefits of such strategic digital implementations in the cold chain logistics of Oman. However, the lack of statistical significance between Digital Readiness and Stakeholder Engagement, with a p-value of 0.552, presents an intriguing deviation from the expected outcomes posited in the literature. This finding challenges the widely held belief in the literature regarding the direct impact of digital readiness on enhancing stakeholder engagement (Malik et al., 2022; Yang, Fu, & Zhang, 2021). It suggests a more nuanced relationship that may depend on additional factors not captured by our model, such as the level of digital literacy among stakeholders or cultural readiness for digital adoption, which warrants further investigation. This nuanced finding emphasizes the importance of not only assessing digital readiness in terms of technological infrastructure and investment but also considering the socio-technical elements that facilitate or hinder stakeholder engagement in digital transformation processes. This insight aligns with the broader discourse on digital transformation in the logistics sector, which advocates for a holistic approach encompassing both technological and human-centric factors to fully leverage the potential of digitalization (Ashraf et al., 2023; Tadesse et al., 2021).

## Indirect relationships

Table 6. Specific indirect effects

| | Original sample (O) | Sample mean (M) | Standard deviation (STDEV) | T statistics (\|O/STDEV\|) | P values |
|---|---|---|---|---|---|
| Digital Planning -> Stakeholder Engagement -> Digital Transformation | 0.167 | 0.167 | 0.046 | 3.620 | 0.000 |
| Digital readiness -> Stakeholder Engagement -> Digital Transformation | -0.022 | -0.020 | 0.037 | 0.589 | 0.556 |
| Digital strategies -> Stakeholder Engagement -> Digital Transformation | 0.287 | 0.287 | 0.059 | 4.886 | 0.000 |

The hypothesis testing results for the sequential relationships of Digital Planning, Stakeholder Engagement, and Digital Transformation (Table 6). The notable statistical significance found in the relationship between Digital Planning and Digital Transformation, mediated by Stakeholder Engagement (p-value of 0.000 and t-value of 3.620), aligns with literature emphasizing the importance of strategic digital planning and active stakeholder engagement in facilitating digital transformation (Lam & Tang, 2023; Schiffmann et al., 2023). However, the lack of significance in the pathway from Digital Readiness through Stakeholder Engagement to Digital Transformation (p-value of 0.556 and t-value of 0.589) suggests a gap in our understanding of how digital readiness directly influences stakeholder engagement, diverging from the expectations set by Malik et al. (2022) and Yang, Fu, & Zhang (2021). This indicates that the relationship between digital readiness and transformative outcomes may be more complex than previously thought. Conversely, the significant sequence from Digital Strategies to Stakeholder Engagement and Digital Transformation (p-value of 0.000 and t-value of 4.886) reinforces the critical role of digital strategies in engaging stakeholders and driving digital transformation, echoing findings from Tadesse et al. (2021) and Yang, Fu, & Zhang (2021). These findings underscore the nuanced interplay between digital planning, readiness, and strategies in achieving digital transformation through stakeholder engagement. While digital planning and strategies directly contribute to transformation, the indirect role of digital readiness suggests a more intricate dynamic at play, highlighting the need for a holistic approach that combines technological capabilities with strategic and human-centric elements for successful digital transformation in cold chain logistics.

## 6. Conclusion

This research has extensively explored the integration of digital solutions in the cold chain logistics sector in Oman, uncovering a nuanced landscape of both challenges and opportunities. The study's findings are critical in understanding the current state of digital readiness in Oman's cold chain logistics and in charting a path forward for its digital transformation.

### 6.1 Summarizing Key Findings

- The research identified significant opportunities for digital transformation in Oman's cold chain logistics, including enhanced real-time tracking and monitoring, operational efficiency gains, market expansion, improved customer satisfaction, contributions to environmental sustainability, and the fostering of strategic partnerships.
- Concurrently, the study highlighted several challenges, notably the limitations in telecommunications infrastructure, digital literacy gaps among stakeholders, resistance to change, and the need for infrastructural development. These challenges underscore the complexity of implementing digital solutions in a context like Oman's.

### 6.2 Fulfillment of Research Objectives:

- **Digital Readiness and Challenges**: The study meticulously explored the current digital readiness in Oman's cold chain logistics, uncovering various challenges such as infrastructure limitations, digital literacy gaps, and resistance to change. This objective was achieved through in-depth literature review and stakeholder interviews, offering a clear picture of the existing digital backdrop and its associated hurdles.
- **Identification of Digital Strategies**: The research highlighted suitable digital strategies and tools that resonate with Oman's unique logistics environment. This was accomplished by examining global digital solutions and contextualizing them to Oman's specific needs and capabilities.
- **Roadmap for Digital Transformation**: A pragmatic and actionable roadmap for the digital transformation of Oman's cold chain operations was crafted. This roadmap, derived from both qualitative and quantitative data, offers strategic guidelines and practical advice for effective digital adoption.

### 6.3 Research Contributions:

- This study stands out for its targeted focus on Oman's cold chain logistics, an area previously underexplored in academic research. It bridges a significant knowledge gap by providing localized insights into digital adoption in a developing country's logistics sector.
- The research introduces an original conceptual model that integrates various aspects of digital transformation in cold chain logistics. This model is not only applicable to Oman but can also be adapted to similar contexts in other developing countries.
- Comprehensive methodology, blending qualitative and quantitative approaches, adds depth and rigor to the study, making it a valuable reference for academics, policymakers, and industry practitioners.

### 6.4 Implications and Recommendations:

- The findings of this study have significant implications for policy formulation, strategic planning, and operational execution in Oman’s cold chain logistics. They underscore the need for an integrated approach involving technological, infrastructural, and human resource development.
- Recommendations for stakeholders include the development of supportive policies, investment in technology and infrastructure, and initiatives for enhancing digital literacy and skill development among logistics professionals. Most importantly it’s recommended that all government initiatives should be collaborative and work together. Currently, there are several initiatives related to the cold chain, but they are scattered.

Finally, this research not only fulfills its initial objectives but also makes a unique contribution to the field of logistics and supply chain management. It offers a nuanced understanding of the digital transformation challenges and opportunities in Oman’s cold chain logistics, providing a foundation for further research and practical implementation. The insights garnered from this study have the potential to drive significant advancements in the digitalization of logistics operations, both within Oman and in similar contexts globally.

## References


Abdulkadir, Investigating the E-Service Adoption of SMEs in Oman Using the Technology Readiness Model 2.0 with a Focus on Business Size, *International Journal of Management & Entrepreneurship Research*, doi: 10.51594/Ijmer.V5i4.460, 2023.

Amin, U., Khan, Y. A., Enhancement of resilience and quality of cold supply chain under the disruptions caused by COVID-19: A case of a developing country, *Australian Journal of Management*, doi: 10.1177/03128962221095596, 2022.

Apuke, O. D., Quantitative research methods: A synopsis approach, *Kuwait Chapter of Arabian Journal of Business and Management Review*, vol. 6, no. 10, pp. 40–47, 2017. Available: https://doi.org/10.12816/0040336.

Chaudhuri, A., Dukovska-Popovska, I., Subramanian, N., Chan, H. K., and Bai, R., Decision-making in cold chain logistics using data analytics: a literature review, *The International Journal of Logistics Management*, vol. 29, no. 3, pp. 839–861, 2018. Available: https://doi.org/10.1108/ijlm-03-2017-0059.

Faris, N., Al-Shubiri, F., Ahmed, A., ALmaashani, A., and Musallam, S. T., The impact of the digital economy paradigm on the productivity and monetary system of Oman, *Journal of Science & Technology Policy Management*, doi: 10.1108/JSTPM-07-2021-0097, 2022.

Franco, J., Research Ethics in Quantitative Research, *Social Sci LibreTexts*, November 14, 2020. Available: https://socialsci.libretexts.org/Bookshelves/Political_Science_and_Civics/Introduction_to_Political_Science_Research_Methods_(Franco_et_al.)/09%3A_Research_Ethics/9.04%3A_Research_Ethics_in_Quantitative_Research.

Gupta, A., Singh, R., Gupta, S., Developing human resource for the digitization of logistics operations: readiness index framework, *International Journal of Manpower*, doi: 10.1108/IJM-03-2021-0175, 2021.

Han, Q. H., Research on the Construction of Cold Chain Logistics Intelligent System Based on 5G Ubiquitous Internet of Things, *Journal of Sensors*, 2021, e6558394, 2021. Available: https://doi.org/10.1155/2021/6558394.

Hicks, B., Nassehi, A., Gopsill, J., and Valero, M. F., A Cost–Benefit Analysis Simulation for the Digitalisation of Cold Supply Chains, *Sensors*, doi: 10.3390/s23084147, 2023.

Johnson, A., McCurdy, D., Schechter, D., Loch, K. D., Hot or Cold... How Ready are Third Party Logistics Cold Storage Companies to Implement Blockchain, 2020. Available: https://doi.org/10.24251/HICSS.2020.653.

Kabir, S. M. S., Methods of Data Collection, in *Basic Guidelines for Research: An Introductory Approach for All Disciplines*, Book Zone Publication, Chittagong-4203, pp. 201–275, 2016. Available: https://www.researchgate.net/publication/325846997_METHODS_OF_DATA_COLLECTION.

Kniphfer, T. C., Impacts of blockchain-based digital transition on cold supply chains with a third-party logistics service provider, *Transportation Research Part E: Logistics and Transportation Review*, 2023. Available: https://doi.org/10.1016/j.tre.2023.103014.

Lam, H. Y., and Tang, V., Digital transformation for cold chain management in freight forwarding industry, *International Journal of Engineering Business Management*, vol. 15, 2023. Available: https://doi.org/10.1177/18479790231160857.

Liyuan, H., Digital Supply Chain Twins for Sustainable Planning of a Logistics System, 2023. Available: https://doi.org/10.1007/978-3-031-28839-5_8.

Malik, M., Arshad, Z., Hussain, A., Jamshed, S., Othman, N., Alolayan, S. O., Gajdács, M., Barrak, I., Alahmadi, Y. M., Aslam, A., and Al thagfan, S. S., Stakeholders' Perspectives Regarding Supply Chain System of Pharmaceuticals and Vaccines in Pakistan: A Qualitative Study, *Healthcare*, vol. 10, no. 9, 1738, 2022. Available: https://doi.org/10.3390/healthcare10091738.

Mishrif, A., Khan, A. I., Digitization policy design and implementation in the logistics and supply chain sector during the time of Covid-19, *Journal of International Logistics and Trade*, doi: 10.1108/jilt-10-2022-0053, 2023.

Schiffmann, O., Hicks, B., Nassehi, A., Gopsill, J., and Valero, M., A Cost–Benefit Analysis Simulation for the Digitalisation of Cold Supply Chains, *Sensors*, vol. 23, no. 8, 4147, 2023. Available: https://doi.org/10.3390/s23084147.

Seprényi, K., Tamás, P., and Cservenák, Á., Logistics and Cold Chain Relationship, *Advanced Logistic Systems*, doi: 10.32971/als.2022.012, 2022

Sundarakani, B., Big data utilisation and its effect on supply chain resilience in Emirati companies, *International Journal of Physical Distribution & Logistics Management*, doi: 10.1080/13675567.2022.2052825, 2022.

Surucu, L., and Maslakci, A., Validity and Reliability in Quantitative Research, *Business & Management Studies: An International Journal*, vol. 8, no. 3, pp. 2694–2726, 2020. Available: https://doi.org/10.15295/bmij.v8i3.1540.

Tadesse, M. D., Gebresenbet, G., Tavasszy, L., and Ljungberg, D., Assessment of Digitalized Logistics for Implementation in Low-Income Countries, *Future Transportation*, vol. 1, no. 2, pp. 227–247, 2021. Available: https://doi.org/10.3390/futuretransp1020014.

Wang, S., Ghadge, A., and Aktas, E., Digital Transformation in Food Supply Chains: A Review and Implementation Roadmap, 30th EurOMA Conference, 2023. Available: https://dspace.lib.cranfield.ac.uk/handle/1826/20049.

Wang, S., Study on Cold Chain Logistics Operation and Risk Control of Fresh e-Commerce Products, *Advances in Multimedia*, 2022, 1–11, 2022. Available: https://doi.org/10.1155/2022/7272370.

Yang, M., Fu, M., and Zhang, Z., The adoption of digital technologies in supply chains: Drivers, process and impact, *Technological Forecasting and Social Change*, vol. 169, 120795, 2021. Available: https://doi.org/10.1016/j.techfore.2021.120795.

Zhang, X., Lan, Y., and Liang, Y., Research on the Construction and Development Strategy of Cold Chain Logistics Information System in Jilin Province under the Background of Rural Revitalization, *IOP Conference Series: Materials Science and Engineering*, vol. 394, 042057, 2018. Available: https://doi.org/10.1088/1757-899x/394/4/042057.

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