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# Evaluating Sri Lanka's Perishable Cold Chain to Increase Rural Supply to Urban Markets

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## 1. Introduction

Cold Chain has become an increasingly prevalent segment of the global supply chain, particularly when perishable products are moved within appropriate environments at specified temperatures in global export markets. A cold supply chain can be defined as a combination of food logistics and refrigerated systems that helps to preserve the quality of products in their original state. This includes adapting various cold chain practices in different supply chain functions such as transportation, warehousing, procurement and inventory management. Even though cold chains are becoming important segments of supply chains in many developed countries, they are still lagging behind in developing countries like Sri Lanka and huge losses are incurred annually due to poor practices in the sector [1].

## 2. Objective

The main objective of this research is to identify the factors that influence cold chain efficiency and the relationship between them in terms of cost and quality.

## 3. Literature Review

Previous research emphasized factors such as value, integration, resource utilization, minimum wastage, cost and service leadership as being significant in supply chain (SC) efficiency [2]. Furthermore, factors related to infrastructure used in cold chain operations such as supply procurement (pre-cooling system, rural markets, manufacturers), transport (refrigerated trucks, cargo containers, railway wagons) and storage (cold storage and warehouses) are critical [3]. Use of technology to preserve quality [4], the use of information systems for inventory and warehouse management, fleet tracking and temperature monitoring systems [5] are vital to cold chain efficiency. Moreover, use of forecasting and demand management techniques[3], visibility of the cold chain through collaborative relationships between partners to move goods effectively and efficiently [6] and nature of packaging material used directly impact the quality of the product. However, there are many challenges to adopting cold chain practices due to factors such as poor cold storage network, lack of cold storage and irregular power supply. [3].

## 4. Methodology

The research was conducted in three stages. An extensive study of literature was carried out to explore research in the arena of cold supply chains in relation to different supply chain functional areas: namely, transportation, storage, procurement, and inventory management. Based on findings of Phase One, a questionnaire was developed, and a pilot survey conducted through discussions and interviews with industry experts to validate factors found through literature. Using outputs from Phases One, a questionnaire was finalised, and a survey was carried out to identify key factors influencing cold chain efficiency in the Sri Lankan context. In the last stage, data acquired from Phase Two were used for further analysis in assessing the extent to which the factors were important to cold chain efficiency and constructing the relationships between factors.

## 5. Results

The exploratory analysis carried out in the literature review identified 16 factors that affect cold chain performance. This indicated that the results obtained from exploratory factor analysis (EFA) for the 12 observed variables were reliable. Confirmatory factor analysis (CFA) was conducted to verify the factor structure of the identified set of variables as shown in Table 1.

**Table 1: Rotated Component Matrix of the accepted model**

| Observed Variables | Component | | |
|---|---|---|---|
| | **1: Specialized Resources** | **2: Infrastructure & HR Expertise** | **3: Product Characteristics** |
| Separate storage space | 0.898 | | |
| Technologies used for tracking and monitoring | 0.844 | | |
| Quality of packaging | 0.778 | | |
| Temp. controlled transport equipment | 0.649 | | |
| Proper road infrastructure | | 0.798 | |
| Suitable racking system | | 0.706 | |
| Proper training | | 0.688 | |
| Correct handling techniques | | 0663 | |
| Supplier knowledge and awareness | | 0.655 | |
| Proper packaging method | | | 0.777 |
| Planning replenishment | | | 0.772 |
| Forecasting & demand management techniques | | | 0.630 |

The results obtained from several factor reductions resulted in a KMO measure of sampling adequacy of 0.719, which was greater than the initially obtained KMO

measure of 0.696; confirming acceptance of the modified model. The resulting three components explain 74% of total variance and were labelled as follows to explain all factors related to the underlying features of factors under each category. To measure the reliability of latent constructs, the Cronbach alpha test was carried out, and as shown in Table 2 it was more than 0.7 for each of the three components. Accordingly it was indicated that the results were highly reliable [8].

**Table 2: Results from Cronbach alpha from EFA**

| Latent construct | Cronbach Alpha value |
|---|---|
| Specialized resources | 0.874 |
| Infrastructure & HR Expertise | 0.869 |
| Product Characteristics | 0.732 |

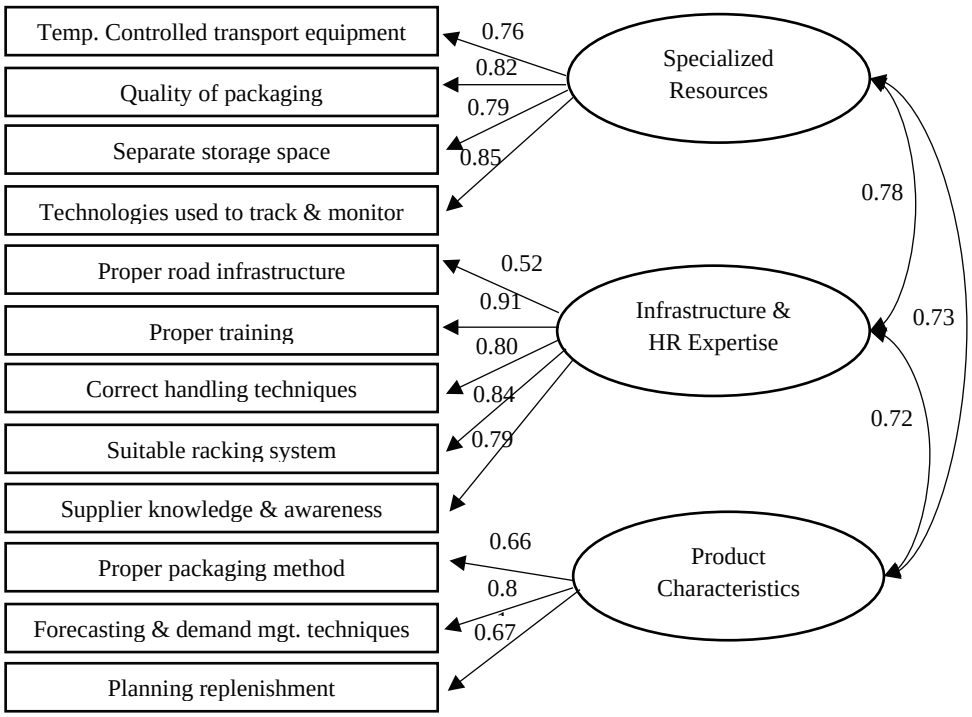


**Figure 1: Output from the accepted model of CFA**

As shown in Figure 1, all factor loadings for the observed variables are above 0.5. Higher loadings of variables suggest that cold chain efficiency is influenced by product characteristics, specialized resources and infrastructure, and human resources (HR) expertise.

For a model to be valid, the CMIN/DF value must be in the range of 1.0-3.0. Therefore, the accepted model is considered as the best fit model extracted from the CFA, with a CMIN/DF value of 2.893. This indicates that the model has achieved the parsimonious fit. In addition, the model is identified as a valid model through achieving uni-

dimensionality (with factor loadings greater than 0.5 for all observed variables) and reliability through the Cronbach's alpha measurement, which is same as the results obtained from EFA [9].

The Structural Equation Model (SEM) is developed to identify relationships between the factors. As shown in Figure 2, all factors have a positive relationship and confirm that all hypotheses developed are acceptable. The model has a CMIN/DF value of 2.893, which is below 3 and above 1: this reveals the model to be a valid one under parsimonious fit [10].

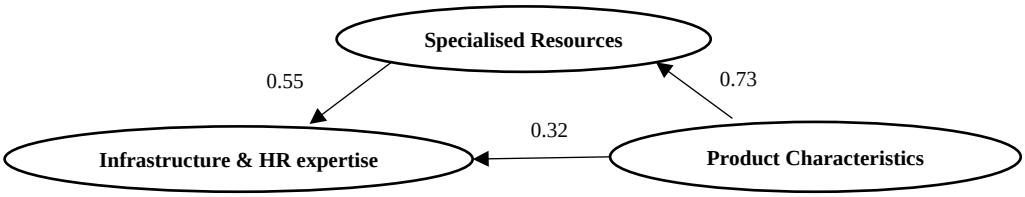


**Figure 2: Output from the Accepted model of SEM**

## 6. Conclusions and Recommendations

This study mainly focuses on identifying the factors that influence cold chain efficiency and their relationships. Sixteen factors were identified from a comprehensive literature review. The analysis of primary data collected through the online survey shows that 12 factors are critical to cold chain performance in Sri Lanka. From EFA and CFA analysis, it was found that the three factors: specialized resources, infrastructure and HR expertise, and product characteristics impact cold chain performance. To identify the relationship between these factors, Structural Equation Modelling was carried out, and results show that:

(i) change in product characteristics will have a positive impact on change in specialised resources,
(ii) change in specialised resources will have a positive impact on change in infrastructure and HR expertise and
(iii) Change in product characteristics will have a positive impact on change in infrastructure and HR expertise towards improving cold chain efficiency.

Product characteristics such as perishability and the quality driven nature have an impact on use of specialized resources. For example, since perishable products have a low shelf life and tends to spoil easily, replenishment should be planned properly using accurate forecasting and demand management techniques. Therefore, such products require to be replenished more frequently compared to other products. To maintain the perishability nature of such products, specialized resources such as temperature-controlled transport vehicles and equipment are necessary. To make it more efficient, infrastructure and HR expertise should be reformed accordingly. For example, to maintain such requirements employees need to be competent to navigate and identify

issues if any and rectify them immediately. Otherwise, despite having better infrastructure, wastage will increase. Depending on product characteristics, the use of appropriate infrastructure and HR expertise differs. For example, proper packaging in transport and storage should be handled by trained and experienced employees. More wastage happens during handing process especially for perishable products such as meat and dairy due to their delicacy and being prone to contamination rapidly [1]. Suppliers should be aware of product characteristics to avoid unnecessary spoilage that could happen at the origin of the supply chain. Initial packaging, storage and distribution practices should be well established according to the product features. As per the findings it is highlighted that while these three factors contribute individually, they also positively influence each other to further improve cold chain efficiency as relationships between those elements seem to have a high correlation with each other.

It may however be noted that the sample size and questionnaire responses could be subject to industry-wise bias, experience bias, extreme response bias and social desirability bias, which could make the real scenario deviate away from these findings.

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