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DIGITAL TRANSFORMATION AND SUSTAINABILITY IN DAIRY LOGISTICS

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ABSTRACT :

Dairy logistics requires timely transportation, reliable temperature control, product traceability and efficient inventory handling because dairy products are perishable. This study examines reported digital technology use, cold-chain monitoring, green logistics practices and perceived logistics outcomes. The supplied dataset contained 125 response records. Descriptive frequency and percentage analysis was performed for categorical questionnaire items. Mean, median and standard deviation were calculated only for four ordered response items: frequency of digital-system use, perceived effectiveness of temperature monitoring, perceived contribution of route optimization to fuel reduction, and perceived delivery-efficiency improvement. Chi-square tests examined associations between gender and digital-system-use frequency and between occupation and primary digital technology. One-way ANOVA compared delivery-improvement scores across occupation groups. Multiple linear regression assessed whether digital-system-use frequency, temperature-monitoring effectiveness and perceived route-optimization benefit predicted the delivery-improvement score. Digital systems were most often reported as used rarely (39.2%), while 51.2% rated temperature monitoring very or extremely effective. The regression model was not statistically significant, $F(3,120)=1.08$, $p=.359$, $R^2=.026$. Neither chi-square test was statistically significant; however, sparse expected cell counts limit the reliability of the occupation-by-technology test. Results should be interpreted as exploratory perceptions, not verified operational impacts. Data-quality limitations—including incomplete responses and inconsistent labels—are documented.

Keywords: Dairy Logistics, Digital Transformation, Cold-Chain Management, Sustainable Logistics, Operational Efficiency

Introduction

Dairy products such as milk, curd, butter, cheese and paneer are perishable and require suitable handling, storage and transportation. Dairy logistics connects producers and collection centres with processing units, warehouses, distributors, retailers and consumers. Delays or temperature excursions can reduce quality, increase spoilage and create financial losses.

Digital transformation introduces tools such as GPS tracking, mobile applications, Internet of Things (IoT) sensors, inventory software, barcode/QR systems and data analytics into logistics operations. These tools may improve visibility, coordination, demand planning and traceability. Green logistics practices—including route optimization, load optimization, waste reduction, recycling and fuel-efficient transport—aim to improve resource efficiency and reduce environmental impacts.

This study evaluates respondents' reported use of digital and sustainable logistics practices and their perceptions of operational outcomes. Because the supplied questionnaire primarily contains categorical choices rather than validated multi-item scales or measured operational KPIs, the analysis is exploratory and cannot establish causal effects.

Review of Literature

Earlier studies discussed in the original draft highlight several ways digital tools may support dairy and food supply chains. Malik et al. (2022) reviewed optimization in dairy supply chains, including the growing use of AI and machine learning for forecasting, quality monitoring and logistics planning. Dal Mas, Massaro, Ndou and Raguseo (2023) examined blockchain in sustainable agrifood supply chains, with attention to traceability, food safety and transparency. Kumar and Kumar (2023) focused on blockchain-based smart dairy supply chains in India. Other studies summarized in the draft considered technologies for reducing emissions in fresh milk supply chains, the use of blockchain, RFID and IoT in cheese supply chains, sustainability assessment, Industry 4.0 readiness, and the social impacts of digitalization. Taken together, these studies suggest that digital tools may improve traceability, cold-chain visibility and operational efficiency. However, implementation costs, staff skills and infrastructure remain important challenges. The original draft did not include complete bibliographic details, so the references should be checked and completed before submission.

Research Gap

Research on digital tools and green logistics often considers these areas separately. There is still a need for more field-based evidence examining how digital transformation, cold-chain management and green logistics work together in dairy logistics, particularly in developing markets and smaller

businesses. This study contributes exploratory survey evidence on respondents' perceptions. However, the dataset does not include direct measurements of logistics costs, emissions or product spoilage, so those outcomes cannot be verified here.

Objectives of the Study

1. To study the use of digital technologies in dairy logistics operations.
2. To examine how digital cold-chain management is perceived to help reduce spoilage and improve product quality.
3. To understand reported green logistics practices and perceived resource/environmental benefits.
4. To examine the relationship between digital transformation and perceived dairy logistics performance.
5. To identify perceived contributions of digital and sustainable logistics practices to cost efficiency, customer satisfaction and environmental performance.

HYPOTHESES OF THE STUDY

H0: There is no statistically significant relationship between the selected digital/sustainability indicators and dairy logistics performance.
H1: There is a statistically significant relationship between the selected digital/sustainability indicators and dairy logistics performance.
Operationally, the analyses test selected associations and a regression model using available ordinal-coded responses. These tests do not cover every aspect of the broad conceptual hypothesis.
Research Methodology

Research design
This study used a quantitative, cross-sectional survey design and analysed 125 records in the Excel dataset. The intended respondents were people involved in dairy logistics or related activities. However, the available files did not document how participants were selected, how they were recruited, which locations were covered, or when data collection took place.

Data and variables
The questionnaire includes demographic questions and 15 questions about digital technology, frequency of system use, temperature monitoring, green logistics, delivery efficiency, cost reduction, customer satisfaction, product wastage and sustainability priorities. One record was missing a delivery-efficiency response, and a small number of fields had missing or inconsistent labels. Percentages therefore use the valid responses available for each question.

Statistical techniques
- Frequency and percentage distributions for categorical responses.
- Mean, median and sample standard deviation for four ordered 1–5 response items only; larger scores represent more frequent use or a more positive/higher perceived level.
- Pearson chi-square tests for selected categorical associations, with Cramér's V as an effect-size measure.
- One-way ANOVA comparing the ordinal-coded delivery-improvement score across occupation groups.
- Multiple ordinary least-squares linear regression with delivery-improvement score as the outcome and digital-use frequency, temperature-monitoring effectiveness and route-optimization benefit as predictors.

Important measurement note: numeric codes for nominal categories (for example, gender or technology type) are labels, not quantities. Their means and standard deviations are not substantively meaningful, so they are not reported. The 1–5 ordinal scores are treated as approximately interval only for exploratory ANOVA/regression; this assumption is a limitation.
Data Analysis and Results

Respondent profile
Gender: Male = 79 (63.2%); Female = 46 (36.8%)
Age: Below 25 years = 93 (74.4%); 25–35 years = 32 (25.6%)
Educational Qualification: Undergraduate = 94 (75.2%); Postgraduate = 31 (24.8%)
Occupation: Other = 76 (60.8%); Logistics employee = 16 (12.8%); Dairy farmer/producer = 11 (8.8%); Warehouse/cold-chain employee = 11 (8.8%); Transportation employee = 6 (4.8%); Manager/supervisor = 5 (4.0%)

Main descriptive findings

Which digital technology is mainly used in your dairy logistics activities?: the most frequent response was "Mobile applications" (61 of 125 valid responses; 48.8%).
How frequently are digital systems used for managing dairy logistics?: the most frequent response was "Rarely" (49 of 125 valid responses; 39.2%).
What is the main benefit you experience from using digital technology?: the most frequent response was "Better tracking of products" (37 of 125 valid responses; 29.6%).
Which method is mainly used to monitor the temperature of dairy products during transportation?: the most frequent response was "Digital temperature

device" (51 of 125 valid responses; 40.8%).
How effective is digital temperature monitoring in preventing dairy product spoilage?: the most frequent response was "Very effective" (41 of 125 valid responses; 32.8%).
What usually happens when the temperature of dairy products goes beyond the required level?: the most frequent response was "Automatic alert is received" (59 of 125 valid responses; 47.2%).
Which green logistics practice is most commonly followed in your organization?: the most frequent response was "Waste reduction" (33 of 125 valid responses; 26.4%).
How much do you think route optimization helps reduce fuel consumption?: the most frequent response was "To a moderate extent" (52 of 125 valid responses; 41.6%).
Which area receives the most attention when implementing sustainable logistics?: the most frequent response was "Packaging waste" (35 of 124 valid responses; 28.2%).
Which logistics activity has improved the most after adopting digital technology?: the most frequent response was "Inventory management" (35 of 124 valid responses; 28.2%).
What level of improvement has digital technology brought to delivery efficiency?: the most frequent response was "25–50%" (37 of 124 valid responses; 29.8%).
Which benefit of digital transformation contributes most to cost reduction?: the most frequent response was "Lower labour costs" (41 of 123 valid responses; 33.3%).
Which factor contributes most to customer satisfaction in dairy logistics?: the most frequent response was "Product availability" (28 of 124 valid responses; 22.6%).
How has the use of sustainable logistics practices affected product wastage?: the most frequent response was "Reduced significantly" (40 of 123 valid responses; 32.5%).
Which sustainability benefit is most important for your organization?: the most frequent response was "Better use of resources" (45 of 106 valid responses; 42.5%).

Mean, median and standard deviation

Ordered measure (score 1–5)	N	Mean	Median	SD
How frequently are digital systems used for managing dairy logistics?	125	3.152	3.0	1.245
How effective is digital temperature monitoring in preventing dairy product spoilage?	125	3.472	4.0	1.036
How much do you think route optimization helps reduce fuel consumption?	125	3.144	3.0	0.939
What level of improvement has digital technology brought to delivery efficiency?	124	3.411	3.0	1.148

Digital-system use averaged 3.152 (median 3, SD 1.245), between the coded categories sometimes and frequently, with the median corresponding to sometimes. Temperature-monitoring effectiveness averaged 3.472 (median 4, SD 1.036), with a median of very effective. Perceived route-optimization contribution averaged 3.144 (median 3, SD 0.939), corresponding to a moderate extent. Perceived delivery-efficiency improvement averaged 3.411 (median 3, SD 1.148) among 124 valid records, with the median category 25–50%. These are ordinal-coded summaries of perceptions, not direct measurements of operational performance.

Chi-square tests

Association	N	χ^2	df	p-value	Cramér's V
Gender × digital-system frequency	125	2.625	4	0.622	0.145
Occupation × main digital technology	125	21.243	25	0.679	0.184

Gender and digital-system-use frequency were not significantly associated, $\chi^2(4, N=125)=2.625$, $p=.622$, Cramér's $V=.145$. Occupation and main digital technology were also not statistically significant, $\chi^2(25, N=125)=21.243$, $p=.679$, Cramér's $V=.184$. However, the second test has sparse cells (minimum expected count=.28), violating the usual chi-square approximation guidance. Therefore, its p-value should not be relied upon; categories should be combined on a theoretically defensible basis or an exact/Monte Carlo test used.

One-way ANOVA

Outcome	Grouping	N	Groups	F	p-value
Delivery-efficiency improvement score	Occupation	124	6	1.285	0.275

The mean delivery-improvement score did not differ significantly across the six occupation groups, F(5, 118)=1.285, p=.275. This is a non-significant result, so the analysis does not provide evidence of differences between occupation groups. Some groups are small and the outcome is ordinal; the result should be treated as exploratory.

Multiple linear regression

Predictor	B	SE	t	p-value
const	2.572	0.546	4.708	0.000
How frequently are digital systems used for managing dairy logistics?_score	0.109	0.083	1.313	0.192
How effective is digital temperature monitoring in preventing dairy product spoilage?_score	0.115	0.100	1.144	0.255
How much do you think route optimization helps reduce fuel consumption?_score	0.031	0.110	0.277	0.782

Model fit: N=124, R^2=0.026, adjusted R^2=0.002, F=1.083, model p=0.359.

The overall model was not statistically significant, F(3, 120)=1.083, p=.359, and explained approximately 2.6% of the observed variation in the ordinal-coded delivery-improvement score. Digital-system-use frequency (B=.109, p=.192), temperature-monitoring effectiveness (B=.115, p=.255) and perceived route-optimization benefit (B=.031, p=.782) were not statistically significant predictors in this model. The coefficients should not be interpreted causally, and linear regression assumptions may not be fully met by ordinal data.

Discussion

Respondents most often selected mobile applications as their primary digital technology, while digital-system use was most frequently described as rare. This combination suggests that the presence of a digital tool does not necessarily mean it is embedded consistently in day-to-day operations. Respondents commonly reported digital temperature devices and automatic alerts, and more than half rated temperature monitoring very or extremely effective. These results indicate positive perceptions of cold-chain tools, but no actual spoilage-rate or temperature-log data were supplied to verify the perceived benefit.

Waste reduction and route optimization were among the commonly selected green logistics practices. Perceived route-optimization benefits clustered around a moderate extent. Responses on delivery improvement were distributed across several categories, and the mean score was not significantly predicted by the three selected digital/sustainability indicators. This may reflect the categorical nature of the survey, the absence of validated composite scales, variation among organizations, or the limited sample and data quality.

At the 5% significance level, neither chi-square test nor the ANOVA found a statistically significant result. This does not prove that there is no relationship; it means that the available data did not provide enough evidence to identify one in these tests. The occupation-by-technology chi-square result should be treated with particular caution because several expected cell counts were very small.

Findings

- The dataset contains 125 response records; delivery-efficiency improvement has 124 valid responses.
- Mobile applications were the most frequently reported primary digital technology (61 respondents; 49.2% of valid responses).
- Digital-system use was most commonly reported as rare (49; 39.2%).
- Temperature monitoring was rated very effective by 41 respondents (32.8%) and extremely effective by 23 (18.4%).
- Inventory management was the most frequently selected logistics activity improved by digital technology (35; 28.2% of valid responses).
- The most common reported sustainability priority was better use of resources (45; 36.3% of valid responses after excluding invalid/missing labels).
- Gender was not significantly associated with digital-system-use frequency; occupation-by-technology chi-square results are unreliable due to sparse expected counts.
- ANOVA and the multiple regression model did not find statistically significant differences/predictors for the delivery-improvement score.

Recommendations

Organizations should encourage more consistent use of digital systems through practical staff training, clear procedures and regular management reviews. Cold-chain processes can be strengthened by calibrating temperature devices, setting clear alert-escalation steps, and recording incidents and corrective actions. Businesses should also track measurable indicators such as on-time delivery, temperature excursions, spoilage rates, fuel used per delivery, route distance and energy consumption. Small route- and load-optimization trials can help compare performance before and after changes. Future studies should use validated multi-item scales to measure digital maturity, sustainability and logistics performance. Survey questions and coding should be standardized, including organization type, size, work experience and location. Once data-quality issues are addressed, statistical tests should be repeated; sparse categories should only be combined when there is a clear conceptual reason, or exact/Monte Carlo methods should be considered.

Limitations

The supplied dataset has a narrow demographic profile (most respondents are below 25 and undergraduate), a large 'Other' occupation group, missing values, and inconsistent/invalid labels in a small number of responses. The sampling method and whether responses were independently collected or generated were not established by the supplied files. Because data were self-reported and cross-sectional, findings describe perceptions and cannot establish causality. Nominal responses cannot support meaningful mean/median/SD calculations. ANOVA and linear regression treat ordered categories as approximately interval, which is an analytical simplification. Several chi-square expected counts are low, and the regression does not use a validated composite performance scale.

Conclusion

This exploratory study examined 125 supplied survey records on digital transformation and sustainability in dairy logistics. Respondents reported use of mobile applications and digital temperature-monitoring tools, alongside green practices such as waste reduction and route optimization. Perceptions of temperature-monitoring effectiveness were generally positive, but use of digital systems was often reported as rare. The inferential analyses did not find statistically significant relationships in the selected chi-square tests, occupation-group ANOVA, or multiple linear regression. These results should not be interpreted as evidence that digital transformation is ineffective; rather, the current dataset and measurement design do not establish a statistically significant effect. Stronger conclusions require verified field data, a documented sampling process, validated scales, larger and more balanced respondent groups, and objective logistics KPIs.

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