Challenges and Mitigation Strategies for Implementing a Sustainable Supply Chain in Bangladesh's Dairy Industry: A Case Study on BRAC Dairy & Food Project

By

Md. Sakib Hossain
23282012

A thesis submitted to the Department of BRAC Institute of Governance and Development in partial fulfillment of the requirements for the degree of Masters in Procurement and Supply management (MPSM)

BRAC Institute of Governance and Development
Brac University
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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

Student's Full Name & Signature:

_____

MD. SAKIB HOSSAIN

Student ID: 23282012

Approval

The thesis/project titled "Challenges and Mitigation Strategies for Implementing a Sustainable Supply Chain in Bangladesh's Dairy Industry: A Case Study on BRAC Dairy & Food Project" submitted by

1. **Md. Sakib Hossain (ID: 23282012)**

of Fall 2023 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Masters in Procurement and Supply management on October 2025.

Examining Committee:

Supervisor:
(Member)

_____
Md. Wasim Jabbar, MCIPS
Faculty, BIGD
BRAC University

Program Coordinator:
(Member)

_____
Mohammad Sirajul Islam
Senior Academic Coordinator
BIGD, BRAC University

External Expert Examiner:
(Member)

_____
M Syed Abdulla Tanzim Al Bayezid
Procurement and Contracting Manager
Embassy of the United States of America, Dhaka

Departmental Head:
(Chair)

_____
Dr. Imran Matin
Executive Director
BIGD, BRAC University

Ethics Statement

This study was conducted in accordance with established academic ethical standards and the research guidelines of BRAC University. The research focused on professionals and stakeholders within BRAC Dairy's supply chain and involved administering a structured survey to 47 participants.

Participation in the study was entirely voluntary. Prior to completing the survey, participants were informed of the research's purpose, the study's scope, and how their responses would be utilized. Informed consent was obtained from all respondents, and participants were assured that they could withdraw from the study at any point without providing a reason.

To ensure confidentiality, no personally identifiable information was collected. Responses were anonymized and are reported only in aggregated form. Data were stored securely, accessed only by the researcher, and used solely for academic purposes connected to this thesis.

As the research explored professional perspectives on sustainable supply chain practices, it posed minimal risk to participants. Every effort was made to respect the rights, dignity, and privacy of all respondents throughout the research process. Approval of the research design and ethical procedures was obtained from the thesis supervisor in accordance with university requirements.

Abstract/ Executive Summary

This study explores the challenges and mitigation strategies of implementing sustainable supply chain management (SSCM) in Bangladesh's dairy sector, with a focus on the BRAC Dairy & Food Project (Aarong Dairy). A mixed-methods case study was conducted with 47 respondents across different supply chain roles, combining survey data with open-ended questions. Quantitative analysis included descriptive statistics, reliability testing, correlation, ANOVA, and multiple regression, while thematic analysis provided qualitative depth.

The findings show that awareness of sustainability is high, and most stakeholders see it as essential for BRAC Dairy's long-term success. However, persistent barriers remain, such as seasonal disruptions, the high cost of eco-friendly technologies, weak infrastructure, and consumer demand for cheaper products. Cold chain investments stood out as the most effective intervention. Regression analysis further revealed that logistics strategies, waste reduction practices, and farmer engagement were significant predictors of effectiveness, while procurement practices were not.

The study emphasizes that real progress in sustainability depends on balancing economic, environmental, and social dimensions of the supply chain. Key recommendations include adopting renewable energy, introducing biodegradable packaging, expanding farmer training and incentives, and ensuring stronger government support.

This research contributes to SSCM literature by situating the triple bottom line within a smallholder driven dairy industry. It also offers practical guidance for policymakers, supply chain managers, and development practitioners in Bangladesh and other emerging economies.

Keywords: Sustainable Supply Chain Management (SSCM); BRAC Dairy and Food Project; Cold Chain Systems; Eco-friendly Packaging; Renewable Energy; Sustainability

Dedication

To the resilient people of Palestine. May their strength, courage, and unwavering hope in the face of adversity inspire future generations.

To my family, especially my wife and two children, whose unwavering support and sacrifices made this journey possible, thank you for believing in me even when the path seemed uncertain.

Moreover, to the mentors who guided me, the friends who encouraged me, and the challenges that shaped me, this work is as much yours as it is mine.

Acknowledgement

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Finally, I want to acknowledge the researchers whose work inspired this study. This thesis is far from perfect, but it carries the lessons and efforts of many people. Any faults are mine alone.

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List of Acronyms

AI	Artificial Intelligence
ANOVA	Analysis of Variance
BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BDFP	BRAC Dairy and Food Project
BIDS	Bangladesh Institute of Development Studies
BRAC	Bangladesh Rural Advancement Committee
CARE	Cooperative for Assistance and Relief Everywhere
DPM	Direct Purchase Method
ETP	Effluent Treatment Plant
FAO	Food and Agriculture Organization of the United Nations
FAT	Fat Testing
GAFSP	Global Agriculture and Food Security Program
GDP	Gross Domestic Product
HR	Human Resources
IBM	International Business Machines (SPSS software)
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LTM	Limited Tender Method
OTM	Open Tender Method
QA	Quality Assurance
QM	Quality Management

REEEP	Renewable Energy and Energy Efficiency Partnership
SD	Sustainable Development
SPSS	Statistical Package for the Social Sciences
SSCM	Sustainable Supply Chain Management
TBL	Triple Bottom Line

Glossary

ANOVA (Analysis of Variance)	A statistical test used to compare the means of three or more groups to determine whether differences are significant.
Cold Chain	A temperature-controlled supply system that preserves milk and dairy products from collection to retail, reducing spoilage and waste.
Correlation (Pearson's r)	A statistical measure showing the strength and direction of the relationship between two variables.
Cronbach's Alpha	A measure of internal consistency or reliability of survey items; values above 0.7 indicate acceptable reliability.
Descriptive Statistics	Statistical methods (mean, percentage, frequency, standard deviation) used to summarize and describe data.
Eco-friendly Packaging	Packaging that reduces environmental impact by being recyclable, biodegradable, or sustainably produced.
Effluent Treatment Plant (ETP)	A facility that treats wastewater from industrial processes to remove pollutants before reuse or discharge.
Farmer Capacity Building	Training and support programs that help smallholder farmers improve productivity, milk quality, and sustainability.
Mixed-Methods	A research approach combining quantitative (numerical) and qualitative (thematic) data collection and analysis.
Purposive Sampling	A non-probability sampling method where participants are deliberately chosen for their relevance to the research.
Snowball Sampling	A sampling technique where existing participants recruit additional respondents, useful for hard-to-reach groups.

Supply Chain Management (SCM)	The management of the flow of goods, information, and resources across all stages, from suppliers to end consumers.
Sustainable Supply Chain Management (SSCM)	The integration of environmental, social, and economic principles into supply chain activities.
Thematic Analysis	A qualitative method used to identify, analyze, and interpret recurring themes or patterns in data.
Triple Bottom Line (TBL)	A framework that evaluates sustainability performance across three dimensions: economic, environmental, and social.

Chapter 1:

Introduction and Overview of the Dairy Industry

1.1 Introduction

Sustainability has become a central concern in contemporary supply chain management, especially in high-impact sectors such as food and dairy, which directly affect human livelihoods and nutrition (Carter & Rogers, 2008; Seuring & Müller, 2008). Companies are being encouraged, and in some cases, required around the world to think green, source green, transport goods in a green manner, and distribute them in a green way, that is as environmentally friendly, socially sensitive, and economically sound as possible.

The dairy sector in Bangladesh is crucial for nutrition and rural livelihoods. Dairy farming is a main source of livelihood for thousands of smallholder farmers and processed dairy products are consumed by urban populations daily. BRAC Dairy & Food Project (trade name Aarong Dairy) is one of the major players in this sector, having made significant efforts to reach rural farmers, improve product quality, and ensure food safety. However, firms in emerging economies, including BRAC Dairy, face hurdles such as inadequate infrastructure, fragile cold chains, and limited environmental awareness among suppliers, all of which constrain sustainability adoption.

From inadequate infrastructure and expensive transportation to low awareness of environmental practices among suppliers, the challenges are very real and multifaceted. Consider also that global warming, resource depletion, and higher consumer expectations have also increased the expectations placed on companies in both social and environmental terms. The objective of this study is to examine the main barriers to achieving a sustainable supply chain in the Bangladesh dairy industry, with a focus on the sustainability challenges within BRAC Dairy's supply chain, to identify potential awareness for mitigating the challenges.

This study adopts a nuanced perspective on these challenges by examining the case of BRAC dairy in Bangladesh, highlighting not only the issues encountered but also the strategies they have covered and implemented to address them effectively. The results are intended to assist supply chain managers, development specialists, and policymakers in understanding the practical challenges faced by companies and how they can be overcome in a developing economy environment.

Despite global attention on sustainable supply chains, research on dairy in developing economies remains limited, particularly where smallholder farmers dominate production and weak infrastructure shapes outcomes. Most studies emphasize technical or operational improvements but overlook the complex social and institutional realities of countries like Bangladesh. This study addresses this gap by examining the BRAC Dairy & Food Project as a case that demonstrates both opportunities and barriers in embedding sustainability across the supply chain.

1.2 Objectives

The main objectives of this study are:

1.2.1 To identify the key challenges faced by the BRAC Dairy & Food Project in implementing sustainable supply chain practices within the dairy industry of Bangladesh.

1.2.2 To explore the root causes behind these challenges, including operational, infrastructural, environmental, and socio-economic factors.

1.2.3 To examine the current strategies adopted by BRAC Dairy to address sustainability-related issues in procurement, production, logistics, and distribution.

1.2.4 To assess the effectiveness of these mitigation strategies in promoting environmental, social, and economic sustainability.

1.2.5 To provide implementable recommendations for enhancing sustainable supply chain practices in the Bangladeshi dairy sector, especially for organizations working with rural suppliers and smallholder farmers.

Each objective is addressed through both quantitative (descriptive, correlation, ANOVA, regression) and qualitative (thematic analysis) methods, ensuring triangulation of findings.

1.3 Rationale

The origin of this research is from my professional experience in procurement and supply chain management, particularly in Bangladesh's manufacturing and production sectors. While this research is from my professional experience in procurement and supply chain management, its academic rationale lies in addressing a critical research gap: despite the economic and nutritional importance of dairy in Bangladesh, sustainable supply chain management (SSCM) in this sector remains underexplored in both local and global literature (Kabir et al., 2017; Rahman et al., 2019). Over the years, I have come to recognize the critical role that supply

chains play in the national economy and the frequent neglect of sustainability considerations that is particularly pronounced in traditional industries such as dairy, which support the rural farmers and workers.

Having been directly involved on the front lines with organizations regulating grassroots communities, I observe firsthand the widening gap between the sustainable supply chain practices and the urgent need for sustainable long-term solutions. Take the dairy industry, a sector that sustains rural livelihoods, feeds family's critical nutrition, and has untapped growth but also structural issues tied to infrastructure, environment, and farmer practices.

BRAC Dairy, as a socially responsible enterprise in this context, provides us with the opportunity to understand both the challenges and the successes. Their concept excited me to think about how I might bring greater sustainability into the supply chain itself — from farm and factory to consumer.

This study is motivated by a desire to make a genuine, day-to-day difference in supply chain systems and ultimately in the lives of people who are intentionally or unintentionally overlooked. In Bangladesh and beyond, I hope this research can be a small step toward more inclusive and environmentally responsible supply chain practices.

1.4 Goals and Expected Results

The purpose of this study is to investigate the obstacles and opportunities for developing a sustainable supply chain in the Bangladesh dairy industry, particularly in the dairy value chain of the BRAC Dairy & Food Project (Aarong Dairy). The primary objective is to identify the genuine barriers to integrating sustainability practices into supply chain operations, specifically those related to sourcing, production, distribution, and waste management. It also seeks to investigate the measures that BRAC Dairy is currently taking to overcome these challenges and to assess how effective they are in achieving long-term environmental, social and economic sustainability. In doing so, the study aims to provide pragmatic and feasible recommendations, with a primary focus on developing countries like Bangladesh.

This study is anticipated to result in:

- An in-depth comprehension of key sustainability issues related to the dairy supply chain.

- Understanding the root causes of these challenges from an operational, social and infrastructural perspective.
- A consideration of the mitigation measures implemented by BRAC Dairy and their operational performance.
- Pragmatic suggestions meant to spur lessons learned for sustainability in other dairy-supply chains.
- A significant contribution to academia (renewable sustainable supply chain management).

Ultimately, the study aims to close the gap between research and practice by providing important insights for practitioners, scholars, and researchers interested in this area.

1.5 Overview of the Dairy Sector of Bangladesh

Dairy farming is an important part of the rural livelihood of Bangladesh. For many families, it is both a tradition and a critical source of income, food and security. This sector has, over the years, helped reduce poverty and improve nutrition, especially in remote areas where other jobs are scarce. The fact is, dairy has a significant role in the nation's economy. It is the largest agricultural sub-sector in terms of direct contribution to the gross domestic product. Where employment is concerned, there are millions of people either directly engaged in the dairy industry or in services associated with it, such as transporting milk to market, selling feed, or providing veterinary care.

Bangladesh is also a significant milk producer, which satisfies nearly its entire domestic milk demand. In recent years, it has emerged as one of the world's leading producers of milk. However, there are still some significant issues that the industry must address. The vast majority of dairy farms, in fact, are small, family operations that are frequently disheveled and unorganized. Most of the milk that is produced never makes it to the marketplace: It's consumed at home. That stifles growth and hinders private investment. Moreover, farmers do not have the facilities of cold storage or decent transportation, so much milk quality deteriorates before it reaches the buyer. There is also the fact that dairy is expensive to produce. Farmers usually depend on middlemen to sell their milk to the market, resulting in a lower profit. The sector remains dominated by smallholder farmers, many of whom lack access to affordable feed, cold storage, transportation, and training. As a result, milk quality is often compromised, and farmers remain dependent on middlemen, reducing profitability (Kabir et al., 2017;

Rahman et al., 2019). But even so there is a great deal of potential for the dairy business. With better access to credit, training and infrastructure, things can change fast if farmers are at the center of the equation. With the right kinds of government and private-sector support, the dairy industry could become more sustainable and profitable for the farmers and enterprises.

This study therefore critically examines the challenges and opportunities of building an environmentally and socially sustainable supply chain in Bangladesh's dairy sector, with BRAC Dairy serving as a representative case.

1.6 Dairy Sector and Sustainability

The dairy sub-sector is important in Bangladesh, with growing importance in economic, nutritional and industrial fronts. Once a subsistence oriented livelihood, dairying in Bangladesh has evolved into a complex supply chain involving farmers, processors, distributors, and retailers (FAO, 2020). Within this larger context, the sustainability discussion cannot be limited to on-farm practices alone; it should be extended to the linkages throughout the entire supply chain.

Considering its structure, the dairy supply chain in Bangladesh begins with thousands of small-scale dairy farmers, who market raw milk based on different levels of input supply, animal treatment, and infrastructure. This raw milk is collected locally at collection/ chilling points, which are usually managed or owned by larger processors who will supply BRAC Dairy & Food Project. These processors are not only involved in sourcing and quality control, but also in maintaining hygiene standards in their facilities, logistics (getting milk to markets on time) and relationship management with numerous suppliers in the hinterlands.

The role of purchasing is particularly important in achieving sustainability. When it comes to sustainable procurement in the dairy sector, consider ethical sourcing, long-term supplier development, waste reduction in collection systems, and quality and safety standards that extend all the way up the supply chain from plant to origin. Many processors report challenges with rostered collections becoming delayed, ineffective volumes, and a risk of contamination due to a lack of access to a cold chain site and trained staff.

In addition to sourcing, processing facilities have their own sustainability requirements. When milk is treated in dairies, it must be done economically, with minimal waste and maximum yield of products. Sustainability at this point implies using energy-efficient equipment, controlling water consumption, discovering solutions for waste treatment and shifting to

cleaner technologies. There is a void in the adoption of industrial sustainability certifications across the industry in Bangladesh, from small operators to major processors.

For the distribution phase, the main issues are generally associated with temperature control, fuel usage and packaging. Spillage rates are high, especially in rural or less developed areas, due to dairy being perishable in the absence of a cold chain transport system. The unsustainable use of non-recyclable or excessive packaging compounds environmental worry. The first two challenges are addressed through investments in cold chain infrastructure and a shift toward sustainable packaging.

The industry, at the retail and consumption stage, has also to ensure that consumers have access to safe, good quality and affordable dairy products. The latter two would involve handling expiration timelines, shelf standards, and customer education. Retailers, particularly small-scale ones, often lack the knowledge and facilities to store goods in a hygienic manner, which can lead to damage to a brand and pose food safety risks.

Last, but by no means the least, sustainability will have to be inclusive if it is to have real value. That also means taking into account the needs of all players along the chain, not just farmers, but purchasing agents, factory workers, transporters, women labourers and informal supply agents, many of whom work on very tenuous terms with little training, few contracts and scant protections.

Within this broader framework, the viability of Bangladesh's dairy subsector hinges on integrated performance improvements across all links of the supply chain. However, boosting farm productivity is not sufficient in itself. They will also need to come together to build a more efficient, ethical, and environmentally mindful system, capable of responding to consumer demand, lowering operational risk, and facilitating long-term growth.

Through this study, the constraints and enablers to establishing such a system, and specifically the BRAC dairy & food project as a case study, are critically examined, with an emphasis on strategic interventions that have the potential to improve resilience and sustainability across the BRAC dairy supply chain.

Chapter 2:

Supply Chain of BRAC Dairy and Food Project

2.1 Background of BRAC Dairy and Food Project (BDFP)

BRAC Dairy was established in 1998 as part of BRAC's mission to create inclusive and sustainable market opportunities for rural producers. Unlike purely profit-driven ventures, BDFP was designed as an inclusive business model that integrates smallholder farmers into formal value chains, ensuring fair prices and market access. This dual objective of commercial viability and social empowerment distinguishes BDFP from conventional dairy enterprises (BRAC, 2023). To operationalize this model, BRAC established milk collection and processing factories, creating a structured link between rural farmers and urban consumers. When operations began, BDFP managed an impressive daily production of approximately 140,000 litres of milk, establishing itself early on as a major player in Bangladesh's dairy sector.

Over the years, BRAC Dairy expanded beyond packaged milk to offer a wide variety of processed dairy products, responding to the changing preferences of consumers and contributing to improved food security. The organization also distinguished itself as the first dairy company in Bangladesh to achieve ISO 22000 certification, signaling a strong commitment to international standards of food safety and quality. This milestone not only built consumer trust but also set an industry benchmark for quality compliance.

From a supply chain perspective, BRAC Dairy's model demonstrates both progress and complexity. On one hand, its initiatives have strengthened the rural–urban supply chain, improved farmer incomes, and increased consumer access to safe dairy products. However, sustaining large-scale operations raises persistent challenges, particularly in quality assurance, logistics, farmer integration, and environmental sustainability, which mirror broader systemic issues in Bangladesh's agrifood supply chains (Kabir et al., 2022).

2.2 Quick Statistics

- Currently, BDFP processes approximately 250,000 liters of milk daily, accounting for nearly 30% of the national packaged dairy market (BRAC, 2023). This scale reflects its strategic significance, but also exposes the enterprise to high operational risks, particularly in cold chain maintenance and farmer coordination.

- The enterprise accounts for 30 percent (Approx) of the national packaged dairy products market.
- Currently, this enterprise serves approximately 25,000 dairy farmers across the entire region of Bangladesh with over 1500 employees working under its umbrella.

Figure 2. 1: Quick statistics of BRAC Dairy's capacity

2.3 Products Diversification

Figure 2. 2: BDFP's product diversification

BDFP has diversified beyond liquid milk into value-added products such as yoghurt, butter, cheese, ghee, and flavored drinks. Product diversification strengthens revenue streams but also complicates sustainability practices, particularly in packaging and cold chain management (Cowbell, 2022).

2.4 Supply Chain Model

BRAC Dairy & Food Project (BDFP) operates a well-integrated supply chain designed to maintain quality, efficiency, effectiveness, and market reach. The chain begins with farmers, who produce raw milk. Milk is first collected at local Aarong collection centers, where it is aggregated and quality-checked. It is then transported to central chilling centers, ensuring freshness through controlled cooling before being sent to the processing factory for pasteurization, packaging, and storage in warehouses.

Distribution reaches consumers through a multi-channel approach: traditional retail channels supply local shops and retailers, direct-to-consumer home delivery services provide convenience and reliability, and branded retail is strengthened through the Aarong network, enhancing urban market presence. Each channel is carefully managed to maintain product integrity, optimize delivery routes, and minimize wastage.

While the model appears well-structured, its effectiveness depends heavily on thousands of smallholders and fragile infrastructure. Seasonal variations, adulteration risks, and cold chain weaknesses make the system vulnerable. Thus, while BRAC Dairy has improved coordination compared to informal supply chains, significant risks remain.

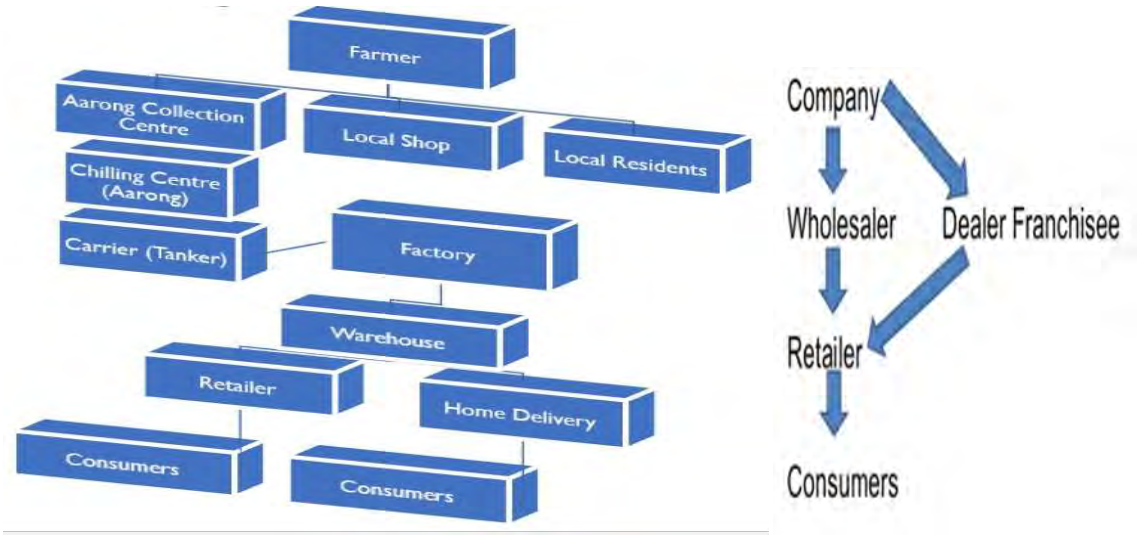

Figure 2. 3: Supply chain model of BDFP

While this structure enhances traceability and efficiency compared to informal dairy chains, it remains heavily dependent on smallholder farmers and vulnerable infrastructure. Seasonal fluctuations, adulteration risks, and cold chain breakdowns create persistent bottlenecks (Kabir et al., 2017; Rahman et al., 2019).

2.5 BRAC Dairy end-to-end supply chain

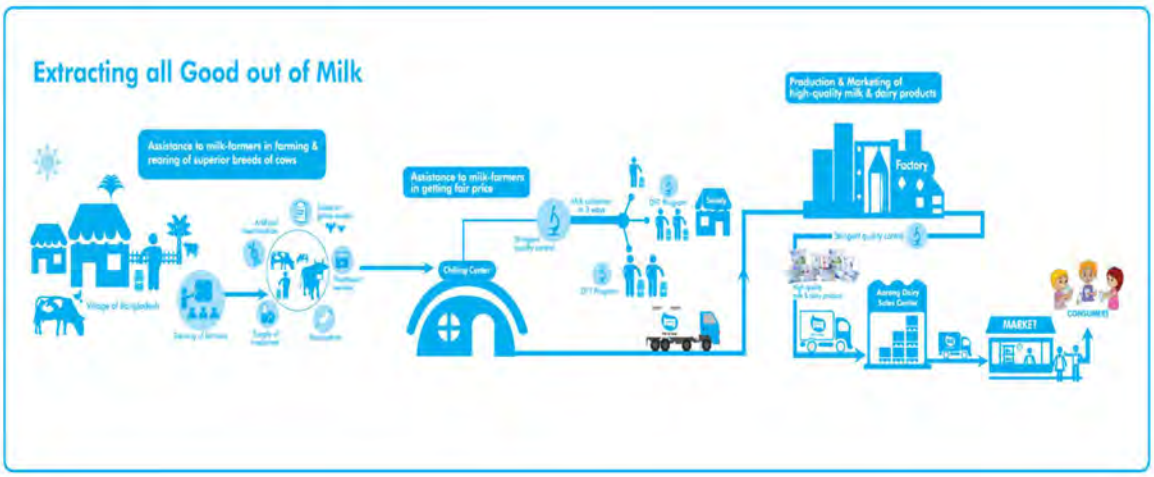

Figure 2. 4: BRAC Dairy end to end value chain model

2.5.1 Raw Milk Collection

The raw milk supply chain is the first link that directly impacts product quality and pricing of the BRAC Dairy & Food Project. Milk is purchased from registered farmers who bear a distinct identifying number, ensuring the source of milk is traceable and the farmers are accountable. The farmers deliver their milk to the chilling center as the first level of aggregation and quality control.

The milk is subjected to physical examination by the chilling center technician (colour, smell and contaminated material). The FAT testing machine subsequently tests a representative sample of the milk to ascertain its fat percentage, a vital parameter of milk quality and nutrition. The milk price is fixed reasonably, with an incentive element to compensate farmers in terms of a percentage of the fat content, based on the fat percentage.

This system ensures traceability, incentivizes quality production, and supports farmer livelihoods. By making price dependent on quality, BDFP motivates farmers to keep high production standards and this enables economic sustainability and better efficiency of the complete supply (reduction of milk spoilage and waste). However, reliance on manual testing and smallholder compliance still limits scalability and consistency (Uddin et al., 2016).

Figure 2. 5: Raw milk collection

2.5.2 Milk Chilling and Transportation

After raw milk is collected from farmers at the chilling center, it is immediately transferred to refrigerated tankers for transportation. During this stage, the milk's temperature is rapidly reduced to around 2°C, ensuring that its freshness and nutritional quality are preserved. This chilling process is crucial in preventing bacterial growth and spoilage during transit to the central processing facility. Once milk is collected and initially chilled at the chilling center to approximately 2°C, it is loaded into refrigerated tankers for transportation to the processing factory. During transit, the milk temperature is carefully maintained and rises slightly to around 4°C by the time it reaches the factory. By maintaining a strict cold chain from the collection point to the factory, BDFP ensures the integrity and safety of its products. The use of temperature-controlled tankers also enables the timely and efficient transportation of large volumes of milk, supporting a smooth supply chain operation while minimizing losses.

Figure 2. 6: Milk chilling and transportation

2.5.3 Quality Control for Milk Processing

After the milk arrives at the processing plant, it undergoes several quality checks and processing steps to ensure the safety, shelf life, and quality of the product. "I would start with some simple tests to look for adulteration, test viscosity and determine overall milk quality. These tests help maintain the highest standard of milk quality and, accordingly, process only high-quality milk. The milk is heat-treated, e.g., by pasteurization, sterilization, or concentration, and the harmful enzymes and microorganisms present are killed. The milk is cooled after pasteurization to extend shelf life by one or two days. Acidification prevents the multiplication of spoilage and/or pathogenic bacteria, and also ensures the bunker silo is transported safely to the main processing lines or industrial plants in some cases. During this stage, the temperature of the milk is closely monitored at approximately 4°C to maintain quality and ensure safe transport.

For raw milk, tests are conducted for the main components of fat, protein, and acidity, as well as adulterants, while microbial tests are conducted for potentially harmful bacteria. As a part of the processing, the inline chemicals assure the product quality, and the finished products are subjected to both chemical and microbial analysis to confirm safety and stability of the shelf life. The mix of chemical and microbial tests across different stages of the supply chain is summarized in Table 2.1.

Stage	Chemical Tests	Microbial Tests	Purpose / Notes
Raw Milk	15	2	Ensures fat, protein, lactose, acidity, and adulterants meet standards; checks for harmful bacteria.
Inline Products	14	0	Monitors key quality parameters during processing; microbial tests not needed due to pasteurization/sterilization.
Finished Goods	14	4	Confirms nutrient levels and quality parameters; microbial tests ensure the safety of consumers and the shelf life of products.

Table 2. 1: Quality testing framework

2.5.4 Milk Processing and Packaging

After the raw milk is received and meets the company's quality criteria, it is further processed to make it safe, prolong shelf life and improve the quality of the final product.

Cooling: Milk is cooled using fluid-based cooling systems, where chilled fluid, cooled by an ammonia gas system, quickly cools the milk. This pre-recipe procedure ensures that freshness is maintained and no bacteria have a chance to grow before proceeding to the next step.

Heating: The milk is pasteurized or sterilised for the packaging and the desired shelf life. Milk, for pasteurization, is heated to 63°C for 30 minutes or 72-75°C for 15 seconds. Bottled milk under pressure is competitive with other proteins on the membrane surfaces with a and Low-Fat Milk intended for sterilization uses 140°C for 4 seconds. Higher temperatures and shorter exposure times to heat are used in larger commercial operations, but this requires expensive equipment and is unsuitable for small operations.

Acidification: The natural acidification process is the result of the action of lactic acid bacteria that transform lactose into lactic acid. This raises the acidity of the milk, prevents the growth of undesirable bacteria, and helps the milk to form a curd. Acidification not only increases the shelf life by several days but also enhances flavour and texture, which have made these products so well-liked.

Separation: Milk is composed of fat, water, proteins, and minerals. The separation of fat from liquid allows for the production of cream (grease), a perishable product that requires special handling. Butter may be churned from milk, and if well-made and well-kept, will remain in an edible condition for several weeks. Ghee can be stored for up to months. It is a highly valuable product with exceptional quality.

Packaging: Packaging is the last stage of milk processing. It is the act of placing processed milk into protective vessels or packets for safe storage and handling. Good packaging not only helps protect the product but is also the first thing the consumer sees, and it can be the factor that sways their opinion and leads to their purchase of the product. Packaging can also be referred to as timeserving, safety and quality maintenance.

2.5.5 Packaging Material Sourcing and Procurement

BRAC Dairy & Food Project (BDFP) has a structured approach of raw material (including milk and other processed items) and packaging materials sourcing and procurement. This implies

that suppliers were ultimately responsible for ensuring the quality of the raw materials, thereby guaranteeing that the products were of good quality and posed no potential threat to consumers. Packaging is selected for durability, transparency, and cost efficiency; however, environmental sustainability remains limited, as biodegradable alternatives are not yet widely adopted, highlighting a key future challenge (Singh et al., 2018).

Then, during the procurement process, it is necessary to verify the dependability of suppliers, the material reality of a standard material, and, from an economic viewpoint, a strict check is required to secure an unlimited quantity of raw materials for production. Through a coordinated planning and strategic approach, BDFP helps ensure that packaging meets product safety, extends shelf life, and seamlessly integrates into the entire value chain of all dairy products.

Figure 2. 7: Packaging material inspection

2.5.6 Storage and Cold Chain Maintenance

In the supply chain of the BRAC Dairy & Food Project, life, safety and quality of milk and other perishable dairy products are preserved by maintaining a cold chain. Products are then kept in temperature-controlled depots after processing, where sophisticated chilling systems regulate the temperatures of the milk and other products to recommended levels. This acts to inhibit bacterial growth, spoilage, and nutrient loss.

Storage is accompanied by careful temperature monitoring, regular temperature measurements and automatic alarms to warn about any violation of the cold chain. These conditions are the same for both raw milk and processed products and are maintained until the products are dispatched for distribution purposes. Proper cold chain control enables BDFP to preserve products, prevent waste, and ensure that consumers receive safe and high-standard products.

2.5.7 Distribution of Products: Cold Chain and Non-Cold Chain Transport

The BRAC Dairy & Food Project (BDFP) employs a dual approach to distribution, utilising both cold chain and non-cold chain transport, depending on the type of product and its perishability.

- **Cold Chain Transportation:** Cold chain transportation refers to the transport of perishables by refrigerated vehicles, which ensures maintaining the necessary temperature throughout the transportation process for products like milk, yoghurt and cream. This is to maintain the quality of the product, prevent spoilage and prolong shelf life. Logistics for cold chains is also closely monitored in a warehouse, from the time the goods leave it to the time they arrive at the retailer, or even the customer's doorstep.

- **Non-cold chain Transportation:** Some processed products, such as ghee, butter, and certain dairy product packs, which have a longer shelf life or low perishability, can be transported through normal vehicles like a covered van without refrigeration. These items are wrapped to protect them during the shipping process so you receive your product the way it was intended to be.

Total products-35
CCP-19 and NCCP-16
SKUs-89

Factory

Particulars	Nos.
Road Milk Tanker	37 units
Carrying Capacity	180,000 Liters
Total refrigerated cover van	84

Distribution

Particulars	Nos.
Sales Centers	45
Third Party Distributors NCCP	396
Third Party Distributors CCP	226
Retail Shops	1,18,520
Modern Trade	350

Figure 2. 8: BDFP transport statistics

2.5.8 Retail Distribution

The retail sector is a vital part of the supply chain for the BRAC Dairy & Food Project, which links processed products to consumers in both urban and rural settings. Items are distributed to regional retail shops, chain retail stores, and branded retail stores (Aarong outlet).

The channel provides broad market coverage, allowing consumers to easily access a variety of dairy products, including milk, yoghurt, butter, and ghee. Throughout the retail handling, each product is treated with care to preserve its quality, freshness and hygiene. Cold chain items are shipped and stored under cold chain conditions, and ambient items are packed to endure normal handling and environmental conditions.

Retail distribution also takes on a vital significance in brand recognition and consumer confidence, packaging and merchandising of products available in stores will have a major impact on a customer's perception and buying patterns. By effectively controlling retail distribution, BDFP ensures its products are marketed in the best condition for both business and end consumers.

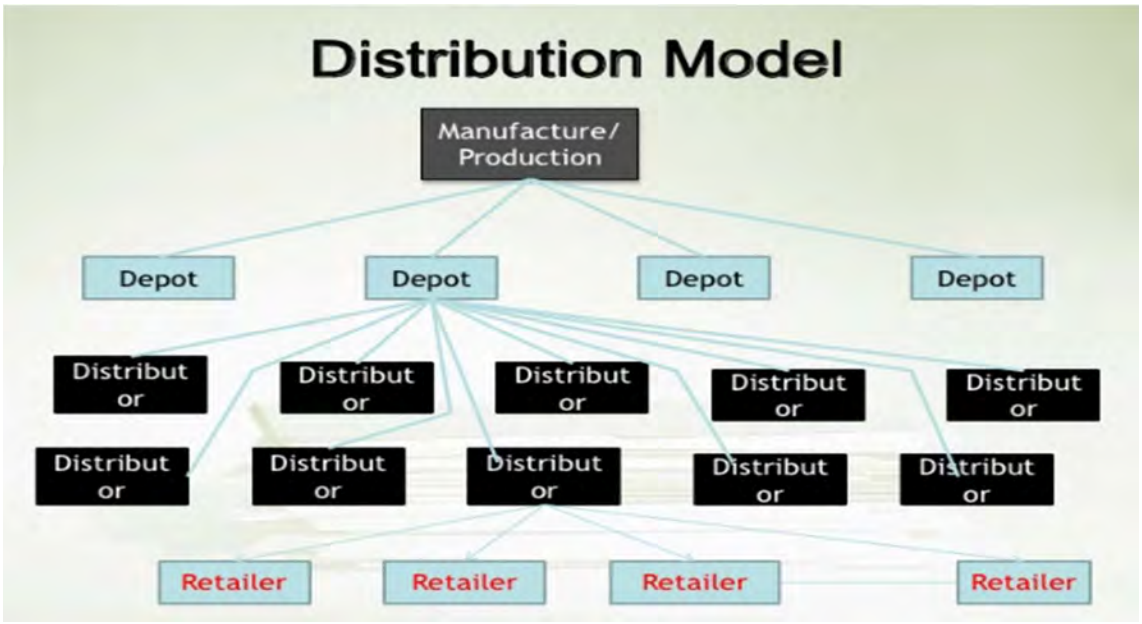

Figure 2. 9: Distribution model of BRAC Dairy

Figure 2. 10: BRAC Dairy products in shelf

2.5.9 Marketing Study of BRAC Dairy & Food Project

BRAC Dairy & Food Project (BDFP) employs a strategic marketing approach to understand consumer behavior, expand market reach, and strengthen brand presence in Bangladesh's dairy sector. The marketing study focuses on consumer preferences, product demand, pricing strategies, distribution effectiveness, and competitive positioning.

Components of BDFP's marketing analysis are:

1. **Consumer Insights:** Studies are conducted to understand consumer preferences and needs in the fresh versus processed milk market, as well as purchase patterns. It contributes to the generation of products that align with market expectations and increase customer satisfaction.
2. **Segmentation by Market**: The dairy market is segmented into urban and rural markets, household consumption and commercial purchases, and by product type (milk, yoghurt, butter, ghee, etc.). Segmentation to enable BDFP to invest marketing efforts efficiently on types of customers.
3. **Competitor Analysis:** BDFP positions itself against competitors such as Milk Vita, PRAN, and Farm Fresh, but unlike them, it integrates a strong smallholder focus. However, limited consumer awareness of sustainability in Bangladesh constrains how far marketing can leverage 'green branding' (Sharma & Singh, 2022).

4. **Marketing and Brand:** We utilize brand reputation, attractive packaging, and exposure activities to earn the confidence of our customers. Already in evidence are chain-branded retail outlets, such as Aarong, that not only sell products but also help create brand awareness and maintain the brand's image.
5. **Distribution Channels Review:** Retail, direct-to-consumer, and home delivery channels will be assessed to optimize product availability and quality, ensuring products reach consumers quickly and with peak freshness.

BDFP's product development, pricing and distribution strategies are based on systematic market studies, which keep pace with consumers' expectations and market trends. This strategy not only acts as a catalyst in sales promotion but also consolidates the position as the number one and trusted market player in Bangladesh's dairy industry.

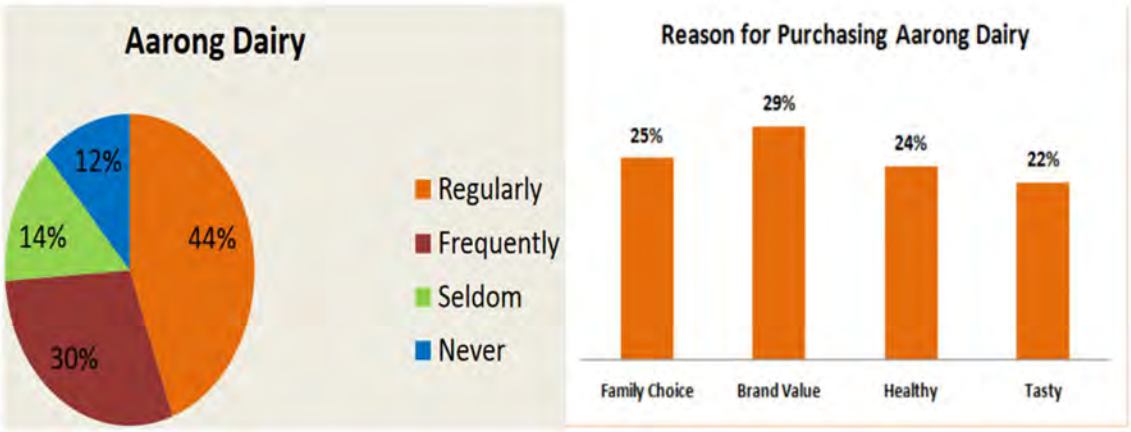

Figure 2. 11: Frequency and reason to purchase BRAC dairy products

2.5.10 Procurement Process and Methods at BRAC Dairy & Food Project

BRAC Dairy & Food Project (BDFP), as part of the BRAC network, follows a strategically structured procurement model that combines centralized oversight with field-level flexibility. This ensures that both high-value capital items and daily operational requirements are sourced efficiently, transparently, and in compliance with quality standards.

2.5.10.1 Procurement Process

Procurement at BRAC Dairy is a well-organized, strategically designed system that allows for the sourcing of both goods and services, enabling the company to obtain the right goods and services at the right time and at the right price with the best quality. It all starts with planning, where the annual needs for raw milk, packaging, ingredients, machinery, and operations at both

the head office and field levels are compiled in the Procurement Plan (PP) by the Procurement Department. Spend analysis is used to minimize the costs and group up demand, especially for high-demand items.

The Sourcing and Procurement procedures that are pursued, in association with the value and nature of purchase, are Open Tendering Method (OTM) for high-value (> BDT 2 Crore), Limited Tendering Method (LTM) for purchases between BDT 50 Lac to 2 Crore, Quotation Method (QM) for medium-value (2 Lac to 50 Lac), and Direct Procurement Method (DPM) for urgent/low-value (< BDT 2 Lac). Suppliers are screened, tested, and chosen based on quality, cost efficiency, and reliability. While this ensures transparency and efficiency, the sustainability integration into procurement criteria (e.g., eco-friendly packaging, green vendor assessment) remains limited, highlighting scope for improvement (Carter & Rogers, 2008).

It is a process that also includes supplier and vendor management. Suppliers are classified, registered and performance is tracked (e.g., Strategic, Major, Niche, Tactical). Critical suppliers of raw milk and packaging are "governed through framework agreements, relational contracting and senior-level engagement by the business." The regular feedback and performance audit make it reliable, consistent and of standard quality.

2.5.10.2 Procurement Methods and Applications

BRAC Dairy applies methods based on value, urgency, and supplier market conditions:

1. **DPM (Direct Procurement Method):** For urgent, low-value items, such as emergency spare parts or perishable goods from smallholder farmers.
2. **QM (Quotation Method):** For medium-value, routine operational items like packaging materials, cleaning supplies, and office furniture.
3. **LTM (Limited Tendering Method):** For specialized or high-volume purchases such as bulk milk powder, Tetra Pak materials, and machinery spare parts.
4. **OTM (Open Tendering Method):** For high-value, strategic procurements, including large-scale machinery, construction of chilling centers, and long-term logistics contracts (cold chain and non-cold chain).

Chapter 3:

Literature Review

3.1 Introduction

This chapter provides a comprehensive review of literature on sustainable supply chain management (SSCM) in the dairy industry, focusing on challenges and mitigation strategies relevant to developing countries such as Bangladesh. It first outlines the theoretical foundations of SSCM, then examines global and local practices in dairy sustainability, situating the discussion in Bangladesh's dairy sector and BRAC Dairy & Food Project. The chapter concludes with a discussion of research gaps and a conceptual framework for analyzing SSCM challenges, strategies, and outcomes (Agyemang et al., 2021; FAO, 2020).

3.2 Theoretical Foundations of Sustainable Supply Chain Management

3.2.1 Conceptual Framework of Sustainability

SSCM integrates environmental, social, and economic concerns into supply chain activities, reflecting the Triple Bottom Line (TBL) approach (Elkington, 1998). Carter and Rogers (2008) emphasized that sustainability is not just about compliance, but a strategic pathway to competitive advantage, one that embeds sustainability across procurement, logistics, production, and stakeholder engagement.

Seuring and Müller (2008) highlighted external pressures (e.g. regulations, NGOs, consumer demand) and internal drivers (cost reduction, efficiency) as determinants of SSCM adoption. Pagell and Wu (2009) extended this by arguing that SSCM requires the redesign of supply chains holistically to integrate sustainability goals.

Performance measurement in SSCM remains complex; Ahi and Searcy (2015) reviewed metrics and concluded that robust, multidimensional indicators are required to capture economic, environmental, and social performance. This insight is crucial in evaluating the effectiveness of BRAC Dairy's current mitigation strategies.

Critics of the Triple Bottom Line (TBL) framework argue that it is conceptually broad and difficult to operationalize in practice, especially in resource-constrained environments (Norman & MacDonald, 2004). In many developing-country contexts, SSCM remains more

aspirational than actionable, as firms prioritize cost survival over environmental or social investments. Recognizing these limitations is essential for contextualizing BRAC Dairy's efforts.

3.2.2 Sustainability in Food Supply Chains

Food supply chains are resource-intensive, vulnerable to climate change, and heavily dependent on coordination among stakeholders (Dekker et al., 2020). Effective SSCM in food systems requires integrated cold chain systems, waste minimization, and equitable value distribution (FAO, 2020).

Matopoulos et al. (2007) found that collaboration and information sharing are critical for sustainable agri-food supply chains. Perez-Aleman and Sandilands (2008) showed how capability-building among smallholders enhances adoption of sustainable practices. Yet, smallholder-dominated systems often lag due to limited resources and weak institutional support (Khan et al., 2022).

3.3 Global Perspectives on Sustainable Dairy Supply Chains

Lessons from developed countries demonstrate the integration of SSCM approaches across economic, social, and environmental dimensions.

- **Environmental**: Reducing methane emissions, renewable energy adoption, and water efficiency (Gerber et al., 2013).
- **Social**: Community engagement, worker welfare, and farmer inclusion (FAO, 2020).
- **Economic**: Price stabilization, logistics efficiency, and technology adoption (Zhu et al., 2018).

Emerging technologies, such as precision livestock farming, smart cold chains, eco-friendly packaging, and digital tools (including IoT, blockchain, and AI), have been adopted in New Zealand, the Netherlands, and the United States to enhance sustainability (Li et al., 2021; Sharma & Singh, 2022). Glover et al. (2014) stressed the role of institutional norms in mainstreaming sustainable dairy practices, while Xu and Gursoy (2015) highlighted the importance of integrating sustainability into hospitality and food supply chains.

While developed countries such as New Zealand and the Netherlands demonstrate advanced SSCM practices, precision livestock farming, smart cold chains, and eco-friendly packaging,

the direct transferability of such practices to Bangladesh is limited. Instead, lessons point to the importance of low-cost, scalable, and context-specific interventions (Li et al., 2021).

3.4 Bangladesh Dairy Industry: Structure and Sustainability Context

3.4.1 Industry Characteristics and Economic Contribution

The dairy sector makes a significant contribution to Bangladesh's rural economy, nutrition, and employment. It accounts for 7.75% of agricultural GDP, engaging more than 5 million people in farming, transportation, feed, and veterinary services (Alam & Hossain, 2019; BBS, 2022). Bangladesh produces 12 million metric tons of milk annually, achieving over 90% self-sufficiency (FAO, 2020). Growth is supported by improved breeds, access to feed, and farm modernization (Rahman & Parvin, 2020).

3.4.2 Structural Challenges and Sustainability Barriers

Despite growth, structural barriers persist: smallholder dominance, fragmented supply chains, weak infrastructure, and policy gaps. Studies identify low productivity, poor milk quality, high post-harvest losses, and limited awareness of sustainable practices (Rahman et al., 2019; Rotz et al. (2021).

- **Seasonal variation**: Milk yields fluctuate 10–30% due to heat stress and monsoon flooding (TBS News, 2023).
- **Skill gaps**: Over 90% of smallholders lack training in sustainable practices (BIDS, 2022).
- **Financial constraints**: Limited access to credit restricts investment in sustainable feed, storage, or technologies (GAFSP, 2023).

Uddin et al. (2016) highlighted the profitability challenges faced by smallholder farmers, while Rahman et al. (2019) noted inefficiencies in value chain coordination. Comparative evidence from South Asia shows similar constraints. In India, smallholder productivity challenges have been partially mitigated through large cooperative models like Amul, which create scale economies (Kurien, 2007). In contrast, Nepal's fragmented dairy sector faces issues of informal markets and weak infrastructure, mirroring Bangladesh's difficulties (FAO, 2020). Such comparisons show that structural challenges are regional in nature but solutions vary depending on institutional and organizational models.

3.4.3 Climate Vulnerability and Adaptation

Bangladesh's dairy sector faces climate stress, including drought, heat, and flooding. Adaptation strategies include climate-resilient breeds, feed security, and investment in cold chains (IPCC, 2022; Rotz et al. (2021)). Thornton (2010) emphasized that climate change will disproportionately affect livestock in developing countries.

3.5 Sustainable Supply Chain Dimensions in Dairy Context

3.5.1 Economic Sustainability

Economic viability requires efficiency and resilience across the chain. BRAC Dairy's practices, direct sourcing, digital inventory, and price stabilization—support smallholder incomes (BRAC, 2023). Shukla et al. (2019) found that sustainable logistics and waste reduction improve both efficiency and profitability in dairy supply chains.

3.5.2 Social Sustainability

Social sustainability encompasses farmer empowerment, fair employment practices, and community engagement (Khan et al., 2021). Farmer training and producer groups enhance livelihoods (CARE, 2012; BRAC, 2023). Glover et al. (2014) observed that institutional norms strongly shape the adoption of social sustainability practices across dairy supply chains.

3.5.3 Environmental Sustainability

Environmental strategies focus on energy use, waste reduction, and emissions mitigation (Gerber et al., 2013). BRAC has piloted solar chilling centres and eco-friendly packaging (REEEP, 2023; Cowbell, 2022). Singh et al. (2018) identified cost barriers as a major obstacle for Indian dairy firms in adopting green practices, highlighting parallels with Bangladesh.

3.6 BRAC's Role in Sustainable Dairy Development

3.6.1 Integrated Development

BRAC Dairy integrates breed improvement, veterinary services, feed supply, training, and fair market access, thereby addressing both economic and social sustainability (BRAC, 2023).

3.6.2 Innovation and Technology Adoption

Technologies such as digital fat testing, IoT monitoring, and solar-powered chilling have reduced waste and improved quality (Promethean, 2022; Li et al., 2021). CARE's SDVC program demonstrated how farmer training and input services improve productivity and sustainability in Bangladesh (CARE, 2012). However, adoption remains fragmented, and scalability is constrained by cost and infrastructure barriers (Promethean, 2022; BRAC, 2023)

3.7 Mitigation Strategies for Sustainability Challenges

Challenge	Mitigation Strategy	Outcome
Seasonal milk variation	Cold storage & solar chilling centers	Reduced spoilage, stabilized supply (BRAC, 2023; REEEP, 2023)
Skill gaps	Farmer & staff training	Increased adoption of sustainable practices (CARE, 2012; BRAC, 2023)
Financing limitations	Microcredit & price incentives	Access to green technologies (BRAC, 2023; GAFSP, 2023)
Infrastructure barriers	Route optimization & transport upgrades	Reduced losses, improved delivery (Shukla et al., 2019)
Environmental impacts	Eco-friendly packaging, manure management	Lower emissions & waste (Singh et al., 2018; Cowbell, 2022)

Table 3. 1: Mitigation strategies for sustainability challenges

3.8 Research Gaps and Study Justification

3.8.1 Context-Specific Limitations

Most SSCM literature in South Asia addresses challenges (Singh et al., 2018; Rotz et al. 2021) but few integrate perspectives across environmental, social, and economic dimensions simultaneously. While South Asian literature has examined adoption barriers (Singh et al., 2018; Rotz et al. 2021), there is limited empirical work assessing the effectiveness of mitigation strategies in the Bangladeshi dairy sector. Moreover, few studies integrate the perspectives of frontline actors (e.g., collectors, transporters, processors), which this research specifically addresses.

3.8.2 Implementation and Performance

Existing studies emphasize adoption barriers but rarely assess the effectiveness of mitigation strategies (Khan et al., 2022). There is also limited evaluation of institutional support, smallholder integration, and technology scalability (Shukla et al., 2019).

3.9 Conceptual Framework Development

The conceptual framework for this study links:

1. **Challenges**: Financial, infrastructural, technological, regulatory, HR, climate (Seuring & Müller, 2008).
2. **Strategies**: Procurement, logistics, waste reduction, technology adoption, capacity building (Li et al., 2021).
3. **Dimensions**: Economic, social, and environmental (Carter & Rogers, 2008).
4. **Contextual factors**: Smallholder dominance, market fragmentation, weak policy (Kabir et al., 2017; Khan et al., 2022).
5. **Outcomes**: Profitability, resilience, reduced environmental impacts, social inclusion (Pagell & Wu, 2009).

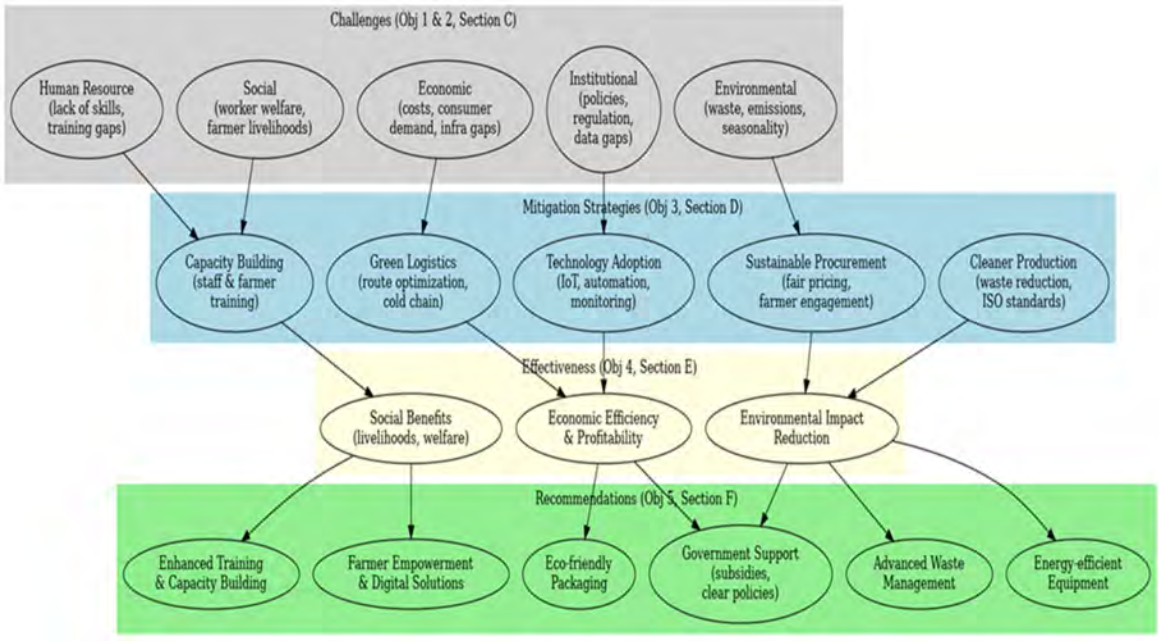

Figure 3. 1: Conceptual framework for SSCM in Bangladesh's Dairy industry

This framework illustrates how key challenges (environmental, social, economic, institutional, and human resource) influence the adoption of mitigation strategies such as sustainable procurement, green logistics, cleaner production, technology adoption, and capacity building. These strategies yield measurable outcomes in environmental, social, and economic sustainability, which in turn inform future recommendations for BRAC Dairy and the broader Bangladeshi dairy sector.

3.10 Observation

Bangladesh's dairy industry faces interconnected environmental, social, and economic challenges. The BRAC Dairy & Food Project demonstrates how integrated procurement, training, infrastructure, and technology adoption can mitigate sustainability risks.

The literature highlights significant gaps: limited case-based analysis, inadequate assessment of effectiveness, and insufficient focus on smallholder integration. This study addresses these gaps by applying SSCM frameworks to BRAC Dairy, guided by its challenges, strategies, and outcomes (FAO, 2020; Gerber et al., 2013).

Chapter 4:

Research Methodology

4.1 Introduction

This chapter outlines the methodological approach adopted to investigate challenges and mitigation strategies in implementing SSCM in Bangladesh's dairy sector. The chapter outlines the philosophical approach, research design, population, sampling strategy, data collection procedures, analytical techniques, and measures to ensure reliability and validity. Ethical considerations and limitations are also discussed. The overall aim is to establish a transparent, rigorous, and contextually relevant methodological framework to address the research objectives (Creswell & Creswell, 2018; Saunders, Lewis, & Thornhill, 2019).

4.2 Research Philosophy and Approach

The study is grounded in a pragmatic research philosophy, emphasizing practical solutions to real-world challenges in sustainable supply chain management (Saunders et al., 2019). Pragmatism allows for the combination of quantitative and qualitative methods, which is essential for capturing both measurable trends and contextual operational insights within BRAC Dairy's supply chain.

A primarily deductive approach guided the research. Existing theories and frameworks of sustainable supply chain management informed the initial hypotheses regarding common challenges, such as financial constraints, infrastructure limitations, and climate-related disruptions, as well as mitigation strategies, including green procurement and cold chain optimization (Carter & Rogers, 2008; Seuring & Müller, 2008). Simultaneously, the study maintained an inductive element through the use of open-ended questions, allowing respondents to provide new insights and context-specific perspectives that enriched understanding beyond the existing literature (Braun & Clarke, 2006).

4.3 Research Design

We used a mixed-methods design, connecting quantitative survey data with rich details on sustainability challenges and remediation actions to gain a more complete picture of context

(Creswell & Plano Clark, 2017). This strategy allows for triangulated data, thereby strengthening the richness and credibility of the findings.

The research used a single-case study design and restricted the focus to the BRAC Dairy & Food Project (Yin, 2018). As one of the largest and established dairy interventions in Bangladesh, BRAC Dairy serves as an excellent site to study operational, logistical, and managerial sustainability issues in depth. Based on the paradigm, the research is descriptive and explanatory in nature, where the practices of sustainability take place, and reasons behind the success and failure of some of the mitigation measures are investigated.

4.4 Population, Sampling, and Sample Size

The target population of this study included professionals and stakeholders directly involved in BRAC Dairy's supply chain operations. This group comprised chilling center operators, milk collectors, transport staff, procurement specialists, production and processing workers, inventory and distribution managers, engineers, and quality assurance officers. These individuals were selected due to their direct involvement in activities that impact the sustainability of BRAC Dairy's supply chain.

A purposive sampling method was used to ensure participants had relevant experience and knowledge of BRAC Dairy's operations. Initial respondents were intentionally selected from different functional areas to gather diverse perspectives, and snowball sampling was then employed to identify additional knowledgeable participants (Patton, 2015). This method aligns with previous research on smallholder-based dairy supply chains in Bangladesh (Kabir et al., 2017).

In total, 47 respondents completed the survey. Although modest, this sample is diverse in terms of roles, years of experience, and educational backgrounds, providing a solid foundation for exploratory analysis. To evaluate statistical adequacy, Yamane's (1967) formula for finite populations was applied.

$$\boldsymbol{n = \frac{N}{1 + N(e^2)}}$$

Where:

- n = required sample size
- N = population size
- e = margin of error (level of precision, usually 0.05)

Although BRAC Dairy employs approximately 1,500 staff, including temporary workers, the relevant population for this study was limited to employees directly involved in supply chain functions with decision-making responsibilities (procurement, milk collection/chilling, transport & logistics, processing, QA, inventory, and distribution). Based on HR estimates, this subpopulation is approximately 200 individuals.

Applying Yamane's (1967) formula with N = 200 and e = 0.05 for a 95% confidence level produced a required sample size of approximately 133 respondents.

$$n = \frac{200}{1 + 200(0.05^2)} = \frac{200}{1 + 0.5} = \frac{200}{1.5} \approx 133$$

However, given time and access constraints, and considering the case study design of this research, the achieved sample of 47 was deemed sufficient. In line with Yin (2018), exploratory case studies prioritize the depth and diversity of responses over representativeness. Similarly, Creswell and Creswell (2018) and Saunders, Lewis, and Thornhill (2019) emphasize that in mixed-methods research, smaller but information-rich samples can generate valid and meaningful insights. Furthermore, qualitative saturation was reached (Guest, Bunce, & Johnson, 2006), as additional responses did not reveal substantially new themes.

Accordingly, the sample size of 47 is considered appropriate for the study's objectives: to identify key sustainability challenges, assess current practices, and explore future directions within BRAC Dairy's supply chain.

4.5 Research Instrument Development

A structured questionnaire was developed, combining closed-ended Likert-scale items and open-ended questions. This design ensured both the measurability of constructs and the exploration of nuanced perspectives. Content validity was established through expert review and pilot testing, while items were drawn from established SSCM literature (Carter & Rogers, 2008; Kabir et al., 2017). The questionnaire included six sections:

1. **Demographics and General Information:** Capturing participant role, experience, age, and education.
2. **Awareness and Importance of Sustainability:** Measuring understanding and perceived significance of sustainability practices.

3. **Key Challenges in Sustainable Supply Chain Implementation:** Assessing operational and strategic barriers, including financial, infrastructural, regulatory, human resource, market, information, and climate-related challenges.
4. **Current Sustainability Strategies:** Evaluating practices across procurement, logistics, waste reduction, staff training, technology use, and supplier engagement.
5. **Effectiveness of Mitigation Strategies:** Measuring outcomes of initiatives such as cold chain systems, waste management, emissions reduction, and farmer engagement.
6. **Recommendations and Future Priorities:** Capturing participant suggestions for sustainability improvement initiatives.

4.6 Data Collection Procedure

Prior to full-scale data collection, a pilot study was conducted with 8 participants representing different supply chain roles. The pilot identified ambiguities, tested the flow of questions, and ensured cultural appropriateness. Feedback from chilling center operators, transporters, production staff, and managers was incorporated to refine the final instrument (Bryman & Bell, 2015).

The questionnaire was administered using a multi-modal approach. Face-to-face interviews were conducted with chilling center operators, milk collectors, and transport personnel to ensure accurate responses. For office-based staff, including production, procurement, and logistics personnel, online or paper-based questionnaires were employed to accommodate work schedules and accessibility constraints.

Ethical protocols were strictly maintained. Participants provided informed consent, were assured of confidentiality and anonymity, and retained the right to withdraw at any time. To enhance response rates, the research purpose was clearly communicated, reminders were issued, and estimated completion times were shared with participants (Israel, 2013).

4.7 Data Analysis

4.7.1 Quantitative Analysis

For the Likert scale, descriptive and inferential statistics were used. Data were summarized using descriptive statistics, including means, standard deviations, frequencies, and percentages,

to report perceptions of awareness regarding sustainability, challenges, effectiveness and mitigation strategies. The relationships between the demographic and information sources used with the perceptions were tested using inferential analysis (correlation and ANOVA). Reliability of the instrument was determined in Cronbach's alpha for internal consistency (Nunnally & Bernstein, 1994, Field, 2018). Finally, multiple regression analysis was performed to identify which sustainability strategies significantly predict the perceived effectiveness of BRAC Dairy's practices. The effectiveness index (mean of Q27–Q30 from the questionnaire) served as the dependent variable, while strategy items such as procurement, logistics, waste reduction, and farmer engagement were used as independent variables.

4.7.2 Qualitative Analysis

Thematic analysis (Braun & Clarke, 2006) was used to analyze open-ended responses. Open coding to analyze the repeated operational barriers, axial coding to link themes, and construction of a theme hierarchy were used in this procedure. Qualitative understanding contextualized quantitative trends on why some measures were successful or not.

4.7.3 Data Integration

Quantitative and qualitative findings were integrated through sequential explanatory and convergent parallel analyses. The combined data provided a nuanced understanding of the challenges, operational dynamics, and effectiveness of mitigation, enabling the development of actionable recommendations for BRAC Dairy (Creswell & Plano Clark, 2017).

4.8 Reliability and Validity

Reliability was ensured through internal consistency (Cronbach's alpha), test-retest checks during the pilot study, and consistent qualitative coding by multiple researchers. Validity was addressed through expert review, alignment with literature, and methodological triangulation. Instead of factor analysis, construct validity was supported through pilot testing and expert feedback, which is appropriate for case study research with a smaller sample size. To enhance qualitative rigor, Lincoln and Guba's (1985) trustworthiness framework (credibility, transferability, dependability, confirmability) was applied.

4.9 Limitations and Mitigation

Methodological limitations include the single-case study design, reliance on self-reported data, and the use of cross-sectional data collection. Practical constraints included access limitations to remote sites, seasonal operational variations, and resource constraints for comprehensive geographic coverage. These limitations were mitigated through data triangulation, multi-channel data collection, and detailed contextual reporting, which enhanced transparency and applicability (Patton, 2015).

4.10 Observation

This chapter provides a comprehensive, practical, and contextually grounded methodology for investigating sustainable supply chain practices at the BRAC Dairy & Food Project. The mixed-methods design, combined with systematic data collection and rigorous analysis, ensures that the research findings are both reliable and actionable. Ethical safeguards and validity measures enhance credibility, while the pragmatic focus ensures insights can inform real-world improvements in Bangladesh's dairy supply chain sustainability.

Chapter 5:

Data Analysis and Observation

5.1 Introduction

This chapter discusses the findings of the study and presents the analysis of the survey, which was conducted among stakeholders of the BRAC Dairy & Food Project. This chapter aims too, to describe how the data from the field has addressed the research objectives which were established at the outset of this study.

The respondents' profiles are presented in the opening part of the chapter, including their age, education, involvement in the value chain, and years of experience. This is valuable because it provides insight into the context of Portrait & Anneke's participants and the lenses through which they view the study. Results are then reported based on the research objectives. These are: identification of the major challenges of adopting sustainable supply chain practices, exploration of the underlying causes of these challenges, illumination of the SD strategies being utilized by BRAC Dairy, evaluation of the efficacy of these strategies, and conclusion with some concrete recommendations for the dairy.

Results from the Likert-scale questions and open-ended responses are presented in this paper. Tables, figures and excerpts are included where appropriate in the analysis. The findings, presented here, are used in Chapter 7 to evaluate them against the existing literature and to address broader implications.

5.2 Demographic Profile of Respondents

Before presenting the main findings, it is useful to describe the background of the respondents who participated in the survey. A total of 47 respondents provided complete data, representing different functions across the BRAC Dairy supply chain. Their demographic characteristics, including age, education, role in the supply chain, and years of experience, are presented in the Table 5.1.

Variable	Category	Frequency	Percent (%)
Age	26–35 years	23	48.9
	36–45 years	18	38.3
	46–55 years	4	8.5
	56 years and above	2	4.3
Education Level	Secondary school or below	1	2.1
	Diploma/Technical training	6	12.8
	Bachelor's degree	16	34.0
	Master's degree or higher	24	51.1
Role in Supply Chain	Chilling center/Collector	6	12.8
	Transporter	7	14.9
	Procurement	7	14.9
	Processor (Production)	5	10.6
	Inventory and Distribution	5	10.6
	Engineering & Maintenance	5	10.6
	QAD	5	10.6
	Others	7	14.9
Years of Experience	1–3 years	10	21.3
	4–6 years	11	23.4
	7–10 years	12	25.5
	More than 10 years	14	29.8

Table 5. 1: Demographic profiles of respondents

The demographic profile indicates that most respondents were between 26 and 35 years old (48.9%) or 36 and 45 years old (38.3%), reflecting a predominantly early- to mid-career workforce. Educational attainment was high, with over half holding a Master's degree or higher

(51.1%) and a further 34.0% possessing a Bachelor's degree, while only a small proportion reported diploma or lower qualifications.

Roles within the supply chain were broadly distributed: transporters, procurement staff, and others each accounted for 14.9% of the sample, while chilling center operators represented 12.8%, and processors, distributors, engineers, and quality assurance (QA) each made up 10.6%.

The experience was also well-balanced, with nearly one-third having more than 10 years in the dairy sector, alongside significant representation from those with 7–10 years (25.5%), 4–6 years (23.4%), and 1–3 years (21.3%). This diversity across age, education, role, and experience provides a strong basis for analyzing sustainability challenges and practices in the BRAC Dairy supply chain.

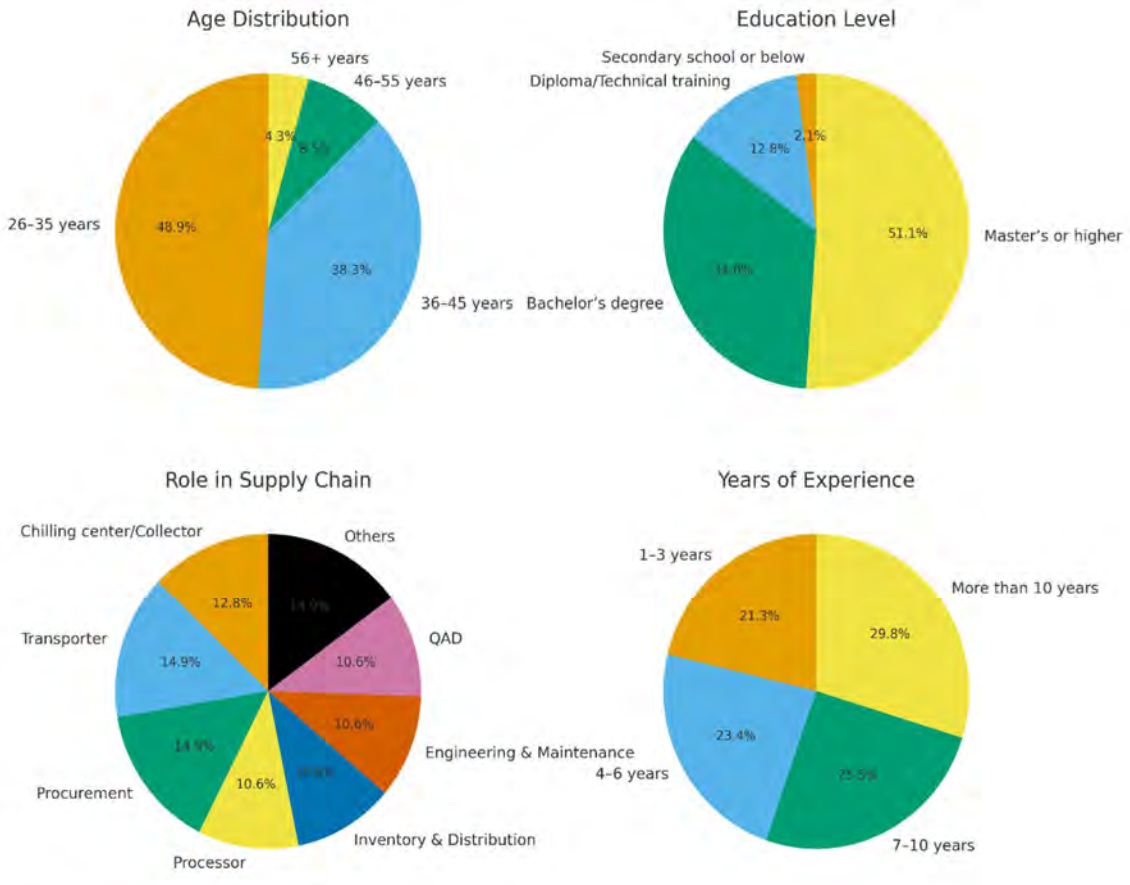

Figure 5. 1: Pie chart of demographic profiles of respondents

5.3 Awareness of Sustainability:

5.3.1 Quantitative analysis:

This section presents the respondents awareness of sustainability concepts and their views on the importance of sustainability for BRAC Dairy's long-term success. Respondents awareness of sustainable supply chains and their views on its importance are summarized in Table 5.2.

Awareness and importance of Sustainability				
	N	Mean	Median	Std. Deviation
	Valid			
I am aware of the concept of a sustainable supply chain in BRAC Dairy's operations.	47	3.94	4.00	.734
Sustainability is important for the long-term success of BRAC Dairy's supply chain.	47	4.40	5.00	.681

Table 5. 2: Awareness and importance of sustainability

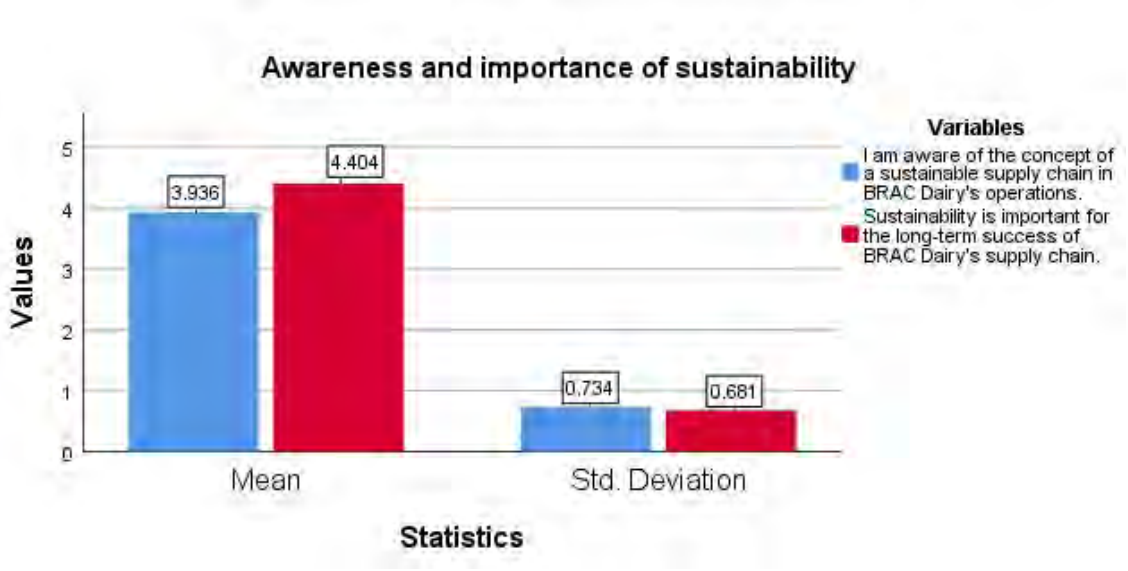

Figure 5. 2: Bar chart of awareness and importance of sustainability

The findings show that respondents generally had a good level of awareness. On a 5-point scale, awareness of the concept of a sustainable supply chain scored a mean of 3.94 (SD = 0.734), indicating that most participants were familiar with the idea. However, some variability existed in their understanding of it.

More notably, the perception that sustainability is important for the long-term success of BRAC Dairy's supply chain received a higher mean score of 4.40 (SD = 0.681). This indicates strong agreement among respondents that sustainability is not just an abstract concept, but a crucial factor for the organization's ongoing performance and resilience.

5.3.2 Correlation between Awareness and Importance of Sustainability

As shown in Table 5.3, there is a moderate positive correlation between awareness and the perceived importance of sustainability.

Correlations			
Particulars		I am aware of the concept of a sustainable supply chain in BRAC Dairy's operations.	Sustainability is important for the long-term success of BRAC Dairy's supply chain.
I am aware of the concept of a sustainable supply chain in BRAC Dairy's operations.	Pearson Correlation	1	.357*
	Sig. (2-tailed)		.014
	N	47	47
Sustainability is important for the long-term success of BRAC Dairy's supply chain.	Pearson Correlation	.357*	1
	Sig. (2-tailed)	.014	
	N	47	47
*. Correlation is significant at the 0.05 level (2-tailed).			

Table 5. 3: Correlation between awareness and the importance of sustainability

A Pearson correlation test was performed to explore the relationship between respondents' awareness of sustainable supply chains and their belief in its importance for BRAC Dairy's long-term success. The results indicate a moderate positive correlation ($r = 0.357$, $p = 0.014$). This indicates that participants with higher awareness of sustainable supply chains were also more likely to recognize their significance for the organization's future. The relationship is statistically significant at the 0.05 level, suggesting that awareness and perceived importance are meaningfully linked.

5.3.3 Qualitative Insights on Understanding of Sustainable Supply Chain

Respondents were asked to define what a sustainable supply chain means in the context of dairy operations by an open question: In your own words, what does "sustainable supply chain" mean to you in the context of dairy operations? Out of 47 participants, 43 provided substantive responses, while a few gave brief answers, such as "Excellent" or "Green operation". Thematic analysis of the responses revealed several recurring ideas that align closely with the three pillars of sustainability: economic, environmental, and social. Qualitative responses on the meaning of a sustainable supply chain in dairy operations are summarized in Table 5.4.

Theme	Frequency (n=43)	Percentage (%)	Illustrative Quote
Balance of environmental, social, and economic responsibilities	12	27.9%	Managing every stage of the dairy value chain from feed production to distribution in a way that balances economic viability, environmental stewardship, and social responsibility.
Eco-friendly and environmentally responsible practices	10	23.3%	A sustainable supply chain refers to procuring and sourcing products and services that will not affect the environment.
Fair farmer treatment and social responsibility	8	18.6%	It ensures fair treatment of farmers, reduces waste, maintains product quality, and supports long-term growth without harming future resources.
Efficiency, quality, and waste reduction	7	16.3%	Managing milk collection and transport in an efficient, ethical, and eco-friendly way that reduces waste and ensures quality.
Long-term resilience and profitability	4	9.3%	A sustainable dairy supply chain means producing and delivering milk in a way that is profitable, fair to farmers, and environmentally safe for future generations.

Other (minimal/very brief responses)	2	4.6%	Excellent; Green operation.
Total	**43**	**100%**	

Table 5. 4: Qualitative data on the understanding of the sustainable supply chain

The responses reveal that most participants view sustainability in dairy supply chains as a holistic balance of environmental, social, and economic dimensions (27.9%). They emphasized the importance of integrating eco-friendly practices, ensuring fair treatment of farmers, and optimizing operational efficiency to ensure long-term viability.

A large number highlighted the environmental dimension (23.3%), emphasizing eco-friendly packaging, reducing emissions, and protecting natural resources. Social sustainability also featured strongly, with 18.6% noting the importance of fair farmer treatment, community development, and ethical sourcing.

Another 16.3% of respondents focused on efficiency and waste reduction, particularly in cold chain, storage, and distribution systems. In comparison, 9.3% mentioned long-term resilience and profitability, underlining that sustainability must also support economic viability. A few respondents provided minimal answers such as “Excellent” or “Green operation”, which were categorized separately.

In summary, respondents largely recognized that a sustainable supply chain in dairy operations must strike a balance between environmental care, social fairness, and economic stability. This aligns strongly with the triple bottom line concept, confirming that awareness among stakeholders extends beyond a narrow focus and incorporates broader sustainability goals. These findings directly support Objective 1.2.1 and 1.2.2, showing both awareness and understanding of what sustainability means in practice.

5.4 Key Challenges and Root Causes in SSCM Practices

5.4.1 Quantitative Analysis:

The following results highlight the main operational, financial, environmental, and institutional challenges that respondents believe hinder the BRAC Dairy and Food Project’s efforts toward a sustainable supply chain. Key challenges and root causes identified by respondents are presented in Table 5.5.

Key Challenges & Root Causes				
Particular	**Valid**	**Mean**	**Median**	**Std. Deviation**
Environmental sustainability (waste management, carbon footprint reduction, climate change) is a significant challenge in BRAC Dairy's operations.	47	3.91	4.00	.855
Social sustainability (worker welfare, community impact like CSR, fair practices) is a significant challenge in BRAC Dairy's operations.	47	3.57	4.00	.903
Economic sustainability (cost management, profitability, efficiency) is a significant challenge in BRAC Dairy's operations.	47	3.83	4.00	.868
High costs of eco-friendly technologies hinder BRAC Dairy's sustainability efforts.	47	3.89	4.00	1.005
Infrastructure issues (e.g., unreliable transportation, Power, energy, Cold storage, poor roads) frequently disrupt and negatively affects BRAC Dairy's operations.	47	3.74	4.00	1.093
Consumer demand for low-cost dairy products hinders BRAC Dairy's sustainability goals.	47	3.70	4.00	.998
Unclear government sustainable policies and regulations like BSTI, Food safety create challenges for BRAC's sustainability efforts.	47	3.21	3.00	1.141
Lack of clear supply chain data and end to end visibility is a barrier to BRAC Dairy's sustainability initiatives.	47	3.57	4.00	.927
Lack of skilled personnel trained in sustainable practices limits BRAC's sustainability initiatives.	47	3.62	4.00	.990
Seasonal variations (monsoon flooding, extreme heat, fodder scarcity during dry season) create significant challenges for BRAC Dairy's sustainable supply chain operations.	47	4.09	4.00	1.176

Table 5. 5: Item-wise challenges & root causes data of SSCM practices in BRAC Dairy

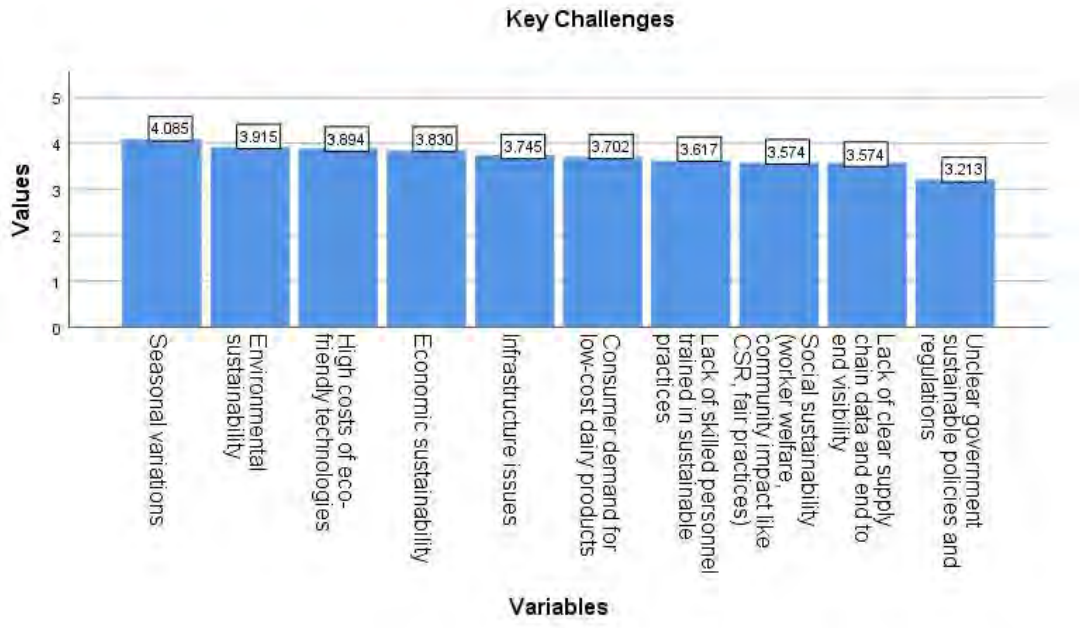

Figure 5. 3: Bar chart of key challenges & root causes mean data

The results show that most challenges scored above 3.5 on a 5-point scale, indicating broad agreement that they significantly affect BRAC Dairy's sustainability efforts. The highest-rated issue was seasonal variations (M = 4.09, SD = 1.18), reflecting the disruption caused by monsoon flooding, extreme heat, and fodder shortages. Environmental sustainability concerns, such as waste management and carbon reduction, were also rated high (M = 3.91, SD = 0.86), along with the high cost of eco-friendly technologies (M = 3.89, SD = 1.01).

Other important barriers included economic pressures related to cost management and profitability (M = 3.83), as well as operational inefficiencies stemming from poor infrastructure (M = 3.74) and consumer demand for low-cost products (M = 3.70). Human resource gaps (M = 3.62) and social sustainability issues, such as worker welfare (M = 3.57), were also evident. At the lower end, unclear government policies and weak regulation scored the lowest (M = 3.21), although they were still noted as a challenge.

In summary, the findings highlight that BRAC Dairy's sustainability is constrained most by climate dependency, environmental pressures, financial costs, and infrastructure weaknesses, while social, human, and institutional gaps further complicate the picture. This addresses Objective 1 by identifying the main obstacles.

From the perspective of Objective 2, the findings point to several root causes:

- Environmental dependence on weather and climate.
- Financial barriers due to the high costs of sustainable technologies.
- Operational inefficiencies from infrastructure gaps.
- Market pressures from consumer demand for low-cost products.
- Human resource limitations due to a lack of skilled personnel.
- Institutional weaknesses in policy clarity and data management.

Together, these insights build a clear picture of why BRAC Dairy struggles with sustainability, setting the stage for analysis of current strategies and their effectiveness.

5.4.2 Reliability Analysis:

A reliability analysis was conducted to evaluate the internal consistency of the 10-item scale. The analysis in Table 5.6 revealed that the scale demonstrated good reliability, with a Cronbach's alpha coefficient of 0.805. This indicates that the items consistently measure the same underlying construct and can be considered reliable for further analysis.

Reliability Statistics	
Cronbach's Alpha	.805
Number of Items	10

Note. Cronbach's alpha was used to assess the internal consistency of the 10-item scale.

Table 5. 6: Cronbach's Alpha reliability analysis statistics

5.4.3 ANOVA – Role in Supply Chain vs. Perceptions of Challenges:

ANOVA results are presented in Table 5.7, comparing perceptions of challenges across different supply chain roles. For clarity, only the key ANOVA results (F-values and significance levels) are reported in the table, while the full SPSS output is available upon request.

Challenge Item	**F-value**	**Sig. (p)**	**Interpretation**
Environmental sustainability	0.83	0.568	Not significant
Social sustainability	1.88	0.099	Not significant
Economic sustainability	1.85	0.106	Not significant

High cost of eco-friendly technologies	1.43	0.223	Not significant
Infrastructure issues	1.36	0.252	Not significant
Consumer demand for low-cost dairy products	2.83	0.017	Significant
Unclear government policies	0.78	0.605	Not significant
Lack of supply chain data	0.54	0.799	Not significant
Lack of skilled personnel	1.18	0.336	Not significant
Seasonal variations	1.95	0.088	Marginal / approaching significance

Table 5. 7: ANOVA – Role in supply chain vs. perceptions of challenges

ANOVA results show that perceptions of most sustainability challenges did not significantly differ across supply chain roles ($p > .05$). This indicates that stakeholders throughout BRAC Dairy generally share similar views on environmental, economic, social, and infrastructural issues. However, the analysis revealed a significant difference in opinions regarding consumer demand for low-cost dairy products ($F = 2.83$, $p = .017$), with procurement and distribution staff perceiving this as a more critical barrier than others. Additionally, seasonal variations ($F = 1.95$, $p = .088$) approached significance, suggesting that those directly involved in milk collection and logistics may experience climate-related disruptions more acutely, although not at a statistically significant level.

5.4.4 Qualitative Insights on Critical Challenges & Root Causes:

Respondents were asked to identify the single most critical barrier to sustainability in BRAC Dairy's operations by an open question: From your experience, which challenge is the most critical barrier to sustainability in BRAC Dairy's operations?

Out of 47 participants, 42 provided substantive answers, while a few gave very brief or unclear responses. Thematic analysis revealed several recurring challenges, most of which reinforce the patterns already seen in the quantitative results. Table 5.8 summarizes qualitative feedback on the most critical barriers to sustainability at BRAC Dairy.

Theme	Frequency (n=42)	Percentage (%)	Illustrative Quote
Cold chain and infrastructure gaps	10	23.8%	The lack of robust cold chain infrastructure leads to milk spoilage, increased waste, and limits market reach, especially in rural and remote areas.
Raw milk quality and availability	9	21.4%	Adulteration-free milk collection is a big challenge, especially during the monsoon season when both supply and quality decline.
Financial/resource constraints (cost of materials, energy, packaging)	7	16.7%	Price fluctuations in raw materials and packaging, as well as high energy costs, make sustainability a significant challenge.
Smallholder farmer dependence and low productivity	6	14.3%	The most critical barrier is the low farm-level productivity of smallholder farmers, which drives higher costs and lower quality.
Policy and coordination weaknesses	4	9.5%	A lack of clear, sustainable government policies and weak coordination across BRAC's service divisions affects sustainability efforts.
Environmental and seasonal disruptions	4	9.5%	Seasonal variations, particularly monsoon flooding and fodder scarcity, significantly disrupt supply and logistics.
Waste management and carbon footprint	2	4.8%	The most critical barrier is effective waste management.
Total	**42**	**100%**	

Table 5. 8: Qualitative data on critical challenges & root causes

The responses indicate that cold chain and infrastructure gaps (23.8%) were the most frequently cited barrier, with participants highlighting unreliable storage and transportation systems that

lead to spoilage and losses. Closely following were concerns about raw milk quality and availability (21.4%), particularly adulteration, seasonal shortages, and inconsistent supply.

A significant share of respondents emphasized financial and resource constraints (16.7%), including rising costs of raw materials, energy, and eco-friendly packaging. Others highlighted the structural issue of dependence on smallholder farmers (14.3%), where low productivity and limited access to modern farming practices reduce both quality and sustainability.

Smaller but significant groups of respondents highlighted policy and coordination weaknesses (9.5%), seasonal and climate-related disruptions (9.5%), and waste management challenges (4.8%).

In summary, respondents viewed sustainability at BRAC Dairy as constrained by a combination of infrastructure bottlenecks, quality and supply issues, financial pressures, and limitations of smallholders, all of which are reinforced by policy and environmental challenges. These findings align with Objectives 1.2.1 and 1.2.2, as they identify the main barriers and highlight the root causes behind them.

5.5 Current Sustainability Strategies:

5.5.1 Quantitative Analysis:

Here, respondents evaluated the effectiveness of BRAC Dairy's existing strategies, including procurement, logistics, waste reduction, training, technology, and farmer engagement shown in Table 5.9.

Current Sustainability Strategies				
Particulars	**N**	**Mean**	**Median**	**Std. Deviation**
	Valid			
BRAC Dairy's procurement practices effectively support its sustainability goals.	47	3.64	4.00	.819
BRAC Dairy's logistics strategies (e.g., route optimization, fuel efficiency) contribute significantly to sustainability.	47	3.43	3.00	.744

Waste reduction practices are effectively implemented in BRAC Dairy's production processes.	47	3.55	4.00	.855
Staff training programs effectively improve sustainable practices at BRAC Dairy.	47	3.47	3.00	.952
BRAC Dairy uses technology (IoT, automation, monitoring systems) effectively to enhance sustainability.	47	3.45	3.00	1.017
BRAC Dairy engages farmers and suppliers effectively in sustainable practices.	47	3.40	3.00	.948

Table 5. 9: Quantitative mean data on current sustainability strategies

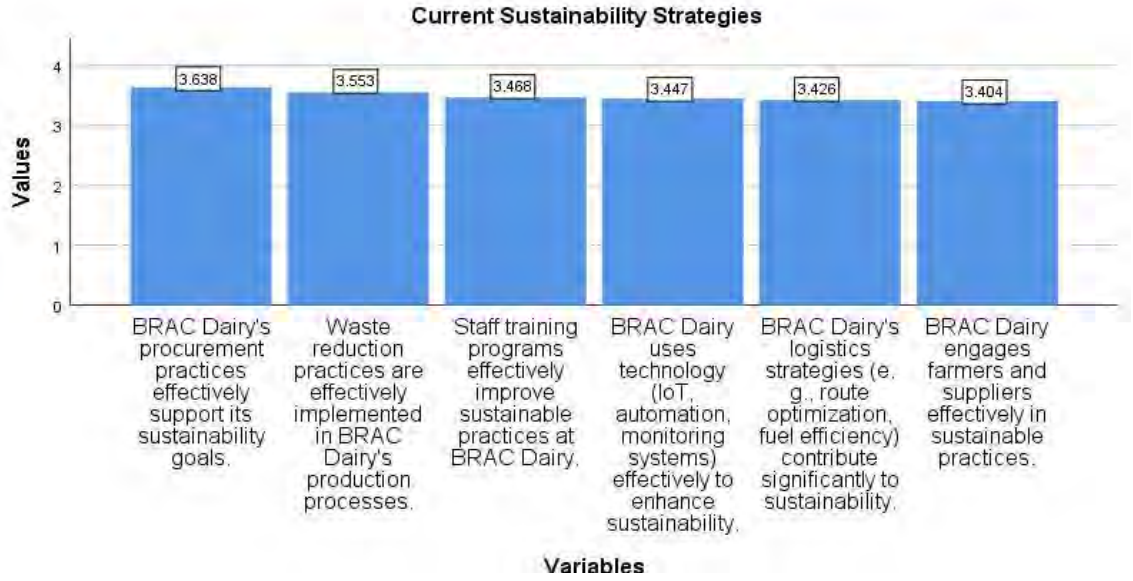

Figure 5. 4: Bar chart of mean data of current sustainability strategies

The results show mixed perceptions of how effectively BRAC Dairy applies sustainability strategies. Overall, the mean scores are clustered around the midpoint, suggesting moderate agreement.

Among the strategies, procurement practices were rated highest (M = 3.64, SD = 0.82), indicating that fair sourcing and pricing arrangements are seen as relatively supportive of sustainability goals. Waste reduction in production also scored fairly well (M = 3.55, SD = 0.86), reflecting some success in managing environmental impacts.

Other areas, including staff training (M = 3.47, SD = 0.95), technology use (M = 3.45, SD = 1.02), and logistics strategies (M = 3.43, SD = 0.74), were rated slightly lower, showing that while initiatives exist, they are not yet perceived as highly effective. Farmer and supplier engagement received the lowest mean score (M = 3.40, SD = 0.95), pointing to challenges in fully integrating external stakeholders into sustainable practices.

In summary, while BRAC Dairy has made progress in procurement and waste management, other strategies such as training, technology adoption, logistics, and farmer engagement require further strengthening. This directly addresses and highlights both the presence of sustainability initiatives and the areas where improvements are still needed.

5.5.2 Reliability Analysis of Strategy Items

The six items measuring sustainability strategies (procurement, logistics, waste reduction, training, technology, and farmer engagement) were tested for internal consistency. The scale produced a Cronbach's Alpha of 0.865, which is well above the commonly accepted threshold of 0.70. This indicates that the items are highly reliable and can be considered a consistent measure of BRAC Dairy's sustainability strategies. The reliability of these strategy items is confirmed in Table 5.10.

Reliability Statistics	
Cronbach's Alpha	.865
Number of Items	6

Note. Cronbach's alpha was used to assess the internal consistency of the 6-item scale.

Table 5. 10: Reliability analysis data of current sustainable strategy

5.5.3 Qualitative Insights on Current Sustainability Strategies:

Respondents were asked to share examples of specific sustainability practices they had personally observed at BRAC Dairy by an open question: Can you describe a specific sustainable practice or initiative you've observed at BRAC Dairy?

Out of 47 participants, 41 gave substantive responses, with a few noting "N/A" or very brief answers. Thematic analysis of these responses revealed several recurring initiatives that highlight both environmental and social sustainability dimensions. Examples of specific sustainability practices observed at BRAC Dairy are summarized in Table 5.11.

Theme	Frequency (n=41)	Percentage (%)	Illustrative Quote
Waste and water management (ETP, WTP, recycling)	10	24.4%	BRAC Dairy has installed effluent treatment plants (ETP) and water recycling systems to reduce environmental impact before releasing wastewater.
Cold chain and milk collection systems	8	19.5%	By using insulated containers and cold chain logistics, BRAC Dairy minimizes milk spoilage and ensures consistent quality.
Farmer training and support	8	19.5%	BRAC regularly conducts training sessions for farmers on sustainable farming techniques and animal health.
Fair pricing and smallholder empowerment	6	14.6%	One sustainable practice at BRAC Dairy is supporting smallholder farmers through fair pricing and collection networks.
Digital technology adoption (fat testing, monitoring)	5	12.2%	The use of portable digital fat-testing devices ensures fair payment to farmers and improves trust in the value chain.
Energy efficiency and carbon reduction	4	9.8%	BRAC Dairy implements energy-efficient processes in production and storage, reducing costs and environmental footprint.
Total	**41**	**100%**	

Table 5. 11: Qualitative data on current sustainability strategies

The most commonly observed initiative was waste and water management (24.4%), particularly the use of Effluent Treatment Plants (ETP) and Water Treatment Plants (WTP), which ensure environmentally responsible discharge and water reuse. This reflects BRAC Dairy's commitment to reducing its ecological footprint.

Another key theme was the improvement of cold chain and milk collection systems (19.5%), where insulated containers, chilling centers, and Village Milk Collection Centers (VMCCs) were credited with reducing spoilage and maintaining product quality. Respondents also highlighted the importance of farmer training and support (19.5%), including programs on animal health, fodder management, and clean milk practices, which improve both environmental efficiency and farmer livelihoods.

Many respondents emphasized BRAC Dairy's role in ensuring fair pricing and farmer empowerment (14.6%), thereby ensuring that rural smallholders benefit economically. The adoption of digital technologies (12.2%), such as portable fat-testing devices, was seen as promoting transparency and trust. Finally, energy efficiency and carbon reduction (9.8%) were mentioned, reflecting BRAC's gradual shift toward resource-saving processes.

In summary, the open responses highlight that BRAC Dairy's most visible sustainability practices center on environmental protection (waste, water, energy) and farmer empowerment (training, fair pricing, technology). These findings align with Objective 1.2.3, which seeks to examine current strategies in procurement, logistics, and production.

After analysis strategies we can say the moderate ratings for logistics, technology use, and farmer engagement suggest that while initiatives exist, they remain underdeveloped. This may reflect structural barriers such as poor rural road networks, high fuel prices, and low farmer literacy, which constrain adoption of advanced practices. Thus, the data show that progress in sustainability is uneven: procurement and waste management have advanced more rapidly than logistics or social engagement.

5.6 Effectiveness of Current Mitigation Strategies:

5.6.1 Quantitative Analysis:

This section reports perceptions of how effective BRAC Dairy's mitigation efforts, such as cold chain systems, waste management, logistics, and farmer engagement, are in addressing sustainability challenges. The perceived effectiveness of mitigation strategies is presented in Table 5.12.

Effectiveness of Current Mitigation Strategies				
Particular	**N**	**Mean**	**Median**	**Std. Deviation**
	Valid			
Cold chain systems effectively reduce product waste and maintain quality at BRAC Dairy.	47	4.15	4.00	.551
BRAC Dairy's waste management systems effectively reduce environmental impact.	47	3.68	4.00	.695
BRAC Dairy's logistics strategies effectively reduce carbon emissions.	47	3.47	3.00	.718
Current farmer engagement programs effectively promote sustainable practices among suppliers.	47	3.40	3.00	.771

Table 5. 12: Quantitative mean data of the effectiveness of current mitigation strategies

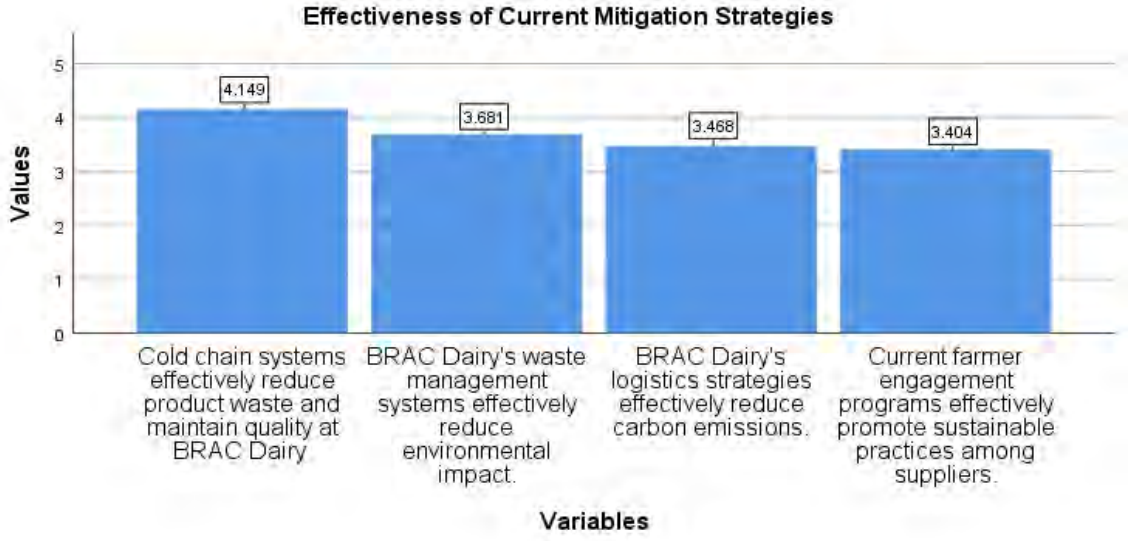

Figure 5. 5: Bar chart of the mean data of the effectiveness of current mitigation strategies

The table and chart present respondents perceptions of the effectiveness of BRAC Dairy's mitigation strategies. The results indicate that the cold chain system was seen as the most effective measure (M = 4.15, SD = 0.55), highlighting its strong role in reducing product waste and maintaining milk quality. This suggests that investments in cold storage and transportation infrastructure have delivered tangible benefits.

Waste management systems were rated moderately effective (M = 3.68, SD = 0.70), indicating that while some practices are in place, respondents believe more could be done to minimize

environmental impact. On the other hand, logistics strategies aimed at reducing carbon emissions scored lower (M = 3.47, SD = 0.72), suggesting that fuel efficiency and route optimization measures are not yet fully realized. Similarly, farmer engagement programs were also rated low (M = 3.40, SD = 0.77), pointing to limited effectiveness in promoting sustainable practices among suppliers.

In summary, the findings indicate that BRAC Dairy's most successful initiative has been in cold chain management, while efforts in waste reduction, carbon efficiency, and farmer engagement have been less successful. This reflects partial progress, but also highlights areas where targeted improvements are still needed.

5.6.2 Reliability of Effectiveness Scale

The four items measuring the effectiveness of BRAC Dairy's mitigation strategies demonstrated good internal consistency, with a Cronbach's Alpha of 0.800. This indicates that the items reliably capture a common construct of perceived effectiveness. On this basis, an overall Effectiveness Index (mean of the four items) was computed and used in further analysis. Reliability analysis of the effectiveness scale is shown in Table 5.13

Reliability Statistics	
Cronbach's Alpha	.800
Number of Items	4

Note. Cronbach's alpha was used to assess the internal consistency of the 4-item scale.

Table 5. 13: Reliability data of the effectiveness Scale

5.6.3 Qualitative Insights on Effectiveness of Sustainability Strategies:

Respondents were asked to evaluate the effectiveness of BRAC Dairy's sustainability strategies and suggest possible improvements by an open question: How effective are BRAC Dairy's sustainability strategies, and what improvements would you suggest?

While all 47 completed the survey, only 38 provided meaningful responses that could be thematically analyzed. Qualitative feedback on the effectiveness of sustainability strategies is given in Table 5.14.

Theme	Frequency (n=38)	Percentage (%)	Illustrative Quote
Moderately effective but needs improvement	12	31.6%	BRAC Dairy's strategies are moderately effective. Waste management and cold chain operations are improving, but logistics and packaging require further strengthening.
Farmer development & fodder support	7	18.4%	There is a need for increased investment in farmer development and fodder supply.
Resource management & eco-friendly packaging	6	15.8%	To be fully effective, strategies should focus on strengthening resource management, eco-friendly packaging, and community programs.
Cold chain, logistics & processing efficiency	6	15.8%	Factory milk processing capacity has expanded, but logistics must be faster and more efficient.
Renewable energy & technology adoption	4	10.5%	Expanding renewable energy and using digital traceability would enhance effectiveness.
Other (positive/very brief responses)	3	7.9%	All strategies of BRAC Dairy are too effective.
Total	**38**	**100%**	

Table 5. 14: Qualitative data on the effectiveness of current sustainability strategies

Table 5.14 illustrates that the highest proportion of respondents (31.6%) feel that the sustainability practices of BRAC Dairy is moderately effective but need improvement. They emphasized the strength of waste management and cold chain systems, but identified weaknesses in logistics, packaging, and system integration.

A considerable number of respondents emphasized farmer capacity building and provision of livestock feed (18.4%), reporting that the future viability of their operations rests on the empowerment of smallholders through training, inputs and credit. As was the case in previous years, resource management and eco-friendly packaging (15.8%) were also frequently cited, a

testament to the rising significance of corporate social responsibility and consumer-oriented efforts. Other covered areas included logistics, the cold chain, and processing efficiency (15.8%), where those polled demanded a rapid and streamlined approach. There was also attention paid to renewable energy and technology adoption (10.5%) linked to digital traceability and clean energy. Only a very few (7.9%) gave only brief comments or extremely positive ones, such as, "All strategies are too effective."

Overall, respondents acknowledged that BRAC Dairy has made significant progress in waste management, cold chain development, and farmer engagement; however, there were also clear opportunities for improvement. The strengthening of farmers' capabilities, the application of green packaging, better logistics and reliance on renewable energy were also identified as key priorities. These findings are directly connected with objective 4: to analyze the effectiveness of existing strategies and identify remaining challenges.

5.6.4 Regression Analysis: Strategy Predictors of Effectiveness

To identify which strategies best explain the perceived effectiveness of mitigation efforts, a multiple regression analysis was conducted. The dependent variable was the Effectiveness Index (Q27–Q30) from the questionnaire. The independent variables consisted of four strategy items: procurement logistics, waste reduction and farmer engagement from the questionnaire.

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.779[a]	.607	.570	.35685

Table 5. 15: Model of Regression Predicting Effectiveness of Sustainability Strategies

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	8.266	4	2.067	16.229	.000[b]
	Residual	5.348	42	.127		
	Total	13.614	46			

Table 5. 16: ANOVA for Regression Predicting Effectiveness of Sustainability Strategies

Coefficient					
Model	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
(Constant)	1.505	.298		5.049	.000
BRAC Dairy's logistics strategies (e.g., route optimization, fuel efficiency) contribute significantly to sustainability.	.236	.097	.323	2.436	.019
Waste reduction practices are effectively implemented in BRAC Dairy's production processes.	.188	.070	.295	2.661	.011
BRAC Dairy engages farmers and suppliers effectively in sustainable practices.	.189	.071	.330	2.666	.011
BRAC Dairy's procurement practices effectively support its sustainability goals.	.014	.078	.021	.179	.859

Note. DV = Effectiveness Index. *p < .05.

Table 5. 17: Multiple Regression Predicting Effectiveness of Sustainability Strategies

The regression analysis examined which strategies best predict the perceived effectiveness of BRAC Dairy's sustainability initiatives. The overall model was statistically significant, $F(4.42) = 16.23$, $p < .001$, explaining about 61% of the variance in effectiveness ($R^2 = .61$, Adjusted $R^2 = .57$).

Among the predictors, logistics strategies ($\beta = 0.32$, $p = 0.019$), waste reduction practices ($\beta = 0.30$, $p = 0.011$), and farmer engagement ($\beta = 0.33$, $p = 0.011$) were all significant positive predictors of effectiveness. This indicates that stakeholders perceive improvements in logistics, stronger waste management systems, and active farmer participation as the most critical factors in driving sustainability outcomes.

By contrast, procurement practices ($\beta = 0.02$, $p = 0.859$) were not statistically significant, suggesting that while procurement may be important operationally, it does not strongly influence perceptions of effectiveness in this context. This finding challenges Carter & Rogers' (2008) framework, which emphasizes sustainable procurement as central to SSCM, suggesting that in developing-country contexts, logistics and farmer inclusion may matter more.

5.7 Recommendations & Future Priorities:

5.7.1 Quantitative Analysis:

The final section of the quantitative results highlights respondents' priorities for enhancing BRAC Dairy's sustainability, including eco-friendly packaging, renewable energy, waste reduction, farmer support, and government policy. Recommendations and future priorities identified by respondents are presented in Table 5.18.

Recommendations & Future Priorities				
Particulars	**Valid**	**Mean**	**Median**	**Std. Deviation**
Eco-friendly packaging initiatives should be prioritized at BRAC Dairy.	47	4.49	5.00	.748
BRAC Dairy should prioritize investment in energy-efficient equipment for sustainability improvement.	47	4.38	4.00	.677
Advanced waste reduction technologies and circular economy (reduce, recycle, reuse) should be prioritized at BRAC Dairy.	47	4.34	4.00	.788
Strengthened farmer capacity building and engagement programs should be prioritized.	47	4.32	4.00	.629
Enhanced staff training programs should be prioritized to improve BRAC Dairy's sustainability.	47	4.30	4.00	.749
Government support (e.g., subsidies, incentives, clear regulation) is important for achieving BRAC Dairy's sustainability goals.	47	4.06	4.00	.895

Table 5. 18: Quantitative mean data of recommendations & future priorities

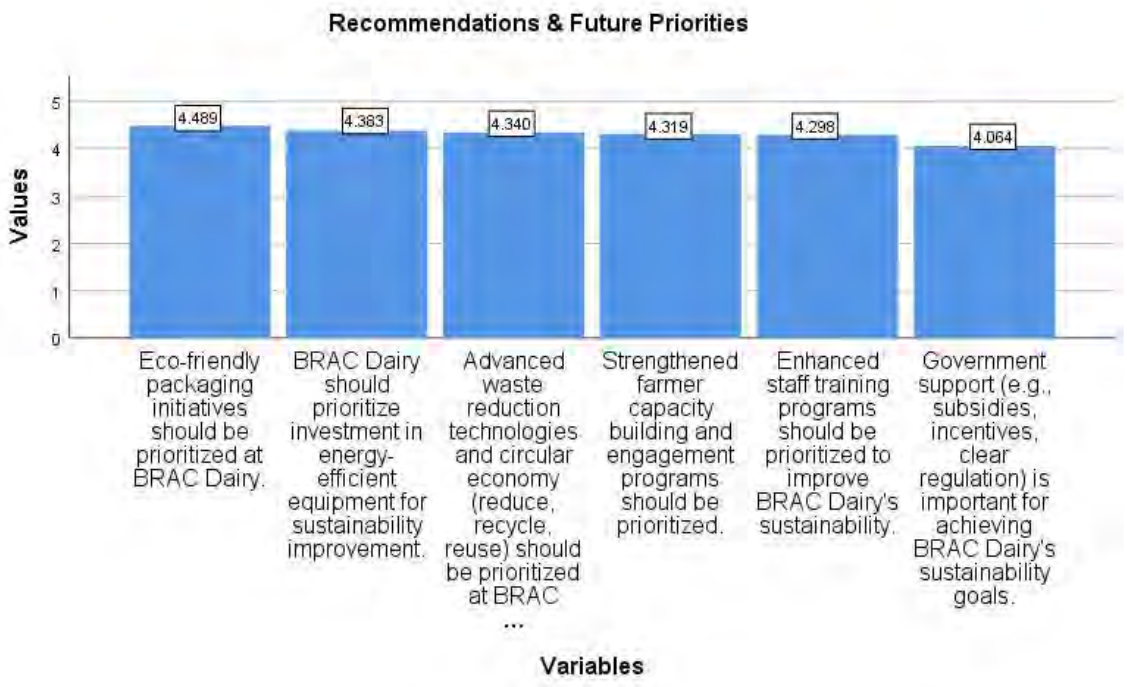

Figure 5. 6: Bar chart of mean data of recommendations & future priorities

Table 5.18 presents the recommendations identified by respondents for strengthening BRAC Dairy's sustainable supply chain. The results show very high mean scores across all items, with every priority rated above 4.0 on a 5-point scale. This indicates a strong overall consensus that multiple areas of sustainability improvement are important for the organization.

The highest priority was given to eco-friendly packaging initiatives (M = 4.49, SD = 0.75), reflecting growing awareness of environmental concerns and consumer preferences. Investment in energy-efficient equipment (M = 4.38, SD = 0.68) and adoption of advanced waste reduction and circular economy practices (M = 4.34, SD = 0.79) were also strongly supported, highlighting the importance of technological innovation.

In addition, farmer capacity building (M = 4.32, SD = 0.63) and enhanced staff training (M = 4.30, SD = 0.75) were rated highly, underlining recognition of the social and human resource dimensions of sustainability. Government support ranked lowest (M = 4.06, SD = 0.90), though it still received strong agreement, suggesting that respondents see external policy support as necessary but place slightly greater emphasis on internal organizational actions.

In summary, the findings indicate that respondents prioritize eco-friendly packaging, energy-efficient technologies, and waste reduction as the most critical future actions, while also recognizing the importance of strengthening people and policy support systems. These results

directly address Objective 5, by offering practical recommendations that align with both operational improvements and broader sustainability goals.

5.7.2 Reliability of Recommendation Items

The six items measuring recommendations and future priorities yielded a Cronbach's Alpha of 0.743, which exceeds the acceptable threshold of 0.70. This indicates that the items exhibit satisfactory internal consistency and can be considered a reliable measure of sustainability priorities. Accordingly, a composite recommendation index (average score of Q31–Q36) was created for further analysis. The reliability of recommendation items is confirmed in Table 5.19.

Reliability Statistics	
Cronbach's Alpha	.743
Number of Items	6

Note. Cronbach's alpha was used to assess the internal consistency of the 6-item scale.

Table 5. 19: Reliability statistics of recommendation

5.7.3 Qualitative Insights of Recommendations & Future Priorities

Respondents were asked to suggest improvements or new initiatives for enhancing sustainability in BRAC Dairy's supply chain through the question: What improvements or new initiatives should BRAC Dairy consider to strengthen sustainability in its supply chain?

Out of 47 participants, 41 provided substantive responses, while the remainder gave minimal or non-specific answers. The thematic analysis of these responses highlights several key areas where BRAC Dairy can advance its sustainability agenda.

Theme	**Frequency (n=41)**	**Percentage (%)**	**Illustrative Quote**
Renewable energy adoption (solar, biogas, wind)	9	22.0%	Shift some of the utility to solar, wind, or biogas energy; spoiled milk can be used for biogas instead of disposal.
Eco-friendly & sustainable packaging	8	19.5%	Introduce green or biodegradable packaging to cut down plastic use.

Farmer training, capacity building & incentives	8	19.5%	Provide capacity-building programs on quality milk production, animal health, and modern farming practices.
Cold chain & infrastructure improvements	6	14.6%	Modernize cold chain infrastructure and improve storage facilities for better quality protection.
Circular economy & waste-to-value systems	5	12.2%	Introduce waste-to-energy systems, composting, and recycling to convert waste into usable resources.
Digitalization & supply chain monitoring	3	7.3%	Implement advanced digital tracking systems for real-time monitoring and transparency.
Policy, governance & community engagement	2	4.9%	Government support, clear regulation, and community-based awareness programs are needed.
Total	**41**	**100%**	

Table 5. 20: Qualitative data of recommendations & future priorities

Table 5.20 summarizes qualitative suggestions for strengthening BRAC Dairy's sustainability practices. As can be seen from the table, the most mentioned improvement was the use of renewable energy (22.0%), including suggestions for chilling vans powered by solar energy, biogas plants from cow dung, and more extensive use of clean energy in production and logistics. It is an expression of listeners' acknowledgement of the high cost of energy and the environmental waste related to the conventional use of energy.

Tightly contested were environmentally friendly packaging (19.5%), and farmer training and incentives (19.5%), which both emphasize the importance of plastic reduction, and that farmers are taught the skills and fairly rewarded for sustainable practices. Respondents also stressed the importance of packaging innovation and farmer capacity development as aspects supporting environmental and social sustainability in the long term.

And in the second most common theme, cold chain and infrastructure improvements (14.6%) would see investment in upgrading storage, decreasing waste and improving logistics systems. Circular economy and waste to value (12.2%) also attracted interest for composting, recycling and converting waste into energy.

Degradation prevention and terrain management (19.5%) and digitalization and supply chain tracking (7.3%) were less frequently recommended, with suggestions including technologies for traceability and demand forecasting and for policy and community engagement (4.9%); e.g. support regulation and (inter) national level, local awareness-raising campaigns.

In general, the results indicate that respondents believe that renewable energy, eco-friendly packaging, farmer's empowerment, and cold chain are the most important aspects to be addressed. These recommendations are consistent with Aim 5, which will aim to deliver practical insights for improving sustainable supply chain practices in the Bangladeshi dairy sector.

5.8 Integration of Quantitative and Qualitative Findings

The combination of survey data and open-ended responses provides a holistic picture of the sustainability practices BRAC Dairy is implementing. Table 5.21 offers here a concurrent presentation of major theme, aggregating mean scores from the qualitative survey with corroborative qualitative evidence. This methodology illustrates where strategies are considered effective, where there are deficiencies and which future priorities stakeholders prioritize really highly.

Theme/Challenge or Strategy	Quantitative Result (Mean)	Qualitative Evidence (Themes/Quotes)
Cold chain systems	4.15	23.8% cited cold chain gaps as the biggest barrier, but many praised improvements; seen as the most effective strategy.
Waste management systems	3.68	24.4% highlighted ETP/WTP and recycling as key practices, but noted scope for improvement.
Logistics (emissions, efficiency)	3.47	Respondents noted logistics is improving but still slow and fuel-intensive.
Farmer engagement & training	3.40	19.5% mentioned farmer training as a need; many saw it as the weakest current strategy.
Procurement & fair pricing	3.64	14.6% mentioned fair pricing and farmer empowerment; seen as supportive but not transformative.

Eco-friendly packaging (future priority)	4.49	19.5% called for biodegradable/green packaging to reduce plastic dependency.
Renewable energy adoption (future priority)	4.38	22% recommended solar/biogas energy and renewable-based chilling systems.

Table 5. 21: Quantitative and Qualitative findings integration

The joint display illustrates how quantitative scores align with qualitative themes, reinforcing the reliability of the findings. Cold chain systems achieved the highest effectiveness rating (M = 4.15) and were widely acknowledged in open responses as the strongest intervention, demonstrating clear progress in reducing spoilage and maintaining quality. Waste management scored moderately (M = 3.68), with respondents highlighting effluent and water treatment plants but also calling for broader application. Logistics strategies (M = 3.47) and farmer engagement and training (M = 3.40) scored lower, consistent with feedback pointing to transport inefficiencies and limited capacity-building for smallholders. Procurement and fair pricing (M = 3.64) were recognized as supportive but not transformative, suggesting that while fair payments are valued, they do not fully address structural challenges. Looking forward, eco-friendly packaging (M = 4.49) and renewable energy adoption (M = 4.38) emerged as strong priorities for future investment, with stakeholders emphasizing green packaging and solar or biogas-based chilling systems.

Together, these integrated findings highlight cold chain and procurement as relative strengths, while farmer engagement, logistics, and long-term sustainability initiatives require greater focus. This synthesis directly informs the subsequent discussion and implications for both BRAC Dairy and the wider dairy sector.

5.9 Observation

This chapter presented the empirical findings and showed how they address the research objectives. The demographic profile highlighted a diverse group of respondents across BRAC Dairy's supply chain, providing a strong basis for interpretation.

The results confirmed high awareness of sustainability and broad agreement on its importance for long-term success. However, several critical challenges were identified, including seasonal variations, environmental pressures, the high cost of eco-friendly technologies, and infrastructure gaps, compounded by financial, social, and institutional barriers.

Current strategies were judged to be moderately effective. Procurement and waste reduction emerged as relative strengths, while training, technology adoption, logistics, and farmer engagement were weaker. Cold chain systems stood out as the most effective intervention, though waste management, emissions reduction, and farmer engagement require further attention.

Looking ahead, respondents prioritized eco-friendly packaging, energy-efficient technologies, advanced waste reduction, farmer capacity building, and enhanced staff training, while also noting the importance of government support.

Overall, the findings reveal both progress and persistent gaps in BRAC Dairy's sustainability practices. These insights set the stage for the next chapter, which situates the results within the broader literature and explores their theoretical and practical implications.

Chapter 6:

Discussion and Implications

6.1 Introduction

This chapter discusses the key findings of the study in relation to the existing literature on sustainable supply chain management (SSCM). It highlights how the results from BRAC Dairy align with, extend, or diverge from prior research, and outlines the theoretical, managerial, and policy implications of the study. The aim is to interpret the results beyond numbers, showing their practical and academic significance. The discussion also revisits the conceptual framework that links challenges, strategies, outcomes, and recommendations, and reflects on the study's limitations and avenues for future research.

6.2 Awareness and Importance of Sustainability

The study found that most respondents were aware of the concept of a sustainable supply chain, and almost all agreed it is crucial for BRAC Dairy's long-term success. This echoes earlier research that emphasized awareness as a precondition for successful SSCM adoption (Seuring & Müller, 2008; Carter & Rogers, 2008).

However, while awareness levels were high, qualitative responses revealed varying interpretations, some emphasized eco-friendly practices, others focused on farmer fairness, efficiency, or profitability. This diversity suggests that, although the concept is understood broadly, its operational meaning remains fragmented. Similar findings have been observed in developing-country agribusinesses, where sustainability is recognized but not uniformly defined (Yadav et al., 2020). The implication is that BRAC Dairy must translate this general awareness into shared organizational definitions and training, ensuring that sustainability is consistently understood across all levels of the supply chain.

6.3 Challenges and Root Causes

The most pressing challenge identified was seasonal variation, flooding, extreme heat, and fodder scarcity disrupt supply and quality. This aligns with previous studies that found climate and weather dependency to be a major barrier for dairy supply chains in South Asia (FAO, 2019).

Environmental concerns, such as waste management and carbon reduction, were also prominent. These reflect the growing global consensus that environmental pressures are increasingly shaping food supply chains (Mangla et al., 2018). Financial barriers, particularly the high cost of eco-friendly technology, were a recurring theme, mirroring Carter & Rogers' (2008) argument that financial viability remains a key obstacle in SSCM adoption. Additionally, infrastructure gaps (roads, electricity, cold storage) and consumer demand for low-cost products echo findings from Bangladesh's wider food sector (Ahsan & Rahman, 2017).

Qualitative insights highlighted further root causes: poor raw milk quality due to smallholder practices, lack of government policy clarity, and weak data integration. Together, these findings show that BRAC Dairy's challenges are multi-dimensional, environmental, financial, operational, social, and institutional.

Unlike India's cooperative system (e.g., Amul), which pools resources to mitigate seasonal disruptions, BRAC Dairy operates with fragmented smallholders who lack resilience against climate shocks. This makes seasonal variations a far greater challenge in Bangladesh than in contexts where farmers have stronger institutional backing.

6.4 Current Strategies and Effectiveness

Procurement and waste reduction emerged as BRAC Dairy's strongest strategies. Fair sourcing and waste management initiatives are positively recognized, aligning with evidence that socially inclusive and environmentally focused practices can strengthen resilience (Miemczyk et al., 2012).

However, other strategies, such as logistics optimization, farmer engagement, staff training, and technology use, were seen as only moderately effective. This mixed perception aligns with case studies from other developing-country dairies, where partial adoption of sustainability practices resulted in modest gains but lacked full integration (Tsolakis et al., 2014).

Cold chain investments were widely viewed as the most effective mitigation strategy, reducing waste and ensuring quality. This finding reinforces the importance of infrastructure in perishable supply chains (Reardon et al., 2019). Conversely, logistics for emissions reduction and farmer engagement were weak areas, suggesting that BRAC Dairy's social and environmental pillars are not equally advanced.

Regression analysis results confirmed that logistics strategies ($\beta = 0.32$, $p < 0.05$), waste reduction ($\beta = 0.30$, $p < 0.05$), and farmer engagement ($\beta = 0.33$, $p < 0.05$) were statistically significant predictors of effectiveness, while procurement was not. This finding highlights the central role of operational efficiency and farmer inclusion, consistent with studies on perishable supply chains (Reardon et al., 2019; CARE, 2012). The moderate effectiveness of farmer engagement programs reflects a broader issue in SSCM theory: strategies often assume enabling policies and institutional support, which are weak in Bangladesh. Without strong policy alignment or investment incentives, even well-designed strategies struggle to achieve scale.

6.5 Recommendations and Future Priorities

Respondents strongly supported eco-friendly packaging, energy-efficient equipment, advanced waste reduction, and farmer capacity building. These align with the triple bottom line approach, where environmental, social, and economic goals are interdependent (Elkington, 1997). Eco-friendly packaging as the top priority reflects global dairy trends, where consumer demand increasingly pressures companies to reduce plastic use (Sharma et al., 2021). Farmer training and capacity building also feature prominently, echoing studies showing that long-term sustainability depends on empowering smallholders (Bijman & Bitzer, 2016). The lower ranking of government support compared to internal actions is noteworthy. While policy frameworks remain weak, respondents clearly believe organizational initiatives should take the lead in driving sustainability.

6.6 Theoretical Implications

This study contributes to SSCM theory in several ways:

- This study validates the TBL framework in a developing country dairy sector, but also reveals its limitations. Economic and operational concerns often overshadow social and environmental goals, confirming Norman & MacDonald's (2004) critique of TBL as difficult to operationalize in resource-constrained settings. Moreover, the finding that procurement was not a significant predictor of effectiveness challenges Carter & Rogers' (2008) framework, suggesting that in emerging economies, logistics and farmer engagement may be more critical levers of sustainability.
- It highlights the tension between awareness and action: while stakeholders recognize sustainability, fragmented interpretations prevent cohesive implementation.

- It extends literature by emphasizing the role of seasonality and climate risks, a factor less prominent in SSCM studies from developed countries.
- It shows that SSCM in developing economies is heavily shaped by smallholder dynamics, infrastructure constraints, and weak policy environments.

6.7 Managerial Implications

For BRAC Dairy, the results indicate some priorities:

- Socialize the understanding of sustainability among employees and farmers through training and common definitions.
- Improve cold chain and logistics to reduce wastage, enhance efficiency and lower emissions.
- Corporate investments are needed to produce environmentally friendly packaging for consumers and the environment.
- Scale training and incentives for farmers to improve quality of milk, minimize adulteration as well as increase productivity.
- Use the power of digital (traceability, fat test, monitoring) to promote transparency and trust.
- Cross-functionally coordinate between feed, AI, milk collection, and processing operations to drive out waste.

6.8 Policy Implications

Policy interventions are vital. Government should provide subsidies for renewable energy and biodegradable packaging, enforce clear food safety and sustainability standards, and invest in rural infrastructure (roads, cold storage, and electrification). Multi-stakeholder partnerships, between government, NGOs, and the private sector are essential to scale sustainability in the dairy sector (Shukla et al., 2019).

6.9 Revisiting the Conceptual Framework

The evidence fits the priority construct of Challenges → Mitigation Strategies → Outcomes → Recommendations. However, findings highlight that some strategies (procurement) do not translate into effectiveness as strongly as theory predicts, while others (farmer engagement)

play a more significant role than expected. This suggests that the framework may need adaptation to smallholder-driven contexts.

- Obstacles such as seasonality, unaffordability, and facility deficiencies were clearly perceived.
- Strategies such as purchasing, waste prevention, and cool chain systems were also evaluated for efficiency.
- Results were mixed, with advances in waste reduction and quality, deficiencies in engaging farmers, and emissions mitigation.
- Proposals exhibited strong agreement around packaging, renewable energy, training, and policy support.

6.10 Limitations

The study provides valuable insight, but it is based on only one case study, BRAC Dairy, and relies on the perceptions of respondents, is cross-sectional in nature, and is self-reported. Seasonal data, expanded geographic sampling, and longitudinal studies would enhance future discoveries.

6.11 Future Research Directions

Future studies could:

- Conduct comparisons between various dairies in the Bangladesh or in South Asia.
- Leverage longitudinal data to measure the effectiveness of sustainability initiatives longitudinally.
- Conduct cost–benefit analyses of green technologies, such as solar refrigeration or biogas.
- Use life-cycle assessment (LCA) to prioritize packaging and logistics environmental impact.
- Investigate consumer perceptions of sustainable dairy in order to connect supply chain practices with market responsiveness.

6.12 Observation

The conversation highlights that BRAC Dairy is advancing its sustainability supply chain approach, particularly in terms of procurement, waste management, and cold chain management. However, the company continues to grapple with climate dependence, financial hurdles, infrastructure and the capacity of its farmers. BRAC Dairy can enhance its standing in the Bangladesh dairy industry by adhering to its own organizational aspirations, considering stakeholder expectations as well as global sustainability best practices. In addition, the findings contribute to the literature on SSCM through evidence from a developing country.

Chapter 7:

Findings and Recommendations

7.1 Introduction

This final chapter presents the most important results from the study, its contributions to date, and a set of recommendations for the BRAC Dairy & Food Project and beyond. It concludes with a discussion of the study's limitations and potential future research. The intention is to bring the thesis to an unambiguous end by illustrating precisely how the research objectives have been met, and what we have learned from it that is of value.

7.2 Summary of Key Findings

This research aimed to examine the challenges, coping mechanisms, and performance, as well as the ways to facilitate sustainability in sustainable supply chain management within the dairy industry in the context of Bangladesh, with a particular emphasis on BRAC Dairy.

The results can be summarized as follows:

1. **Sustainability Understanding:** The proportion of stakeholders with a good understanding of sustainability was relatively high and those strongly agreeing on its importance for the long-term success of BRAC Dairy was very great. However, interpretations differed, suggesting a need for a coherent organisational definition.
2. **Challenges and Drivers:** Seasonal, climate-dependent and environmental challenges were the most important challenges, followed by the high cost of eco-friendly technologies, infrastructure deficiencies, and consumer demands for low-costing products. The reliance on smallholder farmers, the varying quality of milk and opaque policies by the government add layers to the sustainability challenge.
3. **Current Practices:** Procurement and waste reduction measures were perceived to be relatively high, while logistics, farmer engagement, staff training, and technology were moderately effective. Investment in the cold chain proved to be the most effective intervention in reducing waste and ensuring product quality.
4. **Effectiveness of Mitigation:** Respondents perceived cold chain systems as the most effective, followed by waste management, carbon reduction, and farmer engagement. That represents some progress, but also large gaps.

Regression analysis revealed that logistics, waste reduction, and farmer engagement are the strongest predictors of effectiveness, providing clear evidence of where improvements should be prioritized. Other most important areas for future action, with a high level of agreement, include eco-replacement packaging, more energy-efficient machinery, capacity building, and staff training. While government assistance was judged to be significant, the focus of respondents was more on in-house organization responses.

These results suggest that, despite progress towards sustainability, there are structural, financial, and environmental constraints to the BRAC Dairy sustainability journey.

7.3 Recommendations

Based on the findings, the following recommendations are proposed to strengthen BRAC Dairy's sustainable supply chain practices:

7.3.1 Organizational Recommendations

1. **Strengthen Cold Chain and Logistics**: Expand and modernize cold storage and transport systems to minimize milk spoilage, improve efficiency, and reduce carbon emissions.
2. **Adopt Eco-Friendly Packaging**: Introduce biodegradable or recyclable packaging to address consumer concerns and reduce environmental impact.
3. **Enhance Farmer Training and Support**: Scale up programs on clean milk production, animal health, fodder management, and climate-smart farming to improve both productivity and quality.
4. **Leverage Digital Tools**: Use real-time monitoring, traceability systems, and digital fat-testing devices to improve transparency, reduce losses, and build consumer trust.
5. **Expand Renewable Energy Use**: Pilot solar-powered chilling centers, biogas plants, and energy-efficient technologies to lower operational costs and environmental footprint.
6. **Integrate Sustainability into Staff Training**: Ensure all employees, from management to field staff, understand and can apply sustainability principles in daily operations.

7.3.2 Policy and Sectoral Recommendations

1. **Government Incentives:** Lobby to bring about subsidies and provision or promotion of eco-friendly technologies, renewables and sustainable packaging.
2. **Infrastructure Creation:** Work with the government and the NGOs for the upgradation of rural roads, electrification and extension of milk shed area.
3. **Enhanced Regulatory Structure:** Partner with regulators to develop and maintain defined and enforced policies on sustainable dairy production, food safety and other environmental practices.
4. **Multi-stakeholder partnership:** Scale up proven sustainability approaches and strengthen BRAC's collaboration with the government, the NGO sector, and international donors.

7.4 Contributions of the Study

This study makes several contributions:

- **Theoretical**: Extends sustainable supply chain literature by showing how environmental, social, and economic challenges intersect in a developing-country, smallholder-based dairy sector.
- **Practical**: Provides BRAC Dairy with evidence-based strategies to improve sustainability performance.
- **Policy**: Highlights areas where government and sectoral interventions are needed to support long-term dairy sustainability.

7.5 Limitations

The strengths of this study are also its limitations:

1. It was limited to one case (BRAC Dairy) and therefore may not be generalizable.
2. It depended on self-reported information, which could be subject to bias.
3. Since the design is cross-sectional, we are measuring a moment in time and not changes over time.

7.6 Conclusion

This study demonstrates that while BRAC Dairy has made significant progress in procurement practices, waste reduction, and cold chain management, the company still faces structural barriers rooted in seasonality, smallholder dependence, and weak infrastructure. These findings are important not only for BRAC but for other organizations in similar contexts, as they show the need to integrate economic efficiency with social empowerment and environmental responsibility.

For practice, the study highlights actionable priorities: strengthening cold chains, adopting eco-friendly packaging, scaling farmer training, and investing in renewable energy. For theory, it reinforces the value of the Triple Bottom Line but also exposes its limitations in developing economies, where economic and infrastructural constraints often overshadow environmental and social goals. Since regression results statistically confirmed logistics, waste reduction, and farmer engagement as the main drivers of effectiveness, BRAC Dairy should give priority to these areas in its future sustainability initiatives.

Looking forward, achieving sustainable dairy supply chains in Bangladesh will require collective action: organizational innovation, supportive government policy, and collaboration across the private, public, and NGO sectors. Only through such multi-level efforts can sustainability in the dairy sector move from aspiration to reality.

With respect to this study, additional research that could be conducted includes:

1. Compare between several dairy companies in Bangladesh or South Asia.
2. Carry out longitudinal research to evaluate the long-term effectiveness of sustainability actions.
3. In-depth environmental footprints were further assessed using life-cycle assessment (LCA).
4. Investigate consumer views about sustainable dairy products to connect the practices of the supply side and the demand side of the market.

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Appendix A: Questionnaire

Challenges and Mitigation Strategies for Implementing a Sustainable Supply Chain in Bangladesh's Dairy Industry: A Case Study on BRAC Dairy & Food Project

Introduction & Consent

This questionnaire is part of a research study for a Master's thesis in Procurement and Supply Management at BRAC University. The objective is to explore the challenges and mitigation strategies in implementing sustainable supply chain practices in Bangladesh's dairy industry, focusing on BRAC Dairy & Food Project.

Your responses will remain confidential and anonymous. Participation is voluntary, and you may skip any question or stop at any time. The survey will take approximately 15-20 minutes to complete.

Do you consent to participate in this questionnaire? ☐ Yes ☐ No

Section A: Demographic & General Information

1. **What is your role in the dairy supply chain?**
   ☐ Chilling center/Collector
   ☐ Transporter
   ☐ Procurement
   ☐ QAD
   ☐ Processor (Production)
   ☐ Engineering and Maintenance
   ☐ Inventory and Distribution
   ☐ Other: _____
2. **How many years have you been involved in the dairy supply chain?**
   ☐ Less than 1 year ☐ 1–3 years ☐ 4–6 years ☐ 7–10 years ☐ More than 10 years
3. **Age?**
   ☐ 18–25 years
   ☐ 26–35 years
   ☐ 36–45 years
   ☐ 46–55 years
   ☐ 56 years and above

4. **Education Level?**
   ☐ Secondary school or below
   ☐ Diploma/Technical training
   ☐ Bachelor's degree
   ☐ Master's degree or higher

Instructions for Rating Questions

For each statement, please give a score from 1 to 5:

- **1** = Very Low / Strongly Disagree / Not at all
- **2** = Low / Disagree / Slightly
- **3** = Moderate / Neutral / Somewhat
- **4** = High / Agree / Mostly
- **5** = Very High / Strongly Agree / Extremely

Section B: Awareness & Importance of Sustainability

5. I am aware of the concept of a sustainable supply chain in BRAC Dairy's operations.
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. Sustainability is important for the long-term success of BRAC Dairy's supply chain.
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. In your own words, what does "sustainable supply chain" mean to you in the context of dairy operations?
   ……

Section C: Key Challenges in Sustainable Supply Chain Implementation

8. Environmental sustainability (waste management, emissions reduction) is a significant challenge in BRAC Dairy's operations.
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

9. Social sustainability (worker welfare, community impact, fair practices) is a significant challenge in BRAC Dairy's operations.
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

10. Economic sustainability (cost management, profitability, efficiency) is a significant challenge in BRAC Dairy's operations.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

11. High costs of eco-friendly technologies hinder BRAC Dairy's sustainability efforts.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

12. Infrastructure issues (e.g., unreliable transportation, power outages, poor roads) frequently disrupt and negatively affects BRAC Dairy's operations.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

13. Consumer demand for low-cost dairy products hinders BRAC Dairy's sustainability goals.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

14. Unclear government sustainable policies and regulations like BSTI, Food safety create challenges for BRAC Dairy's sustainability efforts.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

15. Lack of clear supply chain data and transparency is a barrier to BRAC Dairy's sustainability initiatives.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

16. Lack of skilled personnel trained in sustainable practices limits BRAC Dairy's sustainability initiatives.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

17. Seasonal variations (monsoon flooding, extreme heat, fodder scarcity during dry season) create significant challenges for BRAC Dairy's sustainable supply chain operations.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

18. From your experience, which challenge is the most critical barrier to sustainability in BRAC Dairy's operations? Please explain why.

……

Section D: Current Sustainability Strategies

19. BRAC Dairy's procurement practices effectively support sustainability goals.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

20. BRAC Dairy's logistics strategies (e.g., route optimization, fuel efficiency) contribute significantly to sustainability.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

21. Waste reduction practices are effectively implemented in BRAC Dairy's production processes.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

22. Staff training programs effectively improve sustainable practices at BRAC Dairy.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

23. BRAC Dairy uses technology (IoT, automation, monitoring systems) effectively to enhance sustainability.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

24. BRAC Dairy engages farmers and suppliers effectively in sustainable practices.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

25. Can you describe a specific sustainable practice or initiative you've observed at BRAC Dairy that has been particularly successful or unsuccessful? Why?
……

Section E: Effectiveness of Current Mitigation Strategies

26. BRAC Dairy's waste management systems effectively reduce environmental impact.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

27. Cold chain systems effectively reduce product waste and maintain quality at BRAC Dairy.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

28. BRAC Dairy's logistics strategies effectively reduce carbon emissions.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

29. Current farmer engagement programs effectively promote sustainable practices among suppliers.
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

30. How effective are BRAC Dairy’s sustainability strategies, and what improvements would you suggest?
……

Section F: Recommendations & Future Priorities

31. BRAC Dairy should prioritize investment in energy-efficient equipment for sustainability improvement.
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

32. Advanced waste reduction systems should be prioritized at BRAC Dairy.
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

33. Eco-friendly packaging initiatives should be prioritized at BRAC Dairy.
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

34. Enhanced staff training programs should be prioritized to improve BRAC Dairy's sustainability.
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

35. Government support (e.g., subsidies, incentives, clear regulation) is important for achieving BRAC Dairy's sustainability goals.
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

36. Strengthened farmer capacity building and engagement programs should be prioritized.
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

37. What improvements or new initiatives should BRAC Dairy consider to strengthen sustainability in its supply chain?
