

Cold chain logistics

The case of Paraguay and territories
along the bioceanic corridor

Rocío Aguayo
Mical Rodríguez Laconich
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List of abbreviations

ABRAFARMA	Brazilian Association of Pharmacy and Drugstore Chains
AFD	Development Finance Agency (<i>Agencia Financiera de Desarrollo</i>)
ANDE	National Electricity Administration (<i>Administración Nacional de Electricidad</i>)
ANVISA	Brazilian Health Regulatory Agency
BNF	National Development Bank
CAIASA	<i>Complejo Agroindustrial Angostura S.A.</i> (Angostura Agro-industrial Complex Inc.)
CAPAREV	Paraguayan Chamber of Air Conditioning, Refrigeration and Mechanical Ventilation
CONAB	Companhia Nacional de Abastecimento (National Supply Company)
INTN	National Institute of Technology, Standardization and Metrology
DINATRAN	National Transport Authority
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
FAO	Food and Agriculture Organization of the United Nations
FLV	Fruits, vegetables, and leafy greens
GDP	Gross Domestic Product
IWW	Inland waterway transport
LPI	Logistics Performance Index
LLDC	Landlocked Developing Countries
MAG	Ministry of Agriculture and Livestock
MERCOSUR	Mercado Común del Sur (Southern Common Market)
MIC	Ministry of Industry and Trade
MOPC	Ministry of Public Works and Communications
MPT	Master Transport Plan
MSMEs	Micro, small, and medium-sized enterprises
MSPBS	Ministry of Public Health and Social Welfare
NIP	National Immunization Program
NLP	National Logistics Plan
NSA	Nuestra Señora del Asuncion (Our Lady of Asuncion)
RFID	Radio-frequency identification
SUS	Unified Health System
WSN	Wireless sensor networks

Abstract

This report analyzes the current state of cold chain logistics in Paraguay, with a specific focus on the departments of Alto Paraguay and Boquerón, two key regions located along the Bioceanic Corridor. The study maps the structure and capacity of the cold chain infrastructure, including refrigerated transport fleets, storage facilities, airport and port infrastructure, as well as the national vaccine distribution system. It also identifies logistical bottlenecks and infrastructure gaps that affect the efficient storage and distribution of temperature-sensitive products.

The findings highlight that Paraguay has a functional baseline infrastructure for cold chain logistics, although its cold storage and transportation capacity is largely concentrated in the central region. Additionally, public ports currently lack refrigerated storage, and airports offer only minimal infrastructure for short-term handling. Nevertheless, the cold chain is not perceived as a constraint to the current production levels of refrigerated and frozen products. Similarly, it does not appear to pose an obstacle to potential increases or the development of new products in any region of the country.

Lastly, the report presents a set of public policy recommendations and investment priorities to strengthen Paraguay's cold chain. These include expanding infrastructure in underserved regions, developing credit lines for cold chain projects, designating a specific institution for licensing refrigerated chambers, centralizing existing records into a unified database, and offering specialized training courses for the cold chain. Closing the existing gaps could reduce post-harvest losses, enhance the resilience of the health system, and strengthen Paraguay as a competitive logistics hub in the Southern Cone.

Introduction

A. The Importance of Cold Chain Logistics for trade Integration and infrastructure projects such as the Bioceanic Corridor

The proposal of the bioceanic corridor finds its origins in the Initiative for the Integration of Regional Infrastructure in South America (IIRSA), launched by a group of South American countries in the year 2000. Over the past 21 years, the project has undergone significant changes. It envisions a road corridor that will connect Brazil, on the Atlantic Ocean, to Chile, on the Pacific Ocean, passing through regions of Paraguay and northern Argentina. If the proposal is fully implemented, it will connect the port of Santos, in Brazil, to the port of Antofagasta, in Chile. Among its main objectives, the initiative aims to provide economically viable alternatives for export and import routes for the countries involved.¹

The first stage of this new logistics corridor will begin in Campo Grande, which is the capital of the Brazilian state of Mato Grosso do Sul (MS), and end in the port city of Antofagasta, in Chile, passing through Paraguay and Argentina. This major infrastructure project will shorten the distance traveled by a significant portion of agricultural and mineral production in the surrounding areas, whose final destination is Asian markets. The operationalization of the logistics corridor could enhance logistics integration throughout the region, including potential hubs in Campo Grande-Mato Grosso do Sul, that could serve to supply Brazil's central and northern regions. Similarly, the project is expected to attract productive investments and generate socioeconomic development in eastern Paraguay, northwestern Argentina (NOA), and northern Chile.

Within this regional context, this study focuses on Paraguay, a landlocked country in South America, with particular attention to the departments of Alto Paraguay and Boqueron, both of which are strategically located along the Bioceanic Corridor. Alto Paraguay and Boqueron houses important producers of primary products for both domestic and international markets. The main products are soybeans, corn, wheat, rice, meat, and dairy products, with meat and dairy being especially dependent on cold chain logistics.

¹ <https://www.iirsa.org/News/Detail?id=217>

Beyond meat and dairy, other products such as fish, fruits, vegetables, and greens (FVG) also require cold chain logistics due to their perishable nature. Additionally, certain non-food items including seeds, pharmaceuticals, vaccines, and cosmetics are temperature-sensitive and demand adequate refrigeration during storage and transport. The following sections provide an overview of the cold chain and its importance for agricultural inputs, pharmaceuticals and vaccines and of business models in the cold chain.

B. Overview of the Cold Chain and its importance for Food, Agricultural Inputs, Pharmaceuticals and Vaccines²

A cold chain system refers to sequence of production and logistics processes that enable the production, transportation, storage, and distribution of food, pharmaceuticals, immunobiologicals, agricultural inputs, cosmetics, and other temperature-sensitive products under controlled temperatures. According to the Food and Agriculture Organization of the United Nations (FAO), a cold chain system includes the stages of pre-cooling, storage, transportation, distribution, retail, and domestic refrigeration (FAO, 2015). When applied to food production, the goal of a cold chain system is to keep products safe for consumption, preserve their nutritional characteristics, and maintain good organoleptic qualities. In the case of immunobiologicals and pharmaceuticals, whether for human or veterinary use, the objective is to preserve their immunizing and therapeutic properties. The term “chain” reflects a systemic perspective, in which each activity within the chain is essential to maintaining the products with the desired qualities. Any failure in one of the stages that define and characterize a cold chain system can compromise the final outcome of the controlled refrigeration process.

There are various technologies available for cold generation. These technologies can cool or freeze products at different speeds, using either continuous or batch processes. In general, they are well-known and commercially available technologies. One of the main cost components of any system for generating and maintaining cold is energy. As a result, much of the technological effort has been focused on developing equipment that is more energy-efficient. It is also worth noting that part of the research is not aimed at cold generation and maintenance systems themselves, but rather at the monitoring systems for said equipment that use technologies such as wireless sensor networks (WSN) and radio-frequency identification (RFID).

Temperature-sensitive agri-food and pharmaceutical products generally follow the same storage standards. Storage and transportation temperatures throughout an agri-food chain vary depending on the type of product and the length of time it will be stored. Broadly speaking, temperature ranges can be divided as follows:

- Freezing (at or below -18°C): mainly used for meat, fish, ice cream, processed foods, etc.;
- Refrigeration (0 to 10°C): mainly used for seeds, certain fruits and vegetables;
- Cooling (10 to 20°C): mainly used for some fruits and vegetables.

Table 1 presents another way of classifying cold storage methods by product type and temperature range.

² This section was translated and based on: Batalha, M. et al. (in editing, ECLAC) and was included as a common analytical block across all national reports developed under the regional project “Transport and trade connectivity in the age of pandemics: Contactless, seamless and collaborative UN solutions”. Unless otherwise noted, the findings in this section rely on primary information gathered from interviews with key actors in the private sector and public institutions, conducted according to the methodology outlined in Section E.

Table 1
Cold storage temperatures for food
(Celsius degrees)

Temperature classification	Temperature range	Examples of foods and food products
Frozen	Less than -40 °C	Tuna
Low Temperature	-40C to -18 °C	Seafood, meat, frozen food, ice cream, bread dough
	-18C to +10 °C	Dairy products, pastries, vegetables, meat, fresh seafood
	Constant Temperature	+5C to +18 °C

Source: ASEAN - Japan Transport Partnership (2018).

In the case of cold chains for pharmaceuticals and immunobiologicals, the temperature ranges are similar to those used in agri-food chains.

- Freezing (-10 to -20°C);
- Refrigeration (2 to 8°C);
- Cooling (8 to 15°C).

It is worth noting that some types of vaccines require storage in equipment that reaches temperatures as low as -70°C for long-term storage.

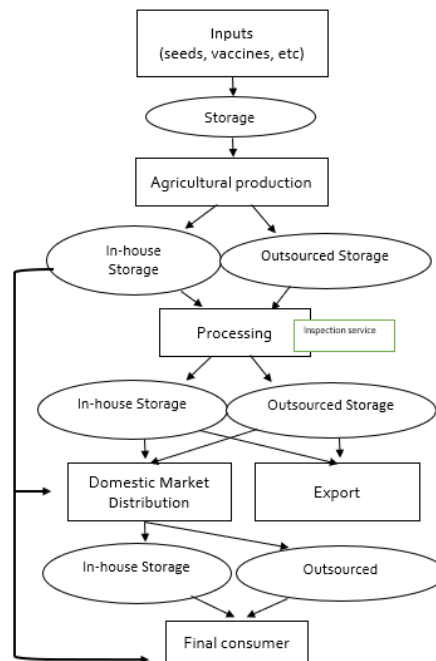
For didactic and illustrative purposes, diagram 1 presents a generic cold chain for agri-food products. It highlights its main segments, with emphasis on cold storage activities associated with real or potential intermediate markets that connect these segments.

At the upstream end of the chain is the agricultural input sector. Actors responsible for producing inputs for livestock farming, mainly vaccines and veterinary medicines, are part of this segment. While these systems are well established in many countries, their adoption in Paraguay is still emerging. For instance, cold storage of seeds is still incipient, although the market has exhibited consistent growth in recent years. Seed warehouses typically operate at stable temperatures around 10°C and relative humidity of 60%. In some cases, even the short-term transportation of seeds, which lasts only a few days, uses climate-controlled trucks to avoid quality loss of the transported products. Scientific and technological advances will be essential to expanding this segment in Paraguay, particularly in light of its growing seed market.

Vaccines are another important input for agri-food production chains that depend on the cold chain. In Paraguay, the quantity of vaccines must be sufficient to cover the entire cattle herd against infectious and contagious diseases, which in 2022 numbered around 14 million animals. These vaccines, as with those intended for human use, must also be kept in a controlled refrigerated environment, typically stored at temperatures between 2°C and 8°C. It can be said that the sustained expansion of livestock production in the analyzed territories relies heavily on an efficient animal vaccine production and distribution system, given that the occurrence of health outbreaks has significantly decreased in recent years.

The storage of agricultural production requiring refrigeration can take place either in facilities owned by the producers themselves or in outsourced structures. In the case of agriculture, particularly for the production of certain fruits, vegetables, and leafy greens (FLV), as well as some types of flowers, storage may occur in dedicated cold chambers before the products are distributed in the domestic market through retail or public distribution centers. In some regions of the Southern Cone of South America, it is possible to find refrigerated handling and storage facilities that are owned and managed by farmer associations or cooperatives. This is a particularly appealing handling and storage alternative for small family farmers. Alternatively, production may be directed to cold storage facilities belonging to large retail distributors or agribusinesses. Milk must also be cooled on the farm before being transported to dairy plants, a process that is typically carried out directly on rural properties.

Diagram 1
Generic cold chain for agro-industrial products



Source: Translated from Batalha, M., et al. (in editing, ECLAC).

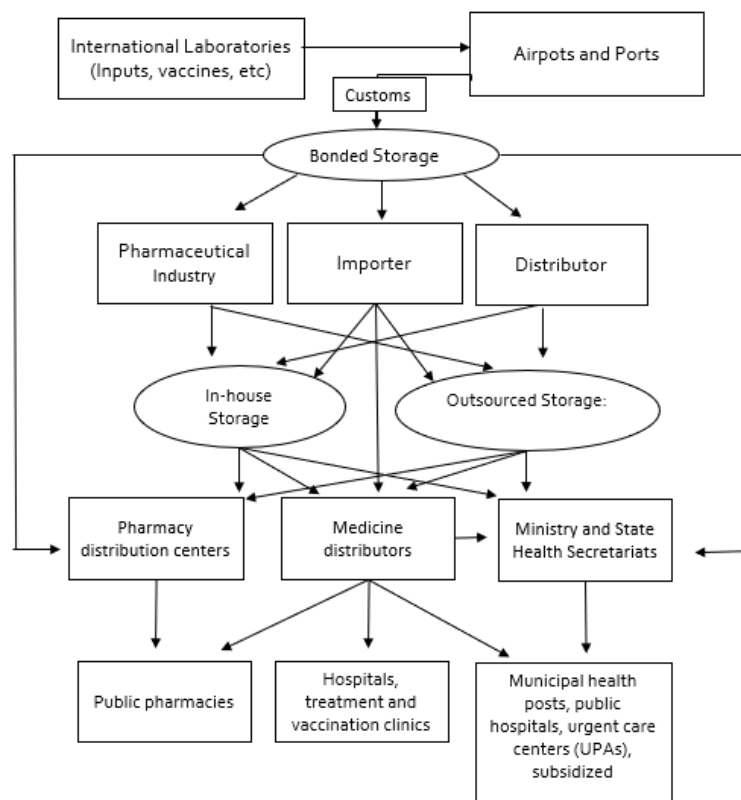
Some food industries are highly sensitive to appropriate temperature conditions for processing and storage, such as the meat and dairy sectors. In these industries, breaking the cold chain can result in a loss of product quality or even the disposal of production. Final products from food industries may be stored in proprietary storage facilities, mostly located alongside processing plants, or in outsourced facilities. In most cases, outsourced facilities consist of private warehouses that provide refrigerated storage services and, in some cases, product handling and repackaging. Surveys indicate that logistics operators tend to concentrate their activities in large urban centers and surrounding areas, such as Asuncion.

At this point, it is important to highlight the vital role that transportation plays in the cold chain. Indeed, cold chain disruptions can occur not only in storage equipment but also during refrigerated transport. The quality of a product manufactured according to proper standards can be compromised by inadequate transportation. Agro-industrial production may reach markets using either proprietary or outsourced transport structures. In Paraguay, specialized logistics operators are active in transporting refrigerated cargo, both for domestic and international markets.

Large and medium-sized retail and wholesale chains have their own storage facilities dedicated to holding the refrigerated products they sell. These facilities are essential not only for maintaining product quality but also for stockpiling; which enables better negotiating conditions with suppliers and helps prevent undesirable supply disruptions. In some cases, retailers may charge suppliers a fee for storing products in their distribution centers. If the supplier does not agree to this fee, they are forced to deliver to multiple points of sale, which may be unfeasible given the logistical constraints of small and medium-sized farmers or manufacturers.

The pharmaceutical and immunobiological production chain is structured in a relatively similar way to the agro-food production chain across the countries in the southern cone of South America. For didactic and illustrative purposes, diagram 2 presents a generic production chain for pharmaceutical and immunobiological products in Brazil, which is described in detail to explain the entire operation. The cold chain runs through all stages of this production chain. Thus, as in the case of agro-industrial production chains, the cold chain is also essential for the production, storage, and distribution of pharmaceutical products and vaccines.

Diagram 2
Generic production chain for pharmaceutical and immunobiological products



Source: Translated from Batalha, M., et al. (in editing, ECLAC).

The Brazilian pharmaceutical industry, composed of public and private laboratories, is responsible for transforming national and imported raw materials into finished products. There are approximately 454 pharmaceutical companies in Brazil, primarily concentrated in the states of São Paulo and Goiás. As in agro-industrial chains, this industrial production can be stored either in the manufacturers' own facilities or in third-party facilities managed by specialized logistics operators. Transport from the manufacturing units to third-party warehouses can be carried out using either the company's own fleet or outsourced services.

There are three major distribution channels for pharmaceuticals and immunobiologicals in Brazil, and they can be supplied either by domestic manufacturers or through direct imports by agents that distribute finished products. Although these channels may overlap, two are primarily private and one is public. One private channel is represented by large pharmacy chains that operate their own distribution centers to supply their retail outlets. The Brazilian Association of Pharmacy and Drugstore Chains (ABRAFARMA),³ an organization that brings together some of these major chains, states that while they represent about 10% of all pharmacy stores in the country, they account for nearly half of the sector's total revenue. This market share is even higher in cities with more than 300,000 inhabitants, whereas in municipalities with up to 50,000 residents, independent stores are the majority.

The second channel is primarily composed of large pharmaceutical distributors. These agents provide wholesale services, supplying not only independent pharmacies that serve the public directly but also treatment and immunization clinics. The Federal Pharmacy Council reports the existence of 4,648 pharmaceutical distributors in Brazil. The distribution centers of large pharmacy chains and distributors

³ <https://www.abrafarma.com.br/>

are equipped with significant cold chain infrastructure for the storage and handling of temperature-sensitive products, such as certain medications and vaccines. It is important to note that treatment and immunization clinics must have cold storage facilities, as is also the case for some retail pharmacies open to the public.

More recently, since the end of 2017, the Brazilian Health Regulatory Agency (ANVISA) has authorized, under strict regulatory conditions, the sale and administration of vaccines in pharmacies (Resolution No. 197).⁴ According to ABRAFARMA, this is a market that could reach annual revenues of R\$ 8 billion. Vaccination in pharmacies would allow, according to industry representatives, more flexible hours for consumers, availability of vaccines not offered by the National Immunization Program (NIP) of the Unified Health System (SUS), and coverage of age groups not included in the NIP. In order to comply with the requirements of ANVISA's Collegiate Board Resolution No. 197, pharmacy vaccination rooms must have cold chain infrastructure, including exclusive freezers and thermal boxes adapted for the storage and preservation of vaccines. Thus, temperature control and monitoring in equipment dedicated to vaccination become especially important within this new area of activity for pharmacies.

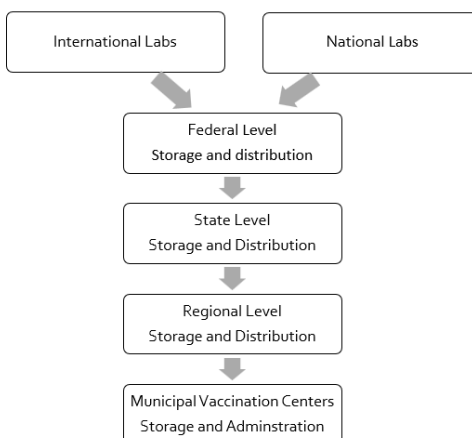
It is important to highlight that the logistics of distribution for the supply chains of thermolabile pharmaceuticals and immunobiologicals in Brazil is mostly operated by large specialized logistics companies, some of which are foreign-owned multinationals. There is, therefore, a relative concentration of these markets within this type of operation. Thus, the transport and storage of these products, from customs warehouses to manufacturers, distributors, or importers, and from manufacturers to the distribution centers of pharmacy chains, drug distributors, and/or state health departments, is carried out almost exclusively by large logistics operators, many of them specialized in cold chain logistics. On the other hand, the so-called "last mile" of these supply chains which refers to the segment that brings the products to pharmacies, hospitals, and immunization clinics is primarily handled by small local carriers or independent truckers. ANVISA's Collegiate Board Resolution No. 430⁵ of October 8, 2020, introduced new requirements for operations within this chain. These requirements contribute to changes already underway in the storage and transport conditions of these supply chains. They may potentially lead to either the strengthening or weakening of specific groups of actors operating in these transport and storage systems. In any case, the various regulatory aspects that shape part of the institutional environment conditioning the functioning of the cold chain must be carefully considered when analyzing the factors that may facilitate or hinder logistical operations, especially transnational ones, along the bioceanic corridor.

The public sector is responsible for a third and important distribution channel for pharmaceuticals and vaccines. According to the interviews with cold chain experts carried out for this research, it is estimated that about 30% of the purchases of medications from national industries are made by public agencies, leaving 70% for the retail pharmaceutical market. The purchase, storage, distribution, and traceability of medicines at the federal public level are guided by the national medicine policy. In turn, the National Immunization Program (NIP) coordinates and carries out the distribution of a large range of immunobiologicals, mainly vaccines, throughout the national territory. The cold chain plays a central role in this process. It is present in every logistical step responsible for maintaining the proper storage of vaccines and other immunobiologicals. It is imperative that the storage temperature be strictly maintained at all stages of the journey from the production laboratory to the patient receiving immunization. To make this possible, the NIP relies on an extensive and complex refrigerated logistics system whose final stage consists of municipal vaccination rooms. Diagram 3 presents a schematic representation of this logistical structure.

⁴ https://bvsmis.saude.gov.br/bvs/saudelegis/anvisa/2017/rdco197_26_12_2017.pdf

⁵ <https://www.in.gov.br/en/web/dou/-/resolucao-de-diretoria-colegiada-rdc-n-430-de-8-de-outubro-de-2020-282070593>

Diagram 3
Refrigerated logistic system used for the national immunization program



Source: Translated from Batalha, M., et al. (in editing, ECLAC).

The national logistics for the distribution of pharmaceuticals and immunobiologicals under federal government programs, such as the National Immunization Program (NIM), is the responsibility of the Ministry of Health. The Ministry's logistics operations are carried out through a private logistics operator⁶ called VTCLog, [online] <https://vtclog.com.br>. This operator provides transportation and storage services. It also manages a logistics complex located next to Guarulhos Airport, in the state of São Paulo. The 36,000 m² facility is divided into climate-controlled areas (temperatures between 15°C and 30°C), refrigerated areas (temperatures between 2°C and 8°C), and freezing chambers (temperatures down to -35°C). The three cold storage chambers occupy an area of 7,000 m². The company also has facilities in Brasília, Rio de Janeiro (Galeão Airport), and Recife. Deliveries from Guarulhos to states located within a 1,400 km radius are made by road. The remaining states are served by air transport, and in the case of northeastern states, through a combination of air and road transport from Recife.

In Brazil, the National Plan for the Operationalization of COVID-19 Vaccination, established by the Ministry of Health in December 2020,⁷ defines the roles and responsibilities for the three levels of government. As a general rule, this structure reflects the overall organization not only of the COVID-19 vaccination campaign, but also of other routine programs involving the Ministry of Health and State and Municipal Health Departments, as detailed below.

Federal management:

- Coordination of the NIP (including defining the vaccination calendar and national campaign vaccines), as well as strategies and technical regulations for their use;
- Provision of immunobiologicals defined by the NIP, considered strategic supplies;
- Management of the NIP information system, including the consolidation and analysis of national data and feedback to the state level.

State Management:

- Coordination of the NIP's state component;

⁶ Logistics Operator: A company holding a Company Operating Authorization (AFE) and a Special Authorization (AE), when applicable, qualified to provide transportation and/or storage services (RDC No. 430/20).

⁷ https://download.uol.com.br/files/2020/12/891107215_2020_12_11_plano_de_vacinacao_covid19__revisado.pdf

- Provision of syringes and needles, which are also considered strategic supplies;
- Management of the NIP information system, including the consolidation and analysis of municipal data, submission of data to the federal level within established deadlines, and feedback to the municipal level.

Municipal management:

- Coordination and execution of vaccination actions listed by the NIP, including routine vaccinations, special strategies, and the reporting and investigation of adverse events and deaths temporally associated with vaccination;
- Management of the municipal stock of vaccines and other supplies, including storage and transportation to points of use in accordance with regulations;
- Disposal and final destination of used vials, syringes, and needles, according to technical standards;
- Management of the NIP information system, including the collection, processing, consolidation, and quality evaluation of data from reporting units, as well as data transfer in accordance with deadlines and flows established at the national and state levels, and feedback to the reporting units.

This system, as it was conceived and remained organized in 2022, ensures extensive coverage and efficient distribution of pharmaceuticals and vaccines throughout Brazilian territory. However, at the same time, it presents storage and transportation challenges that are to be expected in a network of such complexity.

The Paraguayan pharmaceutical and immunobiological production chain, on the other hand, has rather incipient technological and production levels, especially when compared to neighbouring countries such as Brazil or Argentina.

The discussion undertaken in this section makes it clear that aspects related to the generation, preservation, and control of temperature vary significantly depending on the supply chains analyzed. This diversity also extends to the operators and the institutional environments of these chains. This observation applies perfectly to the agro-industrial and pharmaceutical product chains presented in the previous paragraphs. Understanding the structure and dynamics of how these supply chains operate, with temperature control as the central theme, is essential to contextualize the following sections. Any policy proposal, whether public or private, aimed at improving the cold chain along the Bioceanic Corridor necessarily depends on understanding its operating conditions, which in turn can only be achieved by comprehending the structure of the relevant supply chains.

C. Business models in the cold chain⁸

Refrigerated warehouses are fixed-capital facilities used for storing products at controlled temperatures. These warehouses operate with different cooling/freezing technologies (such as conventional cold chambers, controlled-atmosphere storage, gas-controlled cold storage, and freezer storage), and are essential for enabling the proper commercialization of products that require temperature control, such as meat, fish, fruits, seeds, medicines, and vaccines. Storing these products in refrigerated facilities can help prevent spoilage, increase safety, and extend their shelf life. The use of such facilities is also important for complying with storage and commercialization laws and regulations established for certain product categories.

The storage capacity and technology available in the various cold chain facilities studied may vary considerably depending on the business model and the intended purpose of the physical structure. The

⁸ This section was translated and based on: Batalha, M. et al. (2025). and were included as common analytical blocks across all national reports developed under the regional project "Transport and trade connectivity in the age of pandemics: Contactless, seamless and collaborative UN solutions".

literature typically uses two broad classifications for the business models adopted in refrigerated storage facilities, namely:

- (i) refrigerated warehouses available for multiple users on a rental basis ("public" warehouses);
- (ii) refrigerated warehouses operated by an organization for its own use ("private" warehouses).

Warehouses available for third-party rental are referred to as "public" refrigerated warehouses (in the sense of being publicly accessible), even though most of them are operated by privately owned companies. Therefore, the term "public refrigerated warehouses with private capital" may be used to refer to this business model. These warehouses are typically operated by large logistics companies specialized in cold chains, also known as logistics operators. These companies, whose facilities are equipped with technologies that allow storage at different controlled temperatures, offer storage services to their clients under various contractual arrangements. Within this framework, there are two classifications for logistics operators' facilities based on the type of client(s) they serve: (a) Dedicated warehouses; (b) multi-client warehouses. In dedicated warehouses, the facility is fully allocated to a single client, usually under a medium- or long-term service agreement. The warehouse may be multi-temperature or specialized in the specific temperature range required by the stored product. Multi-client warehouses, more commonly observed in practice, involves offering refrigerated storage services to multiple clients. In this case, the facility is multi-temperature, and any economic agent interested in accessing the refrigerated storage service can rent space under terms (price and duration) agreed upon by the parties.

Alternatively, the term "private refrigerated warehouses with private capital" may be used to refer to refrigerated storage structures operated by privately owned organizations for their own use. These facilities, which are not publicly accessible, may exist to meet the needs of an agricultural or industrial producer, or they may be part of storage, distribution, and marketing centers owned by wholesale or retail companies. Examples of this business model include: climate-controlled warehouses of seed producers; cold storage silos and facilities on some farms; refrigerated warehouses of processing agro-industries; and cold chambers found in retail food chains.

There are also some publicly accessible cold storage warehouses operated by publicly owned companies, such as CEASA (a term used for supply centers) and the Brazilian Airport Infrastructure Company (INFRAERO), as well as bonded warehouses. The term "public-access cold storage warehouses owned by public capital" can be used to refer to these facilities. These warehouses are also intended to offer storage services to multiple clients through contractual space rental arrangements. Finally, "privately used cold storage warehouses owned by public capital" were identified. These warehouses are owned by public entities but their use is restricted to a specific agent. Cold chain centers operated by health departments, hospitals, and public universities fall into this business model category.

Table 2 presents a classification⁹ of cold storage facilities based on their user access type (public or private) and source of capital (public or private). This typology, though based on regional examples, lays the groundwork for assessing the types of cold storage business models that could be developed or strengthened in Paraguay in the context of its growing integration with regional trade corridors.

Table 2
Examples of cold storage structure classification by type of user and capital origin

Capital	Public	Private
Public	INFRAERO, CEASA, CONAB (Brazil), Airports and customs (Argentina)	Logistics operators (Brazil, Argentina), Cooperative-owned warehouses (Argentina)
Private	Cold chain centers operated by health departments and hospitals (Brazil, Argentina), universities (Brazil)	Slaughterhouses, retail, wholesale, seed producers, the pharmaceutical industry, refrigerated and rural silos and storage facilities (Brazil, Argentina)

Source: Translated from Batalha, M., et al. (in editing, ECLAC).

⁹ Due to the scarcity of information, only players in the Brazilian and Argentinian cold chain were included.

D. Objectives of the study

This study presents an exploratory assessment of cold chains for agribusiness products and pharmaceuticals/vaccines in the areas of greatest influence of the Bioceanic Corridor in Paraguay. Specifically, it seeks to:

- Assess the installed capacity and operational characteristics of public and private cold storage facilities for agribusiness products and pharmaceutical/immunobiological supplies, with a focus on the departments of Alto Paraguay and Boqueron.
- Describe the broader cold chain infrastructure in Paraguay, including cold storage capabilities at ports and airports, the availability of ultra-low-temperature facilities, and local production of refrigeration equipment.
- Analyze the availability and technical characteristics of refrigerated transportation fleets, used for the domestic and international logistics of temperature-sensitive products.
- Examine the organization and logistics of the national vaccine distribution system, including cold storage, refrigerated transport, and the role of the Ministry of Public Health and Social Welfare (according to its Spanish acronym MSPBS).
- Identify logistical bottlenecks and infrastructure gaps affecting the storage, handling, and distribution of temperature-sensitive products in the studied regions.
- Propose public policy recommendations and regional development strategies to strengthen cold chain logistics and support territorial integration along the Bioceanic Corridor.

E. Methodology

This study adopted a mixed-methods approach, combining the use of secondary data with semi-structured interviews conducted with key stakeholders in Paraguay's cold chain sector. The interviews were carried out remotely via synchronous online platforms that allowed real-time interaction between interviewers and interviewees.

The research design followed a rapid appraisal methodology (Kumar, 1993). This approach is particularly useful for applied research efforts such as the present study, as it seeks to reduce the time and cost of data collection while maintaining analytical rigor. To this end, it maximizes the use of reliable secondary data and qualitative inputs gathered from key stakeholders in the sector or production system under investigation.

Rapid appraisal methods typically rely on interviews to key informants; a qualitative research technique based on semi-structured interviews with individuals who possess expert knowledge of the topic under study (Kumar, 1993). Respondents are often selected from among business leaders, industry associations, academic researchers, research institutions, and public sector agencies. These interviews help capture stakeholder perceptions, concerns, and experiences, and often generate a snowball effect where one interviewee refers others who should be consulted.

While these methods are efficient in terms of time and cost, they require researchers to have prior experience both with the subject matter and with the methodology itself, particularly for conducting and interpreting the interviews.

I. Socioeconomic data and transport infrastructure of the territories along the Bioceanic Corridor

A. Economic and demographic characteristics of Boqueron and Alto Paraguay

Paraguay is a unitary state composed of a territorial division of 17 departments and 263 municipalities.¹⁰ Its total population is estimated at 7,353,038 inhabitants, according to data from the National Institute of Statistics for 2022. Over the past 20 years, Paraguay's economy has experienced an average annual growth of 4%, reaching a GDP (current US\$) of USD 44,458 in 2024 and GDP per capita (current US\$) of USD 6,416.1 according to the World Bank's databank.¹¹ During this period, however, the country's economy has undergone volatility in growth rates, largely driven by fluctuations in the performance of the primary sector, especially agriculture, which is highly sensitive to climatic variability. Broadly speaking, the country's GDP composition can be segmented as follows: primary sector (11.8%), manufacturing sector (33.4%), services sector (47.6%), and tax burden (7.2%).¹²

Regarding agriculture, large-scale production is based on cereals and legumes that do not require cold chain systems, especially soybeans, corn, wheat, and rice. Among the main export destinations, two MERCOSUR member countries stand out: Brazil and Argentina. In 2018, more than 50% of exports were sent to these countries. The European Union, and Russia are the next most important export markets.¹³ Soybean exports via the Paraná River have decreased in recent years, while exports via the Paraguay River have increased due to better navigability conditions. In 2022, 77% of the country's soybean exports are transported through the Paraguay River and only 23% via the Parana River. Although a large portion of soybean production is located near the Parana River, which would naturally be the preferred route for transport. Additionally, the

¹⁰ https://www.opaci.org.py/web/index.php?option=com_wrapper&view=wrapper&Itemid=134

¹¹ <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD>

¹² Data for 2020: <https://www.icex.es/content/dam/es/icex/documentos/quienes-somos/donde-estamos/red-exterior/paraguay/DOC2021886352.pdf>.

¹³ <https://wits.worldbank.org/countrystats.aspx>

poor conditions of the Parana waterway, combined with operational restrictions imposed by the Itaipu and Yacyretá dams, have led producers and trading companies to opt for the Paraguay River waterway instead.

Over the past decade, two major agro-industrial and logistics complexes have been established in the Villeta¹⁴ area: the CAIASA complex and the ADM complex. Together, they have a milling capacity of 4 million tons per year, producing vegetable oil and its derivatives. These complexes, which focus their operations on the soybean value chain as well as the import of fertilizers, handle more than one-third of the country's total production, with a daily milling capacity of 8,100 tons.

The logistics for temperature-sensitive products, such as fruits and vegetables, face severe operational limitations within the national territory. For instance, there is no cold storage available near production areas, and transportation is not carried out in appropriate refrigerated trucks. According to consulted stakeholders, the best storage conditions for this class of products are found mainly in the downstream segments of the supply chain, particularly in retail networks and the central supply market in Asuncion, where intermediaries receive fresh products and, in some cases, store them in cold chambers to extend their shelf life.

In Paraguay, there are also approximately 400 hectares of strawberry cultivation, 50,000 hectares of banana production, and about 5,300 hectares of pineapple, none of which utilize cold chain systems despite being temperature-sensitive fruits. Although bananas are highly temperature-sensitive, they are not handled through a cold chain. Instead, harvest and ripening times are calculated to ensure that the fruit reaches markets in good condition. The main production areas for this crop are located in the north-central part of the Eastern Region. Despite considerable growth in production and exports, its management remains relatively rudimentary, with virtually no producers using cold chain systems during handling and transport to markets. Production is based on smallholders with plots ranging from 1 to 5 hectares. These facts illustrate that the cold chain infrastructure in the departments of Boqueron and Alto Paraguay is practically nonexistent.

B. Road network and main routes in Boqueron and Alto Paraguay

The government of Paraguay has a Master Transport Plan (MTP) designed for a 20-year horizon, which was developed in 2012 and updated in 2018.¹⁵ The government also has a National Logistics Plan (NLP),¹⁶ developed in 2013. The NLP goals include improving efficiency and effectiveness in the sector, upgrading the transport fleet, and diversifying the multimodal transport matrix. The plan also aims to strengthen the regulatory framework to ensure that service providers are strong and efficient, not only for transporting national production, but also to compete with companies from other countries in the regional market.

The purpose of the MTP is to organize, in the short, medium, and long term, the development of infrastructure and transport and logistics services, in order to meet the needs of productive activity and the general population, create access routes for national production to reach international markets, enhance the country's economic competitiveness, and contribute to social development.

As of 2022, the traffic distribution on the road network was heavily concentrated in the central area of Greater Asuncion. Demand projections for 2030 show the same pattern, which is likely to worsen the negative effects of freight transport in urban areas. To address these issues and reduce transportation costs, the country has promoted a road–river intermodal strategy, particularly for the agricultural production chain.

The Master Transport Plan (MTP) was initially designed with a focus on the meat and soybean sectors. Over time, however, it expanded its scope by proposing the development of a logistics platform in the Villeta area, a major agro-industrial and port hub near Asuncion, where the public port of Villeta was the only operational port in 2011. In parallel, the National Logistics Plan (NLP) proposed the creation of a logistics

¹⁴ Villeta is a port and industrial city located 35 km south of Asuncion, along the Paraguay River.

¹⁵ <https://informacionpublica.paraguay.gov.py/public/1897719-tripticopdf-triptico.pdf>

¹⁶ https://www.mic.gov.py/wp-content/uploads/2023/12/PNL_PY-Producto-4-publicable-e290921-2_compressed-1.pdf

activity zone in Villeta, along with the development of the Villeta–Alberdi–Pilar Road corridor. The aim of this infrastructure is to strengthen port development in both Villeta and Pilar, in coordination with the river navigation system between Pilar and Asuncion.

Among the portfolio of proposed projects under the aforementioned plans, the following can be highlighted:

- Institutional framework and public-private coordination for logistics;
- Multimodal infrastructure network;
- Development of business logistics;
- Trade facilitation and investment attraction;
- Opportunities for value-added logistics services;
- Logistics development of the Paraguayan Chaco.

The logistics development of the Paraguayan Chaco project is closely aligned with the objectives of this study. To support its implementation, a specific initiative was proposed in order to explore alternatives for transforming the Chaco region into a logistics hub. This initiative includes the following components:

- Development of improved multimodal infrastructure, regionally connected to relevant logistics hubs;
- Provision and strengthening of logistics and complementary logistics services;

In this sense, the implementation of the bioceanic corridor aligns with the objectives previously set by the Paraguayan government. The goal is to transform the country's western region into an international logistics center. Section 1 of the bioceanic corridor, spans 277 km and connects the Paraguayan cities of Carmelo Peralta (Alto Paraguay Department) and Loma Plata (Boqueron Department). Of this segment, 198 km lie within the department of Alto Paraguay and the remaining 79 km within Boqueron. The connection with Brazil will be made through a new international bridge over the Paraguay River, linking the city of Porto Murtinho (Mato Grosso do Sul) to Carmelo Peralta (Alto Paraguay). The construction is being carried out through a partnership between Paraguay's Ministry of Public Works and Communications (MOPC) and Brazil's National Department of Transport Infrastructure (NDTI). Section 2 of the corridor will span approximately 350 km, connecting Loma Plata (Boqueron) to Pozo Hondo (Boqueron), on the border with Argentina, completing Paraguay's portion of the bioceanic corridor. The link with Argentina will be established through a new bridge over the Pilcomayo River, connecting the town of Pozo Hondo, in the department of Boqueron, with the town of Mision La Paz, in Argentina's Salta province.

It is worth noting that Section 1 of the bioceanic corridor is considered one of the most important infrastructure projects in the Paraguayan Chaco, with an investment of USD 445 million. Once the entire corridor is completed, it is expected to generate new jobs and unlock a range of opportunities for the development of the Paraguayan Chaco. Map 1 illustrates the Paraguayan road network.

Map 1
Paraguayan road network



Source: Adapted from Rodríguez Laconich (ECLAC, 2024).

II. Cold chain infrastructure in Paraguay

A. General cold storage capacity¹⁷

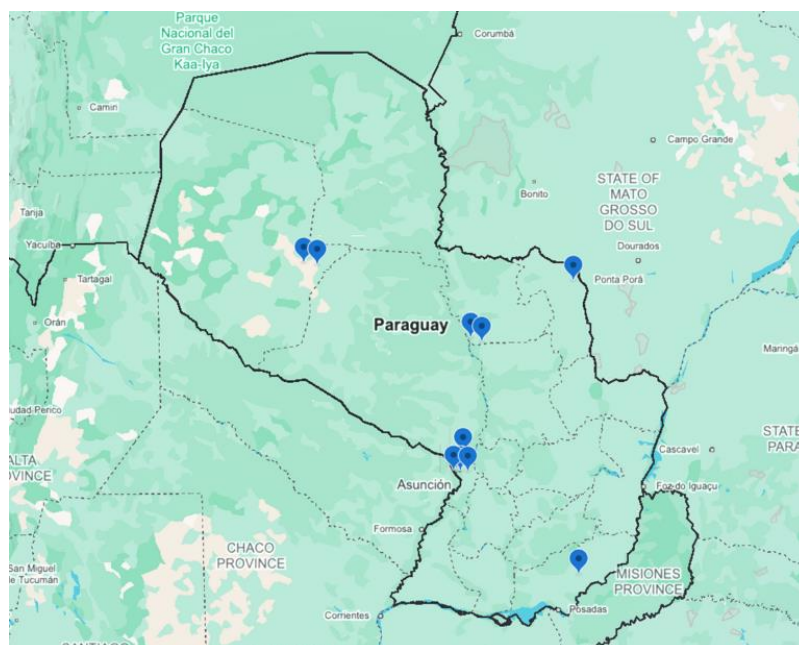
Paraguay's main export product requiring the use of the cold chain is beef, with an annual production of 780,000 tons, of which approximately 390,000 tons are exported frozen or chilled. The largest company in the sector is *Frigorífico Concepcion*, which holds a 25% market share, with an annual production of 240,000 tons and a cold storage capacity of 27,000 m³. Based on these figures, the total cold storage volume in the beef supply chain can be estimated at around 108,000 m³.

Transport logistics for live cattle, chilled meat, frozen meat, or by-products, are mainly carried out by third-party intermediaries who handle the movement of goods to the points of sale, while cold storage is managed by agents specialized in handling this type of product. Refrigerated containers (reefers) for export are handled by international freight operators, who also coordinate overseas shipments. Chile and Russia are the main importers of Paraguay's chilled and frozen beef, respectively. For the Chilean market, transportation is done via refrigerated trucks over a distance of 2,200 km from the meatpacking plants to the final customers. In the case of frozen meat, the refrigerated containers are transported by truck from the meatpacking plants to ports south of Asuncion, where they are almost directly loaded onto container ships with capacities of up to 400 Twenty-foot Equivalent Units (TEUs). These ships then travel to Argentine or Uruguayan ports (1,600 km) before transshipment to ocean-going vessels. A navigation issue means that production from Concepcion must be trucked 450 km to Asuncion in order to access river shipping, since vessels do not sail upstream to Concepcion. This connection increases transportation costs.

¹⁷ Unless otherwise noted, the findings in this section rely on primary information gathered from interviews with key actors in the private sector and public institutions, conducted according to the methodology outlined in Section E.

The main slaughterhouses (for beef and pork) are located in the central Chaco region, in Concepcion, and in and around Asuncion. There are around 20 companies exporting both chilled and frozen meat, which are shown in map 2.

Map 2
Location of the main beef and pork meatpacking plants in Paraguay



Source: Prepared by the authors based on data provided by the private sector.

Meat processing companies have the largest cold storage capacities, due to the need to maintain high stocks of frozen meat, especially for exports to the Russian market. In 2020, total frozen meat exports amounted to 163,000 tons, with the main production and storage centers located in the Central Chaco region, the city of Concepcion, the city of Asuncion, and surrounding municipalities. The distribution of cold storage capacity by region is presented in table 3.

Table 3
Installed cold storage capacity of meatpacking plants in
(Meter³)

Region	Installed capacity m ³
Asuncion	35 261
Concepcion	27 000
Chaco Central	8 996

Source: Prepared by the authors based on data provided by stakeholders during interviews.

The main product for domestic consumption that requires a cold chain is dairy. The company *Lactolanda* is the market leader, with a 50% market share and a cold storage volume of 56,000 m³. Based on this figure, the total installed cold storage capacity in the dairy sector is estimated

at around 112,000 m³. Milk production is dominated by large producer cooperatives. There are about eight companies that produce and market dairy products. The business model is based on the management of dairy basins made up of small and medium-sized producers who supply milk, while reception, storage, production, distribution, and marketing are handled by the industry. The entire cold chain is managed by the industry itself using its own facilities and vehicles. In terms of milk production areas or dairy basins, the main collection and production centers are located in the Central-West part of the Eastern region, particularly in the departments of Caaguazú and Alto Paraná. There is also a major basin in the Central Chaco, in the Mennonite colony area, with reception and production centers located along the bioceanic corridor, where the company *Trebol* stands out with a 27% market share.

On a smaller scale than beef and dairy, there is also an annual production of approximately 20,000 tons of exported processed meats and about 150,000 tons of poultry production, both of which require the use of the cold chain. For these two sectors, the installed cold storage capacity is estimated at around 23,000 m³.

Although pork is not a traditional export product, it has been developing rapidly and finding export markets, in addition to local consumption, which is also significant. Poultry production has shown growth in terms of exports, although the main market remains the domestic one. The primary market for both products is the metropolitan area of Asuncion, which means that a large part of the production and commercialization chain is located on the outskirts of Asuncion, with access to the main export ports on the Paraguay River.

Based on the sectors identified as the main users of cold storage facilities, along with estimates derived from leading industry actors and interviews with suppliers and logistics operators, an estimation exercise was conducted to assess the installed static cold storage capacity in Paraguay. Table 4 presents the estimated distribution of total cold storage capacity by sector.

The interview-based figure presented at the end of table 4 (**Total: 328,500 m³**) was derived from interviews with key stakeholders from the main sectors that utilize cold storage infrastructure. While this estimate provides a solid starting point, it is ideal to validate it using an alternative method or secondary data source. The Global Cold Chain Alliance (GCCA, 2020) report includes an indicator titled *Refrigerated Warehouse Capacity (m³ per urban resident)*. The initial intention was to multiply this value by Paraguay's urban population to estimate the country's total refrigerated capacity, using the formula:

Refrigerated Warehouse Capacity (m³ per urban resident) × Total urban population = National cold storage capacity.

Table 4
Estimated cold storage capacity in Paraguay
(Meter³)

Sector	Capacity in m³
Meat	108 000
Dairy	112 500
Processed meat	12 000
Poultry	18 000
Retail	21 000
Logistics Operators	30 000
Fruits and Vegetables (FLV)	12 000
Other	15 000
Total	328 500

Source: Prepared by the authors based on interviews with production agents.

While the GCCA reports values for other countries in Latin America, it does not provide data for Paraguay, making it impossible to apply this method directly.

To address this limitation and reproduce the formula, the research team developed a method to estimate Paraguay's refrigerated capacity per urban resident based on its Logistics Performance Index (LPI), reported by the World Bank.¹⁸ Before proceeding with the estimation, it was necessary to verify whether LPI scores and refrigerated storage capacity are statistically related across countries. In other words, to corroborate if a country with better logistics performance tends to have higher cold storage capacity.

Data on *Refrigerated Warehouse Capacity (m³ per urban resident)* and *LPI (2018)* were collected for seven Latin American countries represented in the GCCA 2020 report. These data are presented in table 5. The selected countries vary in both logistics performance and cold chain infrastructure, making them a meaningful reference group for constructing a regression model to estimate Paraguay's expected value.

Table 5
Variables used to calculate correlation

Country	Cold storage capacity per capita m ³	LPI 2018	Ranking
Chile	0.133	3.32	34
Mexico	0.138	3.05	51
Brazil	0.107	2.99	56
Colombia	0.075	2.94	58
Argentina	Not available	2.89	61
Costa Rica	0.07	2.79	73
Paraguay	Not available	2.78	74
Uruguay	0.085	2.69	85
Peru	0.071	2.69	83

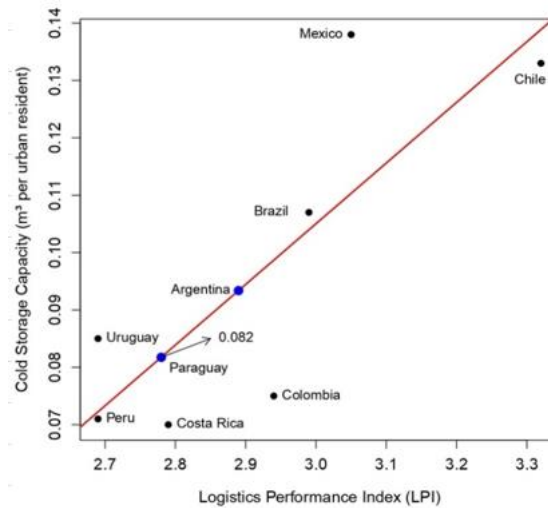
Source: Prepared by the authors based on data from the World Bank (2018) and GCCA (2020).

A non-parametric Spearman correlation test was conducted to assess the degree of association between the two variables. The results, presented in Figure 6, show a strong and statistically significant positive correlation (Spearman's rho = 0.757; p-value < 0.05). This suggests that countries with higher logistics performance tend to have higher cold storage capacity per capita.

Based on this relationship, a simple linear regression model was fitted to predict cold storage capacity per capita as a function of LPI. By applying Paraguay's LPI score for 2018 (2.78) to the regression line, the model produced an estimated value of 0.082 m³ per urban resident. This result is displayed in figure 1, where Paraguay appears on the trend line.

¹⁸ https://lpi-worldbank-org.translate.google/2018?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc.

Figure 1
Correlation between per capita cold storage capacity and Logistics Performance Index (LPI)
(Cold storage capacity m³ per urban resident and LPI)



Source: Prepared by the authors.

The **estimated value of 0.082 per urban resident** was used to calculate Paraguay's total cold storage capacity, applying the following formula:

National cold storage capacity = Refrigerated Warehouse Capacity (m³ per urban resident) or 0.082 × Total urban population

According to the National Institute of Statistics (INE, 2022), **Paraguay's urban population in 2021 was 4,625,061**.

Applying the formula:

$$0.082 \times 4,625,061 = 379,255 \text{ m}^3$$

This estimate is reasonably close to the interview-based figure of 328,500 m³ presented earlier in table 4, suggesting that the data collected through interviews yielded a reliable result.

Moreover, having an estimated per capita value enabled the study to project cold storage capacity at the departmental level, including for Boqueron and Alto Paraguay, which are focal areas of this research. The same formula was applied:

Estimated departmental capacity = Refrigerated Warehouse Capacity (m³ per urban resident) or 0.082 × Urban population of each department

Table 6 presents the estimated cold storage capacity for all 17 departments of Paraguay and the capital district (Asuncion), based on 2021 urban population figures from INE (2022). The results show that Boqueron and Alto Paraguay have estimated refrigerated capacities of 2,216 m³ and 826 m³, respectively, well below the national departmental average of 20,570 m³.

Table 6
Cold storage capacity by department
(Meter³)

Department	Urban Population	Rural Population	Total Population	Refrigerated Warehouse Capacity (m ³)
Asuncion	521 101	0	521 101	42 730
Concepcion	99 064	159 589	258 653	8 123
San Pedro	82 783	357 552	440 335	6 788
Cordillera	107 814	207 431	315 245	8 841
Guair	93 886	136 227	230 112	7 699
Caaguazu	230 837	339 131	569 967	18 929
Caazapá	40 847	153 664	194 512	3 349
Itapua	276 292	348 804	625 096	22 656
Misiones	69 695	60 091	129 787	5 715
Paraguari	89 033	171 298	260 331	7 301
Alto Paraná	608 988	233 319	842 307	49 937
Central	1 954 343	289 449	2 243 792	160 256
Ñeembucu	60 637	30 137	90 774	4 972
Amambay	110 948	63 773	174 721	9 098
Canindeyu	88 573	150 813	239 386	7 263
Presidente Hayes	43 506	86 752	130 258	3 567
Boqueron	27 028	41 052	68 080	2 216
Alto Paraguay	10 071	8 510	18 581	826
Country Total	4 625 061	2 727 977	7 353 038	379 255

Source: Prepared by the authors.

While this indicator is based on a national-level regression and may underestimate or overestimate the capacity of individual departments, it nonetheless suggests that infrastructure in Boqueron and Alto Paraguay at the time of this study (2022) may be insufficient to meet the anticipated growth in demand following the implementation of the Bioceanic Corridor.

The general overview presented in the section provides the foundation for analyzing other key components of Paraguay's cold chain, starting with refrigerated transport capacity which is discussed next.

B. Availability and Characteristics of Refrigerated Transportation Fleets

The agency responsible for the registration of motor vehicles in Paraguay is the National Transport Authority (according to its Spanish acronym DINATRA),¹⁹ under the supervision of the Ministry of Public Works and Communications (MOPC). The refrigerated transport fleet in Paraguay can be divided into two categories: (i) providers of national freight services and (ii) providers of international freight service. According to a 2018 report by DINATRA, there were 291 transport companies authorized to operate internationally, owning a total of 568 trucks and 9,533 trailers. Of these, 547 vehicles had some form of refrigeration capacity, either as refrigerated box trucks or refrigerated semi-trailers. On the other hand, during the same year there were a total of 2,624 refrigerated vehicles used for domestic transportation.

Tables 7 and 8 present the number of refrigerated or reefer vehicles used for the national and international transport of temperature-sensitive goods.

¹⁹ <https://www.dinatran.gov.py/autoridades.html>.

Table 7
Fleet of domestic freight services

Refrigerated box truck		Refrigerated semi-trailer		Refrigerated trailer	
Type	Quantity	Type	Quantity	Type	Quantity
2 Axles	2 352	1 Axle	2	2 Axles	1
3 Axles	164	2 Axles	12	3 Axles	3
4 Axles	44	3 Axles	46		
Total	2 560	Total	60	Total	4

Source: Prepared by the authors based on data from DINATRA (2020).

Table 8
Fleet of international freight services

Refrigerated Box Truck		Refrigerated semi-trailer	
Type	Quantity	Type	Quantity
2 Axles	11	1 Axle	1
3 Axles	9	2 Axles	147
4 Axles	1	3 Axles	378
Total	21	Total	526

Source: Prepared by the authors based on data from DINATRA (2020).

Regarding the provision of transport for refrigerated and frozen products at the time of this study (2022), there are no indications that vehicle capacity limits the transport of refrigerated or frozen goods in Paraguay. According to interviewed stakeholders, national companies operate with adequate quality and safety standards, as they conduct international transport operations in compliance with the regulations of Brazil, Argentina, Chile, and Uruguay. Furthermore, there are enough refrigeration equipment suppliers to support any future expansion of land and river transport fleets.

Nuestra Señora del Asuncion (NSA) the largest logistics company in the country, operates two major logistics centers in the Metropolitan Area of Asuncion. Both centers are equipped with cold storage chambers of 8,000 m³ and a fleet of trucks for general cargo transport. Additionally, it owns a fleet of 60 refrigerated trucks with a capacity of 5 tons and another 60 trucks with a capacity of 25 tons for long-distance transportation. The trucks' cold chambers can operate at 2 to 8°C for chilled products and at -20°C for frozen goods. Frozen products, primarily frozen beef, are typically exported through inland waterways (IWW) in refrigerated containers (reefers). NSA is one of the main carriers of refrigerated meat to Chile and Brazil.

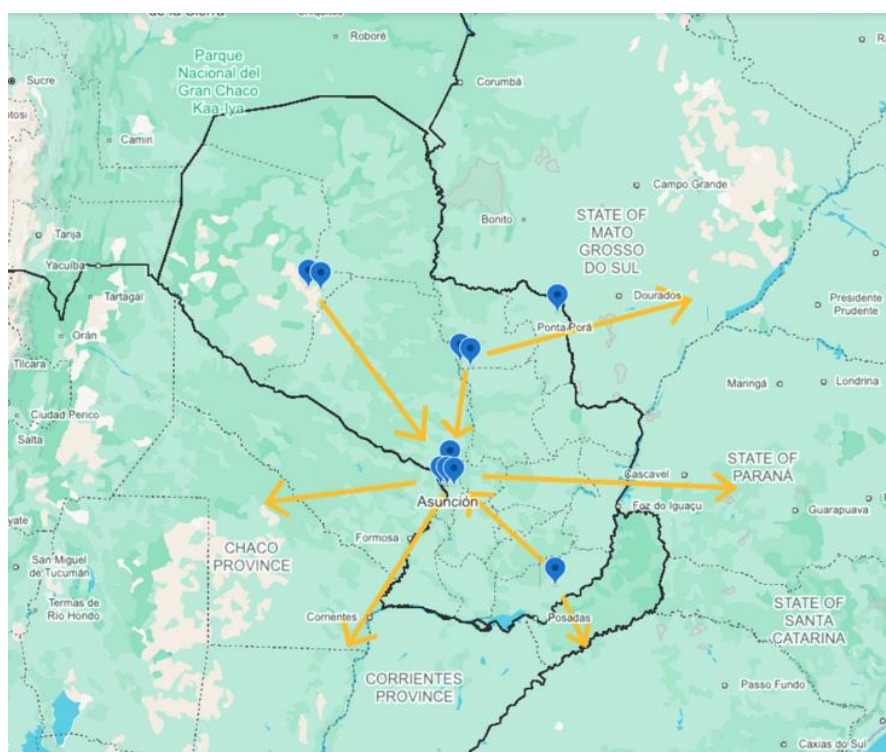
While transportation plays a central role in maintaining cold chains, the infrastructure at export and import hubs is also important. Therefore, the next section examines the storage capacity at ports and airports.

C. Cold Chain infrastructure at export and import hubs

1. Cold storage capacity at major export ports

The main river export ports are located in the city of Asunción and surrounding municipalities, particularly in the port zone of Villeta, about 40 km downstream from Asunción. Therefore, the main export corridors for frozen and refrigerated products are as follows:

Map 3
Main corridors for frozen and refrigerated products



Source: Prepared by the authors based on data provided by the private sector.

River export is the most important in terms of volume. Between 75% and 80% of the country's foreign trade is transported via the Paraguay–Paraná Waterway. The port complex of Villeta alone handles approximately one-third of the total volume of foreign trade in tons.

For instance, of the nearly 60.000 TEUs exported in 2020, 11% corresponded to reefer container exports of frozen meat. It is worth noting that none of the ports has cold storage infrastructure for temperature-sensitive products.

2. Cold storage capacity in paraguayan airports

In Paraguay, the two main airports with cargo handling terminals are located in the Central Department (Silvio Pettrossi International Airport) and in the Alto Paraná Department (Guaraní International Airport). At both airports, the volume of refrigerated cargo is relatively low. Small volumes of refrigerated meat for export, as well as imported medicines and flowers, are handled at these airports without the need for long-term on-site cold storage.

The cold storage infrastructure at both airports is described below:

- Silvio Pettirossi International Airport: Located in the capital city, Asuncion, it has a cold room of 60 m³ with three compartments at different temperatures: -5°C, -10°C, and -15°C.
- Guaraní International Airport: Located in Ciudad del Este, it has two cold rooms of 69 m³ each, with cooling capacity down to -5°C. At the time of this study in 2022, both were idle.

D. Infrastructure for ultra-low temperatures (-70°C)

Equipment designed to store products at extremely low temperatures (-70°C) has very limited use in industrial refrigeration for food storage, and even in the storage of pharmaceuticals and vaccines. It is uncommon to store food, agricultural inputs, pharmaceutical ingredients, medicines, or vaccines at such low temperatures. Typically, small-scale facilities (often already in use) are found in research laboratories at universities, pharmaceutical companies, and some hospitals and clinics. In Paraguay, no physical infrastructure was identified as capable of storing products at -70°C. Equipment designed to store products at -70°C is generally scarce across the region. For instance, within the sub-region comprising Argentina, Brazil, and Chile, ultra freezers are found only at the University Hospital of UFMS in Mato Grosso do Sul and at the Federal University of Goiás.

While the use of ultra-cold storage remains limited, it highlights the need for local technological capacity and equipment manufacturing, which is discussed next.

E. Local manufacturing of cold chain equipment

Broadly speaking, industrial cold chain equipment manufacturers are concentrated in the more developed regions of the country. In Paraguay, they are in the Central Department, mainly in Asuncion and surrounding areas. However, the location of these companies does not appear to be a limiting factor for the production, distribution, and installation of refrigeration equipment in other regions. Companies are able to offer their equipment and services throughout the national territory. It is also worth noting that the supply of industrial refrigeration equipment was not identified by logistics operators and experts interviewed as a bottleneck to the development of the cold chain in the regions analyzed.

Although Paraguay does not have an association exclusively for cold storage service providers or manufacturers, there is an association that brings together a group of affiliated companies offering cold storage, mechanical ventilation, and air conditioning services. This association is the Paraguayan Chamber of Air Conditioning, Refrigeration and Mechanical Ventilation (according to its Spanish acronym CAPAREV). The association includes the main companies that assemble refrigeration equipment and cold rooms in the country. According to interviews with sector stakeholders, Tecnimet is the market leader in Paraguay in this field. The company is responsible for installing cold rooms for major beef processing plants, dairy producers, pharmaceutical companies, supermarkets, and regional markets. Tecnimet manufactures its cold rooms using its own modular or dismantlable insulating panels. It also produces polystyrene and polyurethane panels in thicknesses ranging from 50 to 250 mm and operates continuous production machinery with the capacity to produce up to 1,500 m² of panels per day.

In addition to industrial applications, cold chain infrastructure also plays a crucial role in supporting public health efforts, particularly for vaccine storage and distribution which is the subject of the next section.

F. Characteristics of the cold chain for pharmaceuticals and immunobiologicals

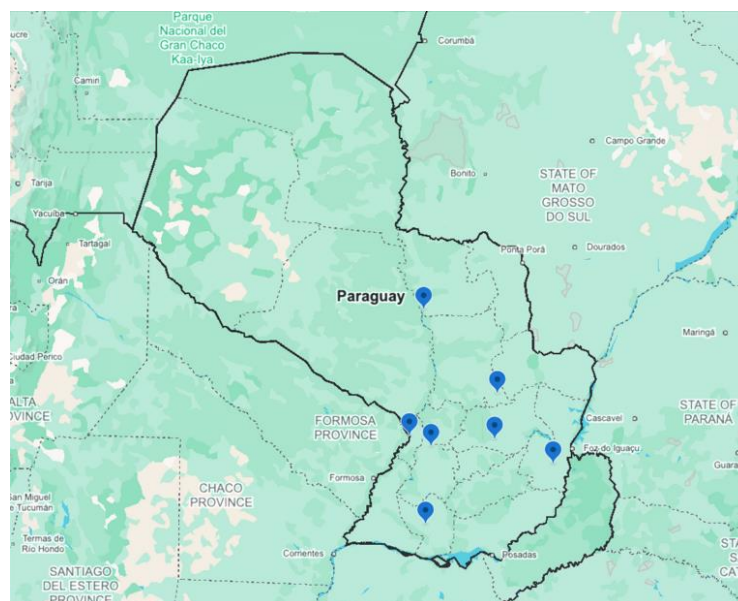
The lack of available data on the cold chain for pharmaceuticals and immunobiologicals in Paraguay, whether at the macro level (industry), meso level (value chain), or micro level (individual companies), makes it difficult to conduct a comprehensive or in-depth analysis of the country's installed capacity in this sector. This scarcity of information underscores the need for further investigation and systematization of the cold chain infrastructure and logistics that supports the national health system.

As of 2021, the national vaccination system in Paraguay was coordinated by the Ministry of Public Health and Social Welfare and is known as the Expanded Program on Immunization (*Programa Ampliado de Inmunizaciones* – PAI). According to Law 2,310/03, it is the responsibility of the Paraguayan State, through the PAI, to provide the population with appropriate protection against vaccine-preventable diseases. This includes the acquisition and free provision of vaccines included in the regular immunization schedule as well as those recommended by the Pan American Health Organization (PAHO) and the World Health Organization (WHO). To fulfill this mandate, the PAI is in charge of the following activities:

- Planning, programming, and budgeting;
- Institutional and intersectoral organization and coordination;
- Training;
- Acquisition and supply of vaccines, syringes, and related materials;
- Cold chain management and safe vaccination;
- Adequate Information systems;
- Epidemiological surveillance;
- Promotion and social communication;
- Supervision;
- Monitoring and evaluation;
- Research;
- Introduction of new vaccines.

Thus, the Ministry of Public Health and Social Welfare was and is responsible for all stages of the COVID-19 vaccination rollout. As of 2022, the PAI operated 12 cold storage centers equipped with refrigerated chambers. On average, these chambers have a capacity of 37.5 m³ and can be set to operate at temperatures ranging from 8°C to -20°C. Generally, around 1.5 million vaccine doses are stored per cold chamber, operating at approximately 60% of their full capacity, meaning that each cold chamber can hold up to 2.5 million doses. Four of these chambers are located in the capital city, while the remaining eight are distributed among regional centers throughout the country, as illustrated in Map 4. As of the time of this study (2022), the western Chaco region is served by the Regional Center in Concepcion, although a new facility is planned for the city of Mariscal Estigarribia, in the Paraguayan Chaco.

Map 4
Location of PAI storage and distribution centers



Source: MSPBS (2021).

By mid-November 2021, the PAI had acquired 7 million doses of COVID-19 vaccines to be administered across 1,600 vaccination sites nationwide. Its installed storage capacity is therefore considered sufficient to meet demand. In addition, the PAI has three refrigerated trucks with a capacity of 8 tons each, and according to 2021 data, transportation from the headquarters in Asunción to any regional center takes no more than 72 hours. As of November 23, 2021, a total of 5,838,507 doses of the COVID-19 vaccine had been administered, as detailed in table 9.

Table 9
Number of COVID-19 vaccine doses administered in Paraguay as of November 23, 2021

Vaccine	Doses			Total
	1 ^a	2 ^a	3 ^a	
AstraZeneca	717 153	463 304	36 141	1 216 598
Coronavac	20 882	18 971		39 853
Covaxin	101 495	93 215		194 170
Hayat Vax	124 864	119 958		244 822
Moderna	202 875	185 730	6	388 611
Pfizer	1 566 665	1 256 757	32 024	2 855 446
Sinopharm	10 785	2 007		12 792
Sputnik-V	492 814	392 861		885 675
Total	3 237 533	2 532 803	68 171	5 838 507

Source: Prepared by the authors based on data from MSPBS.

Although storage centers are located near the country's main urban areas, no significant issues were observed regarding storage or distribution capacity that could have compromised the national vaccination schedule. To prevent new waves of infection in the country, the government has been carrying out promotion and awareness campaigns highlighting the benefits of vaccination for both individuals and society as a whole.

III. Public policies for the cold chain in the bioceanic corridor

A. International public policy approaches to cold chain development

Cold storage and transportation activities are becoming increasingly important in national and regional supply chains. Efficient cold chains are essential to enable the manufacturing and distribution of temperature-sensitive products, especially agro-industrial goods, pharmaceuticals, and immunobiologicals. In the case of food products, activities related to the generation and use of cold allow for production diversification, the manufacturing of higher value-added products, a reduction in losses and waste, improvements in product quality, and access to markets beyond those limited by the perishable and seasonal nature of certain raw materials or final goods.

The importance of the cold chain, as the recent health crisis caused by the coronavirus has clearly demonstrated, also applies to the supply chains of pharmaceuticals and immunobiologicals. In fact, all efforts made by countries to vaccinate their populations require cold chains capable of efficiently storing and distributing vaccines. It is not enough for governments to purchase or produce vaccines—they must also ensure that vaccines reach the population. More importantly, they must reach the target population in acceptable quality conditions, thus providing the desired level of immunization.

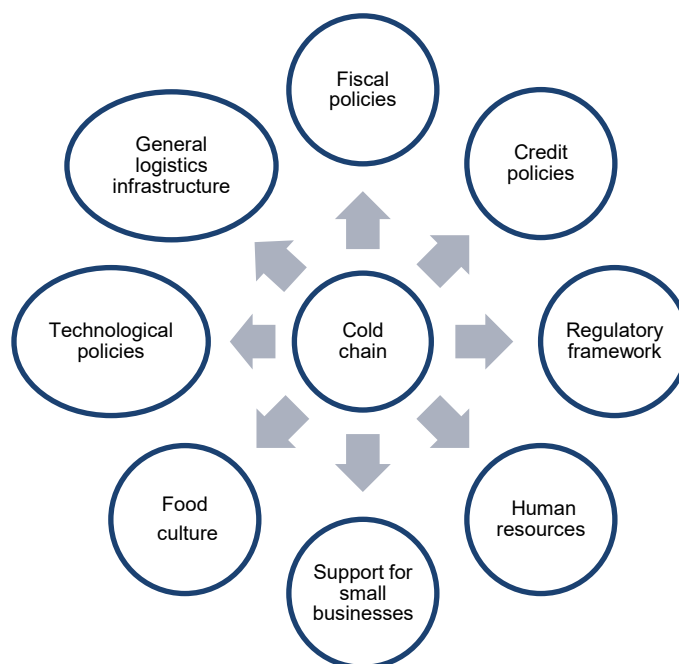
These observations paint a broader picture in which there is abundant evidence of the relationship between a country's level of economic and social development and the cold chain infrastructure available for its agro-industrial and pharmaceutical products. Today, a consumer in a wealthier country can walk to a local grocery store and purchase products that allow them to prepare a meal with safe, high-quality, and affordable ingredients sourced from different parts of the world. Behind this possibility, in many cases, lies an efficient, reliable, resilient, and cost-effective cold chain

The importance and cross-cutting nature of the cold chain as either a limiting or enabling factor for various key economic activities has led many countries to make significant efforts to develop it as deeply and rapidly as possible. These efforts are reflected in a multitude of public policies aimed at this

goal. The social and economic realities of each country largely determine the scope and reach of the policies adopted. Additionally, since the cold chain is closely tied to agro-industrial production chains, cultural factors related to food purchasing, preparation, storage, and consumption also play a crucial role in shaping public policies targeting these activities. China is an example of a country making substantial investments in its cold chain. Some provinces, such as Guangdong, were selected to host the first initiatives under what is known as the *Overall Plan for Developing Supply and Marketing Public Accessible Agricultural Cold Chain Logistics Infrastructure in Guangdong*. This plan includes major government subsidies (an expansionary fiscal policy) and access to credit lines to increase the region's available cold storage capacity, including its fleet of refrigerated vehicles.

Diagram 4 groups and summarizes the main forms and targets of public policies aimed at developing the cold chain across various countries. It is important to note that many countries do not have programs specifically focused on supporting the cold chain, but rather on logistics activities more broadly. Needless to say, the cold chain is a vital component of logistics systems as a whole.

Diagram 4
Policy options to strengthen the cold chain



Source: Translated from Batalha, M., et al. (in editing, ECLAC).

A significant portion of public sector efforts in lower-income countries is focused on creating transparent and feasible laws, regulations, and standards for the various actors and activities involved in the cold chain. Alongside the development of this legal framework, some countries also face the challenge of building state capacity to enforce these obligations effectively, including eliminating the collection of illegal fees. The cold chain is crucial not only for supplying domestic markets but also for enabling international trade in temperature-sensitive goods, such as certain food products. As a result, governments are consistently concerned with establishing legal and sanitary frameworks that regulate the cross-border movement of temperature-controlled goods in a responsible yet transparent and streamlined manner. Time and resource savings achieved through improved operational procedures by importers and exporters can quickly be lost due to bureaucratic trade-related hurdles at international borders.

Governments also frequently run public awareness and education campaigns to highlight the benefits of the cold chain for food safety and to teach consumers how to properly store and cook refrigerated or frozen foods. When consumers recognize the quality gains of products that are properly stored and transported, and reflect this in their purchasing decisions, it encourages both public and private actors to invest in effective and efficient cold chains. Consumers are key stakeholders in shaping commercial practices related to the purchase, preparation, storage, and consumption of food.

The development of general logistics infrastructure such as roads, ports, airports, railways, inland waterways, and energy generation and distribution systems, alongside the establishment and effective operation of cold chains, requires substantial capital investment and operating costs. In more developed countries, this infrastructure has been built over many years. Efficient logistics systems, of which cold chains are a part, depend on adequate transport networks, storage facilities, terminals, ports and airports, energy supply, and communication systems for traceability and operational control. Developing these conditions is both time- and resource-intensive. It is therefore worth emphasizing that cold chains operate within the broader logistical context of a country or region. That said, cold chain logistics activities have specific characteristics that make them more capital- and labor-intensive than those associated with so-called “dry goods,” which can be transported and stored without temperature control. These unique requirements have led many countries to adopt dedicated financing mechanisms for cold chain infrastructure, including trucks, equipment, and refrigerated storage facilities. Policies of special financing conditions for cold chain activities, alongside tax incentive policies, are promoted and implemented not only in developing nations but also in more advanced economies.

Tax incentives have been widely used to strengthen and expand cold chains. In some Southeast Asian countries, for example, tax exemptions are granted for investments in temperature-controlled trucks or refrigerated storage infrastructure. India, which has made significant efforts to improve its cold chain systems, has also adopted fiscal policies to support the sector. Recently, the country reduced a tax on refrigerated containers from 12.5% to 6%. In addition, it lowered import duties on cold storage equipment from 10% to 5% (YES-BANK, 2018). These are just a few examples of the initiatives undertaken by the country in this area.

Public policies aimed at the technological development of the cold chain have also been reported in the literature. In many of these cases, the focus is on increasing the energy efficiency of refrigeration and cooling equipment, in compliance with increasingly strict and important sustainability standards. Steps are being taken to develop technologies that are more compatible with the social, economic, climatic, and territorial characteristics of countries with limited financial and human resources. China, for example, has been investing millions of dollars in research to improve its cold chain. The National Natural Science Foundation of China (NSFC), the Ministry of Science and Technology, and the Ministry of Agriculture are the three main funders of this research. These studies focus on cold storage (machinery, equipment, and management) and post-harvest techniques involving refrigeration.

In addition to promoting products and process innovation for manufacturing cold chain equipment, policies can also support the development of management technologies for cold chain operations. Examples include inventory management technologies for frozen or refrigerated goods that consider the specific characteristics of the products and storage conditions. The development of smart, digital systems for managing temperature-controlled spaces intended for shared use, such as those operated by associations or cooperatives of small-scale farmers, can also be seen as initiatives worth encouraging.

Workforce training initiatives aimed at the various activities involved in planning, building, operating, and monitoring refrigeration equipment are also reported in the literature and have been the focus of real or planned actions in several countries, particularly in lower-income countries. In such cases, the key issue is developing the technical skills needed to design, build, operate, and manage increasingly complex refrigeration systems. For example, the pharmaceutical sector in China suffers

from a shortage of professionals trained in the specific requirements of the sector's cold chain. In India, workforce training for cold chain operations is also a concern. The National Skill Development Corporation (NSDC), a privately controlled organization with 49% government participation, offers several courses specifically tailored to workers in the cold chain.

Notably, a set of public policies aimed at encouraging the use of the cold chain by small entrepreneurs, especially those working in agri-food value chains. These policies may target various macro-segments within the agri-food sector. For instance, small-scale producers of fruits, vegetables, and greens could gain significant and undeniable advantages in marketing their products if they had access to cold storage and distribution infrastructure. The same applies to small dairy producers. Many small-scale food processing businesses, whether individually owned or cooperatively managed, rely on refrigeration infrastructure to produce and market higher-quality products and to access more competitive and profitable markets. Finally, at the downstream end of the agri-food chain, a substantial portion of food distribution carried out by small businesses likewise relies on refrigerated facilities for storage and product display.

B. Main public policies for the cold chain in Paraguay

No credit lines specifically for the installation of cold chains (whether for storage or transportation) were identified in public or private banking. As of the time of this study (2022), the needs of this sector are met through general industrial financing lines available to the industrial and service sectors. The Paraguayan government has sought to complement the private financial sector to reach all areas of the economy by using a range of mechanisms, namely: the Livestock Fund (*Fondo Ganadero*),²⁰ the Development Finance Agency (*Agencia Financiera de Desarrollo* – according to its Spanish Acronym AFD),²¹ and the Agricultural Credit and Housing Institution (*Crédito Agrícola de Habilitación* – according to its Spanish Acronym CAH).²² The Livestock Fund is a state entity that finances livestock-related activities. Loans are accompanied by free technical assistance, provided through field visits by specialists in veterinary medicine or agricultural engineering, who guide producers in achieving maximum production efficiency with the financed resources.

The Development Finance Agency is a second-tier bank that offers loans through first-tier entities of the national financial system, known as Intermediary Financial Institutions. The agency defines credit lines for specific sectors. These funds may be used exclusively for:

- Rural development projects;
- Loans to micro, small, and medium-sized enterprises (MSMEs);
- Creation and development of businesses, with a focus on small, and medium-sized enterprises;
- Export of goods and services and import of medium- and long-term capital goods, especially for MSMEs;
- Tourism development projects;
- Basic infrastructure investment projects carried out by the private sector or through alliances with the private sector;

²⁰ https://www.mef.gov.py/sites/default/files/2025-06/27-04-fondo-ganadero_1.pdf.

²¹ <https://www.afd.gov.py/productos>.

²² <https://www.cah.gov.py/productos>.

- Housing and urban development programs, and other actions aimed at reducing the housing deficit.

The Development Finance Agency financial products include:

- PRODESI - Loans for real estate development companies;
- PROPYMES - Financing for small and medium-sized enterprises;
- PROREGADIO - Financing for livestock and silvopastoral investment projects;
- PROCRECER - Financing for general investment projects.

The Agricultural Credit and Housing products include:

- Instruments to finance productive projects and/or acquisition of equipment, adoption of technological innovations, and/or infrastructure;
- Financial products prioritized by the Ministry of Agriculture and Livestock;
- Credit instruments for micro-entrepreneurs.

C. Food loss and waste: a key argument for cold chain investment

Malthusian theory guided public policies in several countries for decades. Among its various propositions, the theory advocated for population control as a way to ensure food access, given that population growth rates were higher than food production rates. The theoretical postulates of Thomas Malthus were gradually rejected, especially because he completely overlooked the scientific and technological advances that would emerge following the Second Industrial Revolution. In more recent times, global food production capacity has no longer been a primary concern.²³ One of the main challenges faced by modern society is the reduction of food loss and waste along agri-food supply chains.

According to data presented in the most recent report published by the Food and Agriculture Organization of the United Nations (FAO, 2011), about 14% of all food produced globally is lost or wasted before reaching the distribution stage of the supply chain. When the final consumer is included in the analysis, FAO (2015) estimates that the amount lost or wasted could reach almost one-third of all food produced annually. This corresponds to 1.3 billion tons of food across a wide range of categories. It is estimated that this amount of food would be enough to feed 2 billion people every year.

The disposal of food fit for consumption is commonly referred to in the literature as either food loss or food waste. While the terms are sometimes used interchangeably, most specialists distinguish between them depending on the stage of the agri-food chain where the food is lost or discarded. According to Verghese et al. (2015), food loss refers to any unintentional reduction in the quality or quantity of food available for consumption occurring in the earlier stages of the supply chain, namely: production, handling, post-harvest, and processing. Losses in an agri-food system result from a mix of endogenous factors (such as supply chain management inefficiencies) and exogenous factors (such as climatic conditions).

A considerable portion of discarded food is referred to as food waste. In the agri-food context, waste refers to the (voluntary or involuntary) disposal of food that is fit for consumption, but has either spoiled or exceeded its expiration date. In such cases, waste may occur at the distribution or final consumption stages. Per capita food waste in developed countries is significantly higher than in

²³ The analysis conducted is based on aggregated data. However, it is important to note that food insecurity remains a significant issue in many countries around the world, particularly in underdeveloped economies.

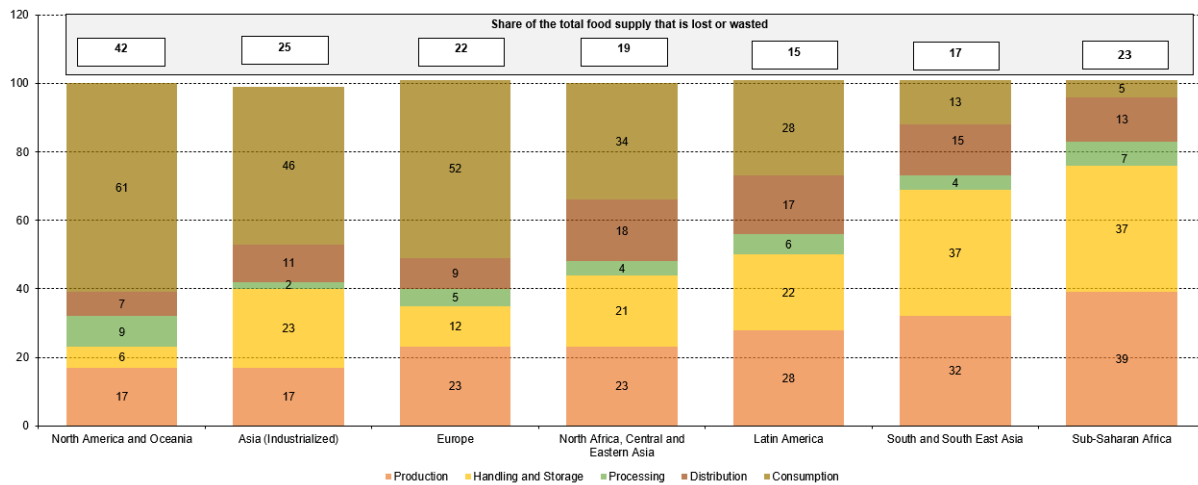
underdeveloped or developing countries. Broadly speaking, food waste results from a combination of social, cultural, institutional, and economic factors. Although it is theoretically possible to envision a world without waste, achieving this in practice may be considered utopian.

Food loss or waste can also be classified as either quantitative or qualitative (FAO, 2011). Quantitative food loss or waste refers to the reduction in the volume of food intended for human consumption that occurs along the supply chain. Alternatively, qualitative food loss or waste refers to the deterioration of the food's physical and chemical properties. The loss of food quality reduces its nutritional value and can make it unsafe for human consumption. Quantitative food losses or waste, on the other hand, reduce supply and can lead to food safety problems. In the end, both result in economic losses for society as a whole.

The reduction of food loss and waste must be regarded as a global imperative, as it brings social, environmental, and economic benefits. When analyzed systemically, it becomes clear that loss and waste are not limited to the excessive disposal of food but also involve the inefficient use of resources for production, processing, transportation, storage, and consumption (PONIS *et al.*, 2017). FAO (2015) estimates that avoidable and unavoidable food waste causes approximately USD 1 trillion in economic losses annually worldwide. In addition, an immeasurable number of resources such as water, land and labor is also wasted, leading to a range of negative social and environmental consequences that are difficult to reverse.

Most food loss and waste occur in developed countries. As shown in figure 2, astonishingly, North America and Oceania together lose or waste around 42% of the available calories in food produced in the region, followed by Industrialized Asia (25%), Sub-Saharan Africa (23%), Europe (22%), North Africa, Western and Central Asia (19%), South and Southeast Asia (17%), and finally Latin America (15%).

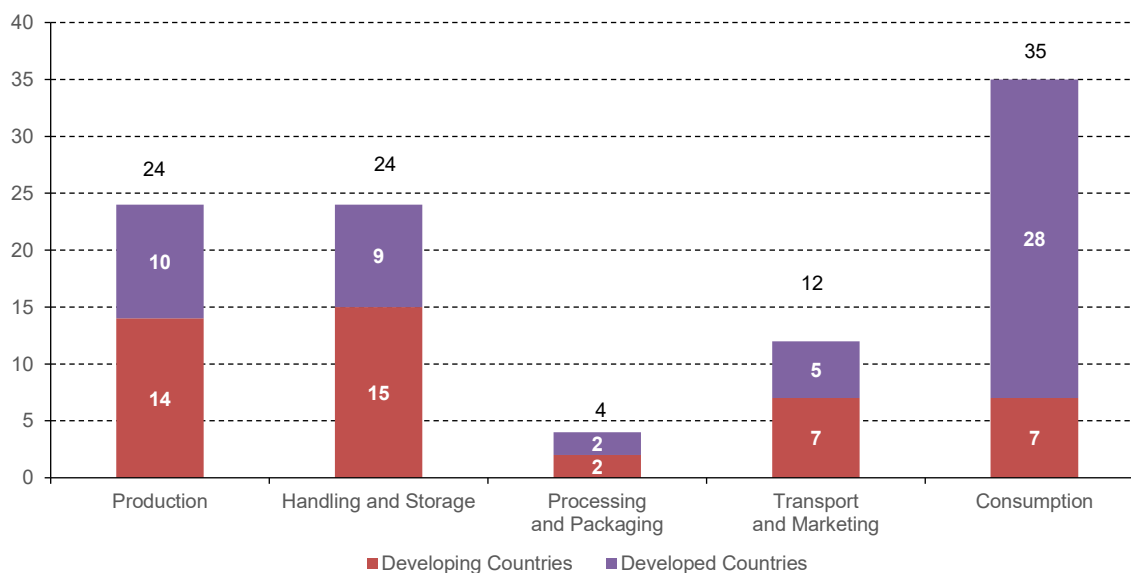
Figure 2
Food calories lost or wasted along the supply chain, by geographic region
(Percentages)



Source: FAO (2011).

Figure 3 exhibits an important contrast across countries at different income levels. Developing countries experience a larger share of food loss, while higher income countries record greater of food losses. This highlights the need to improve logistics infrastructure, including the cold chain, in developing countries, as well as to raise consumer awareness in developed countries to reduce food waste.

Figure 3
Share of total food lost or wasted across the value chain
(Percentages)



Source: FAO (2011).

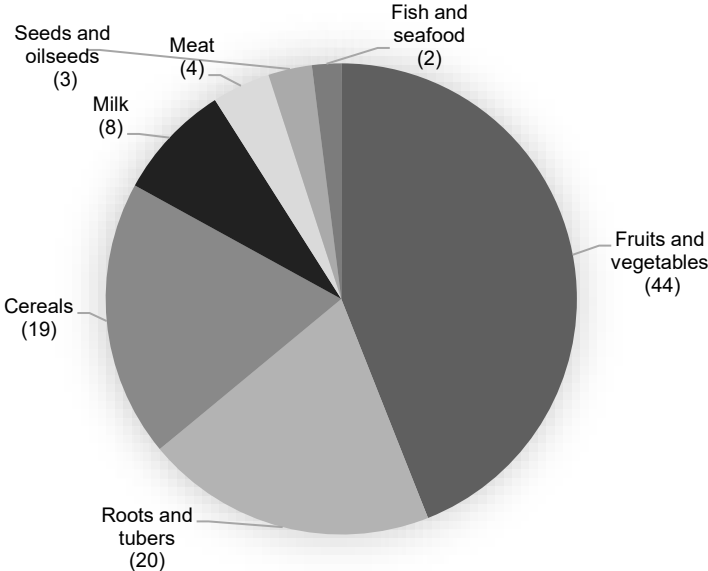
Food loss and waste, cold chain logistics, and food safety are closely linked, primarily due to the perishable nature of many food items. When not stored at the right temperatures, foods such as fruits, vegetables, dairy, and meat products quickly lose shelf life. The cold chain not only helps reduce food loss by maintaining proper temperature conditions but also preserves the physical and chemical properties of food, mitigating potential health and food safety risks that could harm individual or public health.

It is extremely difficult to estimate the losses along the supply chain that are caused exclusively by the absence or inefficiency of the cold chain. Even scientific articles that address the topics of "food waste and loss" and "cold chain" together often overlook the specific issue of food waste generated due to improper temperature management. In fact, making such an estimate would require the development of a methodological framework so complex that it would render any empirical exercise nearly unfeasible in a short period of time. Therefore, given the limitations of this study, any attempt to estimate losses resulting from improper temperature conditions would lack the theoretical foundation necessary to support the results.

The products most affected by logistical inefficiencies are those with shorter shelf lives, as shown in figure 4.

In the case of Paraguay, FAO estimates highlight that the amount of food wasted could meet the nutritional needs of at least 269,000 people for an entire year (FONPLATA, 2018). This underscores the urgency of implementing robust cold chain policies that minimize post-harvest losses. These issues are especially relevant in landlocked and tropical countries such as Paraguay, where high temperatures and long distances from ports amplify the risk of spoilage. In 2025, a collaborative initiative between the National Statistics Institute and the FAO was launched to improve national food waste measurement and monitoring, which indicates a shift toward evidence-based policymaking in this area (INE, 2025).

Figure 4
Global food loss or waste by product category (100% = 1,3 billion tons)
(Percentages)



Source: FAO (2011).

The following sections explore recommendations and proposals that can strengthen the cold chain at the national and regional level.

IV. Conclusions, challenges and proposals

A. Boqueron and Alto Paraguay

The cold chain is not perceived as a constraint to the production of refrigerated and frozen products at the time of this study (2022). Similarly, it does not appear to pose an obstacle to a potential increase in production or to the development of new products in any region of the country. Paraguay has a solid electrical grid, and the establishment of companies in new production areas has been facilitated by grid expansions. Additionally, the National Electricity Administration (*Administración Nacional de Electricidad* – ANDE) offers differentiated rates that benefit the industrial sector, with prices as low as USD 0.04/KWh. From a technological standpoint, there is an adequate number of cold chain suppliers, and no supply issues have been identified regarding equipment or inputs for the industrial sector. Most suppliers are foreign companies, primarily from Argentina and Brazil, with extensive experience in refrigeration systems.

The Paraguayan Ministry of Public Health and Social Welfare, through its Expanded Immunization Program (*Programa Ampliado de Inmunizaciones* – PAI), has sufficient capacity to store and distribute all vaccines included in the national immunization schedule, including the COVID-19 vaccines. The Ministry of Health management of the logistics chain is robust and reliable, and the risk of system failure is relatively low. The main challenge faced by Paraguay's COVID-19 vaccination plan in 2021-2020 was related to the supply of doses from international providers. Therefore, it is necessary to create alternatives to ensure secure vaccine supply across countries and regions of the continent.

No credit lines specifically for the cold chain were identified in public or private banking system. In general, industries have access to adequate financing for the installation, repair, or expansion of cold storage units or refrigeration equipment. Additionally, there are tax incentives for industrial investments. However, financing remains a challenge for small and medium-sized producers, especially in the strawberry, tomato, banana, and pineapple value chains.

Although there is a significant level of cooperativism, the issue may lie in the guarantees for credit access. It is recommended that the Ministry of Agriculture and Livestock (MAG), together with the

Ministry of Industry and Commerce (MIC), design specific credit lines for refrigeration infrastructure, especially for small and medium-sized producers. This financing could be offered through the National Development Bank.

It was also observed that there is little culture of using refrigeration for many products that require temperature preservation and control. Post-harvest losses are estimated to reach up to 30%, especially for temperature-sensitive products. It is advisable to conduct awareness campaigns for producers and develop financial tools to facilitate the acquisition of refrigeration facilities. If the 30,000 tons of bananas exported in 2022 were handled using refrigerated chambers, about 30,000 m³ of storage would be needed to process this production. Table 10 details the main problems, proposals, and strategies for improving the cold chain in Paraguayan territories.

Table 10
Identified challenges, proposed solutions and strategies, and key stakeholders

Identified Challenges	Proposal	Strategies	Key Stakeholders
Lack of cold chain development for small businesses	Establish cooling spaces for small farmers through farmer cooperatives	Encourage the installation of refrigerated chambers in up to three regions of the country through financing and technical assistance for production cooperatives	MAG, MIC
Credit lines for agribusiness that do not target cold chain development	Develop credit lines for the cold chain	Identify needs and development conditions for the cold chain	MAG, MIC, BNF, AFD,
Lack of statistics or records providing a complete and organized picture of the cold chain in the country	Centralize existing records into a unified database for analysis. Designate INTN as the institution responsible for certification and licensing of refrigerated chambers	Establish a unified registry led by INTN	MAG, MIC, INTN
Low availability of training courses on the cold chain	Create specialized training courses for the cold chain	Conduct feasibility studies to create human resource training courses focused on the cold chain	MAG, MIC

Source: Prepared by the authors.

B. Considerations on the bioceanic corridor at the regional level

The proposals derived from this document are not limited solely to the action lines presented in Table 10. The broader context of this work is the development of the bioceanic corridor as a tool for economic, social, and cultural integration. Therefore, several factors that may influence the efficiency of this corridor have also been identified. These factors are presented in Table 11. A detailed discussion of these factors lies beyond the scope of this report. However, even a brief presentation is valuable to raise awareness among the involved stakeholders. Future research should aim to evaluate the most effective strategies for enhancing each of the key drivers of efficiency.

Table 11
Factors that may drive efficiency across the bioceanic corridor

Efficiency drivers	Proposal	Strategies	Key stakeholders
Telecommunications infrastructure along the Bioceanic Corridor	Implement adequate telecommunications infrastructure along the Bioceanic Corridor	Public and private investments	Governments, Regulatory agencies, Telecommunications companies
Customs integration among countries	Develop platforms for integrating customs processes	Harmonize regulatory frameworks and develop common bureaucratic processes	Governments, Ministries
Harmonization of regulations and technical standards for pharmaceuticals and food among Bioceanic Corridor countries	Conduct studies to standardize regulations and technical standards for pharmaceuticals and food	Establish supranational agreements in the area	Governments, Ministries
Integrated planning of logistical activities in the Bioceanic Corridor	Conduct integrated planning studies for logistical activities in the Bioceanic Corridor	Create a supranational planning committee for logistical activities in the corridor	Governments, Companies, Universities, NGOs
Cold chain-adapted logistics hubs at the Brazil-Paraguay border	Create back logistics hubs adapted to the cold chain at the borders of Bioceanic Corridor countries	Conduct feasibility studies and potential implementation of Logistics Hubs at the Brazil-Paraguay border	Governments, Private companies (logistics operators), Financial institutions

Source: Adapted and translated from Batalha, M., et al. (in editing, ECLAC).

Finally, a set of future studies was also identified that would complement the findings of this work and contribute to regional, and potentially national, socioeconomic development. These include studies to better assess the specificities and challenges of cold storage for inputs and products on rural properties, as well as detailed analyses of cold storage capacity within the agro-food and vaccine/pharmaceutical distribution sectors, both wholesale and retail. They also involve developing econometric analyses to estimate the future growth of cold storage and its implications for investment needs, electricity consumption, and job creation. Another key area of work involves evaluating the financing conditions for cold chain development, considering the main lenders, interest rates, terms, guarantees, key borrowers, financial volume trends, and primary uses of funds in order to assess how these factors influence the sector's development. Further efforts should include new diagnostics of cold chain operations in other regions of the country, in-depth analyses of the facilities and operational characteristics of airport and cargo terminals in order to identify storage infrastructure gaps. In addition, cold storage capacity assessments at the region's main ports are crucial to detect comparable deficiencies.

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