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The role of Physical Internet on enabling sustainable multimodal logistics infrastructure: the case of sugar logistics in southeastern Brazil

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THE ROLE OF PHYSICAL INTERNET ON ENABLING A SUSTAINAIBLE MULTIMODAL LOGISTICS INFRASTRUCTURE: THE CASE OF SUGAR LOGISTICS IN SOUTHEASTERN BRAZIL

Thesis presented to the Department of Business Administration Graduation Program of School of Economics, Business Administration and Accounting at Ribeirão Preto of University of São Paulo, for obtaining doctoral degree in Sciences. (Corrected Version. The original is available in Office of the Graduate Registrar of FEA-RP/USP).

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ABSTRACT

DEFINA, D. A. **The Role of Physical Internet on enabling a Sustainable Multimodal Logistics Infrastructure**: The Case of Sugar Logistics in Southeastern Brazil. 2018. 157 f. Thesis (Doctoral degree in Sciences)-School of Economics, Business Administration and Accounting at Ribeirão Preto, USP, Ribeirão Preto, 2018.

Brazilian logistics is the aim of this thesis, which includes discussion concerning main problems and difficulties faced by the Brazilian corporations with respect to transportation infrastrucuture, handling, storage, production and delivery for internal and external marketing. Verifying how Brazil can improve its logistics industry in order to achieve innovative forms of sustainability is the purpose of this discussion. On pursuing this path, historical data was obtained with respect to Brazilian logistics industry, which can partly explain the inefficiency of priority road as a single modal mean and pollution effects. An extensive literature review about sustainability, logistics, Physical Internet and transportation systems is carried out. Concepts from Physical Internet are studied in order to verify how logistics could be improved, national and international commercial relationships and social welfare as well. Through this research, it was possible to obtain evidences that an important Southeast located sugar cane plant uses a small percentage of its own transportation and private hired to distribute its final product. Road transportation covers internal market while road and overseas transportation is directed to external markets. Applying Physical Internet concepts like hyperconnected distribution network using Simulator Logistics Analytics 8, was determinant on verifying that is possible to make use of systemic distribution network, which complies with diverse sorts of multimodality demand and, at the same time, providing sustainability indicators. In Brazil's Southeast it would be possible if governmental and private actors could be interested on investing, maybe on a partnership basis, in a viability project.

Key-words: Sustainability. Logistics. Multi-Modal. Physical Internet. Supply chain.

RESUMO

DEFINA, D. A. O **papel da Physical Internet na viabilização de uma infraestrutura logística multimodal sustentável: o caso da logística de açúcar no sudeste do Brasil**. 2018. 157 f. Tese (Grau de doutorado em Ciências)-Faculdade de Economia, Administração e Contabilidade de Ribeirão Preto, USP, Ribeirão Preto, 2018.

Esta tese compreende um estudo sobre logística brasileira. Os principais problemas e dificuldades que as empresas brasileiras enfrentam em relação à infraestrutura do transporte, manuseio, armazenagem, produção e entrega para comercializar interna e externamente. A proposta foi verificar como o Brasil pode melhorar o sistema logístico em termos de sustentabilidade e de uma forma inovadora. Para isso, a pesquisa levantou os dados históricos em relação à logística no Brasil, o que explicou em parte, os problemas de ineficiência da unimodalidade rodoviária prioritária, além dos efeitos poluidores. Foi realizada uma revisão bibliográfica sobre sustentabilidade, logística, Physical Internet e sistemas de transporte. Os conceitos da Physical Internet foram estudados para verificar como poderim melhorar sua logística, as relações comerciais nacionais e internacionais, bem como o melhor bem-estar social em uma delas. Do ponto de vista metodológico, esta pesquisa baseou-se em um estudo de caso utilizando um software de simulação logística, desenvolvido para esse fim. Por meio da pesquisa de campo, foi observado que uma importante usina de cana-de-açúcar na região Sudeste utiliza uma pequena porcentagem de seu próprio transporte para a distribuição do produto acabado e de empresas de transporte contratadas especificamente para distribuir seu produto na maioria das localidades. O transporte é feito por modo rodoviário, apenas para comercio exterior é que se utiliza rodoviário e marítimo. Aplicando os conceitos de Internet Física, a rede de distribuição hiperconectada, utilizando o Simulador Logístico Anylogic 8, foi possível verificar que é possível utilizar uma rede de distribuição sistêmica, atendendo a diversos tipos de demanda com multimodalidade e, ao mesmo tempo, ter indicadores de sustentabilidade. No Sudeste do Brasil, seria possível que atores governamentais e privados se interessassem e investissem, talvez em parceria, em um projeto de viabilidade.

Palavras-chave: Sustentabilidade. Logística. Multi-Modal. Physical Internet. Cadeia de Suprimentos

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1 INTRODUCTION

Globalization and outsourcing have brought alternatives for companies to create a vast network of suppliers, distributors and logistics and transport providers in order to seek efficiency in supply chain. It is inevitable that the issue of sustainability has emerged from these activities. The interaction between sustainability and supply chain is important as both have a "license" to operate and thus make the companies more competitive. At a broad conceptual level, the term "sustainability" is defined as being a condition in which the needs of the present are met without compromising the capacities of future generations to accomplish their own needs (LEE; WU, 2014).

Sustainability at the company level has multi-faceted meanings and implications, including social corporate responsibility, business ethics and environmental management, which were recently developed with focus on aspects of environmental sustainability due to the increased sense of urgency worldwide. Obviously, there is much more activity and continuous development regarding sustainability. Therefore, it is worth for logistics professionals and supply-chain management researchers to consider the environmental impacts on the traditional beliefs and practices of their fields. However, it is not easy to apply sustainability to logistics and supply-chain management when companies try to reduce costs and make delivery faster without compromising the performance in terms of sustainability and quality (LEE; SAEN, 2012).

Logistics can be defined as the planning and operation of physical, information and management systems needed for inputs and products to overcome special and temporal conditionings economically. This aspect is crucial to understand the concepts involved in the modern approach of logistics problems as these go far beyond the limits observed decades ago in terms of importance and complexity.

The importance of logistics in the current economic conjuncture and technological development has been increasingly enhanced. On the one hand, high financial cost, greater aggregate production value and wide range of products require stock and delivery to be dealt rationally. On the other hand, high price of fuels and the increasing inter-modality perspectives have led to the search for more intelligent solutions in the area of transport.

Nowadays, we live in a environment of great communication among countries. The advent of Internet brought more flexibility in the relationships, mainly regarding the free trade among countries. This shift in trade relations has increased the flow of manufactured and delivered products to their final destination. The means of distribution began to increase and along them, services of packaging, storage, conservation, transport and delivery. The rapid growth has imposed an accelerated pace to the delivery of traded products, and little can be done on how to optimize this process.

Upon the increasing demand, the scholars on logistics could not do much to improve the flow of distribution. Currently, one can realize that the logistics system is inefficient, expensive and non-sustainable. There is also a pressure from the society to improve the means of production aiming at less polluting and more sustainable practices.

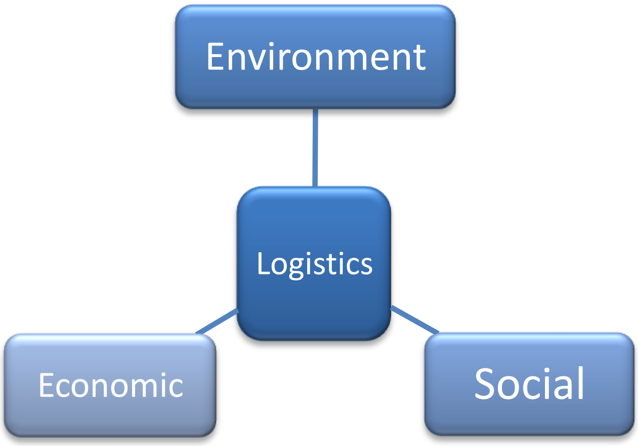
The economy of the Brazilian Southeast is very strong and diversified, being considered the largest in the country, which has gained this recognition since the time coffee and milk economic cycles flourished and enabled a vigorous Brazilian capitalization trend. Nowadays, one of the most important commodity produced in this part of the country is sugarcane. The production of sugarcane began in the colonial time, and today it is one of the main agricultural crops of the Brazilian economy. Brazil is responsible for more than half of all sugar sold in the world, and is also the largest exporter of ethanol.

Different types of sugar are manufactured and this productive output is transported to the Port of Santos mainly through highways using trucks. Cosan, one of the largest business groups in Brazil, which operates in strategic businesses for the country, such as energy and infrastructure terminal has the maximum capacity to receive 650 trucks per day. Arriving at the terminal, the product is dumped in hoppers (funnels inverted under the soil) and falls into a system of mats to be deposited in warehouses with a maximum capacity of 150 thousand tons of sugar. For boarding on ships, a new system of mats and shiploaders is triggered and can move 40,000 tons of sugar daily. During the off-season, the terminal is used for the export of soybeans. In 2009 alone Brazil produced about 670 million tons of sugarcane, with a production value of almost US$ 7.7 billion. The average productivity of the sugarcane was in the same period of about 80 tons per hectare (SILVESTRE, 2015).

After sugar is produced, it is stored for later transportation. When the plant does not have sufficient armaments to support the entire product, it can rent additional space. Transportation of sugar to the domestic market is mainly made by highways so is the majority of the amount of the production that are exported thorough ports, where it is also stored. Such a logistic can lasts for months, incurring in large financial costs to board and ship the production to other countries. Being transported by highways and using fossil fuel, we conclude that it is not a sustainable way of transporting one of the most relevant crop in Southeast Brazil, where the State of São Paulo is responsible for 60% of Brazilian GDP. The costs involving on using port facilities is divided into "OGMOS", that is, a obligation of contracting only unionized workers and controlled by Ports, warehouses and other taxes (EMBRAPA, 2018).

So, green logistics concepts and sustainable development have emerged. Typically, logistics is viewed as a set of practices aiming to minimize costs and maximize profits. These terms are basically used in business areas and financial reports, with the so-called “green logistics” referring to all practices and strategies for reducing both environmental impact and product delivery energy, which mainly involves material packaging, management of residues and transport (SILVESTRE, 2015).

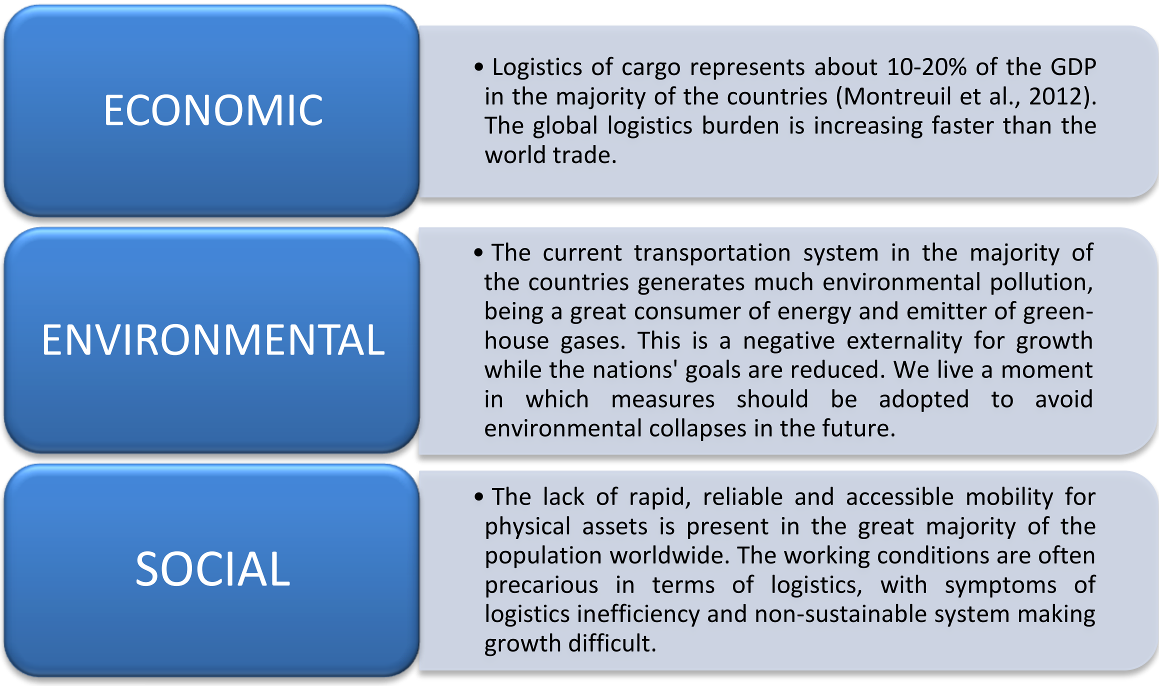
Figure 1 - Logistics as a sustainable development element



Source: elaborated by the author.

Current logistics tends to be inefficient and non-sustainable regarding three fundamental aspects, resulting in the problems shown in Figure 2.

Figure 2 - Aspects of Logistics Inefficiency



Source: Montreuil (2011).

Among the main problems in the current logistics system, the following are raised:

- Transport carrier fill rates are low, with a lot of air and packaging being moved;
- Empty cargo trips are the rule and not the exception;
- Products are usually stored where there is necessity, but many times they are not available where they are needed;
- Production and storage facilities are poorly used;
- Many products are not sold or ever been used (waste);
- Products do not reach people who actually need them;
- Many products move around the world unnecessarily;
- Rapid and reliable inter-modal transport is not a reality yet;
- Often, supplying products in cities becomes a problem;

- Supply networks are not safe in terms of maintenance or robbery;
- Intelligent automation and technologies are difficult to justify.

Logistics has been facing a period of changes in terms of corporate practices in Brazil as well as of efficiency, quality and availability of infrastructure for transporting and communicating. In fact, those are all essential elements for the existence of a modern logistics.

International trade has grown and developed rapidly since the advent of globalization and digital insertion appeared. Import flows has generated a significant demand for international logistics – an area for which the country had never been well prepared in terms of infrastructure and corporate practices form the management point of view. Additionally, the end of the high inflation induced one of the most important changes in the corporate logistics, that is, a growing co-operative movement involving clients and suppliers based on the supply chain management. However, this whole effort by corporations is faced by huge deficiencies still seen in today's infra-structure of transport and communication. There are great opportunities to increase productivity and improve the quality of services. However, facing costs equivalent to 10% of the GDP, Brazilian transport system is highly dependent on highways, the second most expensive, back only air alternative. Inasmuch road transport accounts for 58% of the cargo transported (in tons *per* km) in Brazil, though this proportions amounts to 30%, 28% and 19% in Australia, USA and China, respectively. Taking the North-American patterns into account, where road transport costs are three times higher than railway, six times higher than pipeline and nine times higher than waterway ones, then costs could be potentially reduced in Brazil if the road transportation followed the international patterns by allowing cheaper transport modes to be implemented (SILVESTRE, 2015).

Low productivity is reflected in higher costs for the railway users in Brazil, with an average fare of US$ 23.0 *per* 1,000 tons/km compared to only US$ 16.25 in the USA, despite the huge differences in the quality of services (i.e. represented by high availability, fast delivery and deadline reliability) observed in the latter country. Pipeline network is extremely modest in Brazil, 50 times smaller than USA one, thus resulting in a price three times higher, approximately. Recent privatization of ports and railways and a new legislation on pipelines created great opportunities to increase productivity have reduced costs and improved services. Still incipient, the results of these changes have already been observed. Concerning the first ever privatized railway, the average trip time on the main route was reduced from 11 to six days; the level of usage of locomotives raised from 37% to 65% and the number of employees was reduced from 1,800 to 900 (SILVESTRE, 2015).

As a result, the railway fares were reduced, on average, by 15% and 20%. As for the ports, it was also observed that fares were reduced and services improved substantially. Furthermore, the increased competition for other transporting modes and the pressure for better quality services on shippers have caused road transportation companies to undergo a process of modernization, which implies the adoption of sophisticated information technologies such as routing systems, satellite tracking systems and electronic data interchange (EDI). A great effort towards extending the services already provided has been made in order to shift the transporter's view to a logistics operator's view. Along this way, the road transportation companies are preparing a new competitive environment, which is emerging in the sector of transport and logistics in Brazil. For these Brazilian companies, despite the many changes, there is still much room to conquer a market share. It remains to be seen whether they will go on working to improve their productivity and quality of services, which will eventually lead to a greater competitiveness (SILVESTRE, 2015).

A possible answer for all these problems is called Physical Internet (PI). A model created by Professor Benoit Montreuil from Georgia Institute of Technology, Atlanta, United States. PI is an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. Also, in a simpler statement, Physical Internet is the application of Internet principles to logistics. It is a global, open, interconnected network, using a set of collaborative protocols and standardized smart interfaces, in order to send and receive physical goods contained in standard modules – instead of packets of information, as does the Internet (BALLOT et al., 2016).

Container revolution, which disrupted international trade in the last few decades, offered us a first glimpse, with the emergence of a global standard shared by all players that allowed high consolidation: container lines are now shared by many customers. But the maritime is only one segment of supply chains. Inter-modality remains very limited: in Europe, for example, the efficiency of maritime containers is significantly lower than that of semitrailers. Lastly, the dimensions of a virtually universal tool such as the pallet are not adapted to containers. In short, this is a first step, but there is still a long way to go (BALLOT et al., 2016).

Next steps are more complicated and are being set as we speak. For a better understanding of these issues, the simplest is perhaps to expose the problems that make evolution necessary. These problems can be described in terms of economic efficiency or as environmental issues. But they boil down to this: trucks that travel on our highways, delivery trucks that circulate in our cities, are on average half empty, if not *completely* empty. Even if it is unrealistic to run at 100% capacity at all times, significant progress can be made. And this progress will provide margins to all players in the chain by decreasing the environmental impact and energy consumption (BALLOT et al., 2016).

Actually, a lot of containers and packages filled with air around the world. Empty and/or unnecessary trips are far too many storage systems are often underutilized because they are scaled for the peak. Scattered in a multitude of competing systems, the logistics industry suffers from a huge deficit of efficiency. This type of organization has tangible effects on prices, urban congestion, traffic, pollution. That is a real scenario in many countries. (BALLOT et al., 2016).

Physical Internet offers a response to all these challenges by offering large-scale optimization, made possible by streamlining the system, standardizing tools (both hardware and software) and pooling of resources. The basic building block of this system, the equivalent of the package of information flowing through the Internet pipes, is the smart, standardized, modular container. These are currently being developed and we still need to imagine the networks that will deliver them (BALLOT et al., 2016).

Based on these and other relevant points, one can observe that physical products are often transported, handled, stored, produced, delivered and used across the world in a non-sustainable way. This is not very different from what happens in Brazil, which is a continental-sized country where a logistic map could be efficient, rapid and modern approach and whose transport infrastructure is essentially road-based, with most motorways being poorly distributed, poorly maintained and in precarious condition. Moreover, there is the emission of gases harmful to health and environment. Rail transport is not signifcant and transport via water has the potential for navigation, but both modes need more incentive for development of their logistics. As for exports, the ports are in extremely precarious conditions and are poorly used, with most of the services being concentrated in Santos.

The Brazilian Ministry of Transport has a national logistics plan, called PIL (Logistic National Plan) but which is still in the stage of implementation. There are studies on single cases such as the works by de Silva, Santos & Scherer (2013), Oliveira & Rodrigues (2011) and Santos (2012). However, there is a lack of studies aimed at actions for improving the system as a whole. A relatively few studies on sustainability strategies and actions adopted by logistics companies have been published (EVANGELISTA, 2014).

1.1 Research Matter

Considering the current logistics structure and its environmental implications, the inquiry question guiding this work was focused on the following: how can the concepts of Physical Internet improve the logistics of the sugar companies in the southeastern Brazilian region?

1.2 Objectives

The general objective of this study is to analyze the existing problematic issues of logistics of sugar companies of the Brazilian southeastern and how physical Internet concepts can improve the multi-modal logistics with focus on sustainability.

The specific objectives of this work are the following:

- To list the main problems related to logistics in Southeast region related to sugar transport: structural, environmental and social;
- To identify the main logistics difficulties factors which sugar companies have to commercialize their product to national and international trades;
- To identify the modalities used in the logistics of sugar companies;
- To check if sugar industries or their logistics operators use any sustainability indicator;
- To identify the criteria used for distribution and delivery of sugar at wholesalers in Southeast and South;
- To identify how is logistics today and to verify how Physical Internet changes the logistics in this region;
- Physical Internet contributions to sugarcane industry in Brazilian southeastern region.

1.3 Justification

In the past years, there has been a growing concern on the environmental effects of human activities on the planet. This explains why there is an increased attention on this issue by government agencies, academic literature and general public. The interested third-parties, including public agencies and society, are increasingly more aware of this issue as they have been pressuring the corporations for assuming the responsibility for any negative effect too, resulting from their business activities. The growing attention to more sustainable solutions includes logistics, which plays a very important role as transport systems are one of the main sources of pollution and resources use.

Along the past 50 years, logistics has evolved due to a combination of many factors, particularly, the technological innovations in the field of transports, trade agreements and abundance of natural resources (e.g. energy). In fact, logistics has become so effective that it allows operations to be distributed across the world. Some products can trek from one continent to another with low cost in terms of energy and work. However, the high dependence of productive systems on logistics, including their vulnerability, could change if the conditions of their development were improved. Increase in fuel prices or implementation of taxes on gas emission can raise the transport costs or even make sea or air transport mode unfeasible. This requires logistics structure to be revised.

Current logistics in the world is not sustainable at all, as well as in Brazil. The increased consumption of resources and high rates of green house gas emission contradict the objectives of sustainable development. In addition, the rapid growth of logistics due to business increase as result of easy global communication makes transport services inefficient. Robust data support the movement towards the need for changes in paradigms.

Due to its essential strategic nature, logistics has been object of study by many researchers, institutions and manufacturers across the world. There is evidence that logistics should be developed for sustainability in view of resource consumption, traffic jam, pollution and carbon gas emission.

In Brazil, some works mapping the national logistics network were identified, such as Kazan (2013) and Albano (2014), in addition to articles addressing environmental issues in logistics, such as Lee & Wu (2014) and Seroka-Stolka (2010). Based on the relevant points addressed by these studies, we have conducted an analysis of the problems resulting from inefficient logistics and how a physical network can improve the logistics in Brazil in order to boot the public interest in investments for this structure.

Simulations to predict a more efficient, rapid and sustainable distribution to the final consumer, based on the PI principles are made in this thesis. The main beneficiaries are the society that receives its product faster and with a decrease in unsustainable practices, besides the producers of sugar which may see their costs reduced with transport and storage.

1.4 Thesis Structure

This work is structured as follows: initially, the introduction is presented, which includes the objectives of the study; in the second chapter, the theoretical reference is presented with the main themes addressed in the study: sustainability, logistics, physical internet and transport system. In the third chapter, the state of Southeast Region is presented. In fourth chapter, the main producers of sugarcane of Southeast Region were presented with focus in their logistics for sugar and in chapter five, sugar transport were showed. Chapter six explained Physical Internet concepts and functions. The research method is in chapter seven. Chapters eight and nine shows results and conclusion about how Physical Internet could help solving problems sugar´s transport in Southeast Region of Brazil.

2 THEORETICAL REFERENCE

2.1 Sustainability

Sustainability is a frequently used word aggregating combinations such as: sustainable development, sustainable growth; sustainable community; sustainable industry; sustainable economy; sustainable agriculture, amongst others. This word comes from the Latin *sustentare*, which means “to meet”, “to sustain”, “to support”, “to keep in good condition“, “to hold”, to resist”. In this way, one can say that sustainable means the capacity to be maintained or supported (SICHE et al., 2007).

Human development is something natural. It is necessary to grow, but on a sustainable basis. For doing so, the development should be sustainable (economically, ecologically and ethically) as it turns out to be compatible with environmental preservation. Human beings have the right to healthy and productive life in harmony with nature. Therefore, the development must be sustainable and responsible (BURSZTYN et al., 1993).

Meixell and Gargeya (2005) concluded that global supply chain models need to address the composite supply chain design problem by extending models to include both internal manufacturing and external supplier locations. Manufacturers rarely own the facilities in their supply chains, yet managers aim to achieve a well-designed supply chain. Supply chains typically comprise both internal and external. Global supply chain models need broader emphasis on multiple production and distribution tiers in the supply chain. Many of the models reviewed here address only the first tier of manufacturing, neglecting the performance implications of the suppliers of goods and services. The performance measures used in global supply chain models need to be broadened in definition to address alternative objectives. That more industry settings need to be investigated in the context of global supply design.

The challenge for any particular industry is to strategically decide on those features that will be modeled, to keep the problem tractable, and thereby focus on the special structure of the practical setting. Without a focus, the amount of data required is unnecessarily numerous and may be prohibitively time consuming. This shortcoming represents an important gap between model development and implementation in practice facilities, and this reality needs to be taken into account in global supply chain design models (MEIXELL; GARGEYA, 2005).

Sustainable development requires radical and systemic innovations. Such innovations can be more effectively created and studied when building on the concept of business models. This concept provides firms with a holistic framework to envision and implement sustainable innovations. In the case of sustainability challenges the notion of innovation, in particular, sustainable innovation connected to new business models e is often positioned to be a win-win situation (PORTER; KRAMER, 2011). Consequently, interest in sustainable innovation is rapidly increasing. This is in part a consequence of the number of un-sustainability issues being so large and pervasive across the world that the idea of transforming challenges into business opportunities and new markets has sparked fundamental interest in the business community. The interest is becoming clear from the large increase of capital flowing into sustainable innovations (BOONS et al., 2012).

The European Commission (EC, 2008) defined eco-innovation as, "the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)". Interestingly, elsewhere, the European Commission linked eco-innovation to sustainability and stated (EC, 2007): "Eco-innovation is any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy" (BOONS et al., 2012).

In view of the changes being made in the world, the environmental concern is present in those countries where there is a highly developed awareness of environment. This was the case of the Voisey's Bay environmental management agreement, which was a hallmark in Canada because it introduced the "contribution to sustainability" as a basic acceptance test. The Voisey's Bay proposal was to make an agreement for five environmental points with approval by community members as well as by political and local forces (GIBSON et al., 2012).

In this context, Brazil has been undergoing major transformations due to population growth and urbanization, mainly at the end of the past century. This has also brought modernization to the country's bases of development. In fact, Brazil shifted from an economy predominantly based on exportation of agricultural products to one based on significant industrialization (industrial population growth of 9.3% yearly between 1970 and 1990), with predominance of manufactured products in its export agenda (VIANNA; VERONESE, 1992).

This accelerated pace of industrialization and higher concentration of populations in urban areas, mainly from 1960, started to cause profound impacts on the environment (physically, economically and socially), with industrial activities being the determining factor in these transformations (ANDRADE et al., 2002).

In Brazil, the aggravation of the environmental situation began to be felt in the most industrialized areas, such as Cubatão, Volta Redonda, ABC Paulista and metropolitan cities, amongst others, as a result of the concentration of urban and industrial activities (ANDRADE et al., 2002).

As the main outcome of the Brazil's participation in the Conference of Stockholm, which emphasized the narrow linking between development and its effects on environment, the Brazilian Government felt the need for changes and saw the opportunity to institutionalize its authority at federal level guided towards the preservation of the environment. On 30th October 1973, the Special Secretary for Environment (*SEMA*) was established in Brazil. This federal initiative had been preceded by the establishment of the Environmental Sanitation Technology Company (*CETESB*) on 29th June 1973, according to Law Number 118, and the State Council for Environmental Protection (*CEPRAM*) on 4th October 1973 in the State of Bahia (ANDRADE et al., 2002).

From 1975 on, environmental agencies were created in several states and specific laws and regulations on environmental control started to emerge at federal, state and county levels (ANDRADE et al., 2002). In Brazil, the corporate environmental management varies depending on the size and type of industry. In general, multinational industries and large-sized national companies have environmental units in their plants as well as in their administrative departments with specific functions (VIANNA; VERONESE, 1992).

In the private initiative, some forms of regulation have been recently emerged from great transnational corporations, and in many cases they have also influenced smaller companies involved in their production chain. In this context, institutional pressure from consumers and regulatory requirements can represent profitability for the companies, which in turn can impact the supply chain practices for several reasons (DIAS et al., 2012).

Due to the demands from society for a more suitable and responsible corporate stance to minimize the discrepancy between economic and social results, as well as the ecological concerns, which have been significantly highlighted in face of the quality of life of the populations, the companies have been expected to take a new stance towards their interaction with environment. In the 1980s, the expenses for environmental protection started to be seen by the leading companies as future investments rather than costs, and paradoxically as a competitive advantage. Their attitude has shifted from defensive and reactive to creative and active (ANDRADE et al., 2002).

As benefits from an ecologically-minded management, one can highlight the items listed in Figure 3.

Figure 3 – Benefits from an ecologically-minded management

Source**:** Andrade, Tachizawa e Carvalho (2002).

In addition, there are practices impacting significantly the supply chain, such as: elimination of expenses, risk management of supply chain, and cleaner production. Another conceptual model states that the impact of a lean, resilience, green supply chain management is related to flexible transport services, flexible sources, ISO 14001 and reverse logistics (GOVINDAM et al., 2014)

There are six principles considered essential for responsibly managed companies to be successful in the long-term, as shown in Figure 4.

Figure 4 – Essential principals of a responsible company

Source: Govindam et al. (2014).

There are several motivators for such expansion and concerns. Although some companies may be reactive to external pressures, the proactive ones seek to aggregate values to their products and businesses through responsible practices (DIAS et al., 2012).

On the other hand, consumers are also stimulated to seek more sustainable supply chains and to invest in environmental initiatives based on clear and transparent information on the impacts on environment, including potential improvements in cost economy and reduction of carbon gas emission (COLICCHIA et al., 2013).

Three key elements are characteristic of ecologically-minded management strategies, as shown in Figure 5.

Figure 5 - Strategies of ecologically-minded management

Source: Colicchia et al. (2013).

The concept of environmental management has not yet a *stricto sensu* importance, but there are some corporate proposals on practical guidelines made by environmental community representatives and international organizations. The Valdez principle, the Brundtland Commission and Agenda 21 are documents which present effective measures to companies regarding preservation of environment (ANDRADE et al., 2002).

The literature on sustainability highlights that some gaps in the research have motivated studies on company sizes, for example, which are crucial for implementation of sustainability, although a deeper analysis is also needed. Another aspect involves the logistics services as they have a predominantly outsourced function with significant environmental and social impacts, thus being a relevant field of inter-organizational study which has been rarely addressed by the mainstream research (KUDLA; KLASS-WISSING, 2012).

The international literature is very advanced in the integration of sustainability themes in the supply chain regarding several aspects. The increasing number of international publications on this theme has been observed since 2001, whereas the number of national publications is not significant compared to the international production of pair-reviewed periodicals, although debates on the benefits of green practices is increasing and progressing. As for national publications, the articles on supply chain sustainability management have only been recently published, which shows a necessity for further Brazilian studies on this theme regarding development, expansion, maturation and consolidation (DIAS et al., 2012).

2.2 Logistics

Logistics is in an antagonistic situation in the world: on the one hand, the perspective to become attractive in terms of quickness, flexibility, frequency and costs; on the other hand, the need to improve its performance in terms of environmental and social impacts. For example, the French industry has worked hard to meet the 20-percent reduction of carbon gas emission until 2020, and four times this percentage until 2050 (BOISSIEU, 2006). Some potential paths towards this objective are being investigated: 1) improvement of the energy efficacy; 2) shift from the road-based transport system to a less pollutant one, such as electric trains; 3) information technology to more efficiently develop, explore and manage transport strategies; 4) adoption of policies to change the logistics behavior by using either stimulating or limiting measures, such as carbon taxes, urban access regulation, and control of greenhouse gas emission (BOISSIEU, 2006).

Logistics has evolved and adapted to the changes perceived in this new global context. Differently from the so-called “mass production”, the industry aims at “customized production” in which the production system is lean, avoiding high level of storage and privileging fragmented and more frequent deliveries. More than supporting an industry based on lean production system, the logistics advances have also enabled the emergence of electronic trading, thus allowing companies to overcome the difficulties existing between virtual world with Internet commerce and real world with delivery of goods traded on the Internet. In addition to the new technologies already available, there are new logistics techniques being implemented such as milk run, cross-docking, amongst others. Combined, these changes require new formats of delivery rather than the traditional direct ones, that is, from supplier to client (FAÇANHA; SILVA; FELDMANN, 2010).

Another important complementary way can be explored, which would involve the integration of logistics services in order to increase efficacy, improve multi-modal trips and stimulate innovation around concepts of logistics, such as new standardized, modular containers, new transport modalities and efficient routing algorithms.

2.3 Physical Internet

The Physical Internet (PI, π) was presented by Montreuil (2011) as a response to the Global Logistics Sustainability Grand Challenge. This grand challenge covered three aspects of sustainability: economic, environmental and social, using symptoms from today´s logistics system as evidence of the unsustainability of our present. The PI is defined as an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. The PI enables an efficient and sustainable Logistics Web that is both adaptable and resilient (MONTREUIL; MELLER; BALLOT, 2012).

The term, Physical Internet, employs a metaphor taken from Digital Internet, which is based on routers, all transmitting standard packets of data under TCP-IP protocol. A core enabling technology to make the PI a reality exploit is the encapsulation of goods modular, reusable and smart containers (MONTREUIL, BALLOT, TREMBLAY, 2016).

Symbolically, π is used for Physical Internet (PI) literature. In presenting the Physical Internet elements, we use the prefix π, as the π symbol corresponds to the Greek letter PI, which happens to correspond to the two-letter abbreviation for the Physical Internet. Therefore, we exploit the prefix π in order to differentiate the entities conceived for the Physical Internet from their contemporary versions. With adoption of the Physical Internet, this prefix would no longer serve a purpose. Note also that the Physical Internet is not a closed system and therefore a π- container could be in a current container ship and a π-container could even contain pallets (MONTREUIL; BALLOT; TREMBLAY, 2014).

The π-containers range in modular dimensions from large to small. The usage of π-containers will make it possible for any company to handle and store any company´s products because they will not handling and storing products per se. Instead of handling standardized modular containers, just as the Digital Internet transmits data packets rather than information/files (MONTREUIL; MELLER; BALLOT, 2012).

The goal of this grand challenge is to enable the global sustainability of physical object mobility (transportation, handling), storage, realization (production, assembly, finishing, refurbishing and recycling), supply and usage. From an economical perspective, the goal is to unlock highly significant gains in global logistics, production, transportation and business productivity. From an environmental perspective, the goal is to reduce by an order of magnitude the global energy consumption, direct and indirect pollution, including greenhouse gas emission, associated with logistics, production and transportation. From a societal perspective, the goal is to significantly increase the quality of life of the logistic, production and transportation workers, as well as of the overall population by making much more accessible across the world the objects and functionality they need and value (MONTREUIL, BALLOT, TREMBLAY, 2016).

Another enabling technology of the PI is an open standard set of collaborative and routing protocols. Modularized containers are much easier to route through transport networks as individual “black-box” loads instead of heterogeneous loads of different-sized cases and pallets. But the efficient routing of modular containers over a collaborative network can only be realized if there is a standard set of routing and digital protocols, as well as business and legal conventions that apply across a community of users (MONTREUIL, BALLOT, FONTANE, 2012).

Also, handling and digital interfaces are needed to ensure reliability, security, and transparency as well as that quality of the product being handled is not compromised through its movements. These interfaces cannot be proscribed, but the functional requirements need to be so that innovative interfaces may be developed (MONTREUIL; MELLER; BALLOT, 2012).

A simplified mental image of the Physical Internet business model is to imagine an eBay-like freight transportation “auction” that handles “black-box” modular containers through an open and shared network with a vast community of users that utilize supplier ratings to drive logistics performance. This creates a multi-scale process where at the lowest level we have individual containers and at the highest level we have an international network of transportation, storage and services resources (MONTREUIL; MELLER; BALLOT, 2012).

As most users of the Digital Internet exploit the World Wide Web and its multitude of applications, most users of the Physical Internet are to exploit its enabled Logistics Web. It is composed of five constituent webs respectively focused on enhancing the efficiency and sustainability of moving, storing, realizing, supplying and using physical objects: a Mobility Web, a Distribution Web, a Realization Web, a Supply Web and a Service We. It is network of networks (MONTREUIL; MELLER; BALLOT, 2012).

The physical internet distribution is the practical definition of the current model of network distribution, which is an open global logistics system using physical, digital and operational inter-connectivity by means of encapsulation, protocol and interfaces. The logistics internet is defined as a global set of organizational, physical, digital, human and social players, including networks serving to world’s dynamics and evolution of the logistics needs. In the search for efficiency and sustainability, the physical internet aims at allowing the logistics network to be increasingly more open and global at the same time, in addition to being reliable, resistant and adaptable. The logistics network can be conceived as an incorporation of four interlocked networks, namely: mobility network, distribution network, achievement network, and supply network (MONTREUIL, 2011).

The mobility network deals with the handling of physical objects within a global inter-connected set aimed at opening unimodal and multimodal centers, transits, ports, roads and pathways. The distribution network is concerned with a global set of open warehouses, distribution centers and storage areas, all interlinked to each other. The achievement network is aimed at manufacture, assembly, customization of objects, thus requiring a better adaptation to the global set of interconnected plants of all types. Finally the supply network deals with provision through the global set of open service providers and suppliers (MONTREUIL, 2011). The networks exploit each other to increase their performance.

From holistic simulations made to ensure mobility, a study was performed to allow situations in a variety of contexts worldwide (MONTREUIL, 2009; 2012). In order to assess and quantify the expected impact on economy, environment, social efficiency and sustainability, the researchers studied the current system of cargo transport, which is shifting towards an open logistics network to support the distribution of high consumption goods (MONTREUIL, 2009; 2012).

Montreuil (2011) states that the way how physical objects are transported, handled and stored across the world is not economically, environmentally and socially sustainable. The author supported this by highlighting 13 symptoms of global non-sustainability. Montreuil (2011) proposed an evolution towards a worldwide physical network in order to improve magnitude, efficiency and sustainability of logistics systems in a broad sense. Physical network explores the concepts of universal inter-connectivity of logistics network and services. The same author proposes an encapsulation of goods and products traded in a standardized, green, modular and networked world into intelligent containers which can be flowed and distributed through quick, reliable and eco-friendly systems of multimodal systems and logistics facilities. From his point of view it makes an efficient logistic system (MONTREUIL, 2011).

The Physical Internet (PI) was defined as an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols by Benoit Montreuil, Russel D. Meller and Eric Ballot, see Montreuil (2011) and Ballot, Montreuil, and Meller (2014). According to a report of Science Magazine (Mervis, 2014), the Physical Internet constitutes a path-breaking solution to the inneficiences of traditional proprietary models. It represents an open, global, interconnected and sustainable logistics system (SARRAJ et al., 2014).

This system is based on standard and smart modular containers (LIN et al., 2014; MONTREUIL; BALLOT; TREMBLAY, 2016) that are easily transport means (e. g. planes, trucks, barges, drones and private cars). Modularly sized from small parcels to large maritime containers, the PI containers move through distributed, multimodal transportation networks in which transit sites aggregate containers from diverse origins to optimize the loading on the next segments. Open logistics facilities such as open semi-trailer transit centers, open cross-docking hubs and open warehouses are part of interconnected networks, enabling a global Logistics Web is said to be PI-enabled as the Physical Internet goes beyond the development of agile networks known in the literature.

Essentially, the contributions can be segregated in four key categories conceptual research, assessment research, solutions design research and validation research. Conceptual research was first addressed in the literature. It focuses on defining and enriching the fundamental concepts underpinning the Physical Internet, the Logistics Web, key PI components and conceptualizing PI implementations in key industries, territories and scales. The early conceptual work on the Physical Internet was exposed in evolving versions of the Physical Internet Manifesto (MONTREUIL, 2009; 2012), in Ballot, Glardon, and Montreuil (2010) and Montreuil (2011). Then Montreuil, Meller, and Ballot (2013), Ballot, Montreuil, and Meller (2014), Sarraj et al. (2014) and Hakimi (2014) contributed in the further elaborating the overall Physical Internet concepts and foundations.

There has also been focused conceptual contributions. Similar to the Open Systems Interconnection (OSI) model for the Digital Internet, Montreuil at al. (2012) proposed an Open Logistics Interconnection (OLI) model for the Physical Internet. Crainic and Montreuil (2016) conceptualized the instantiation of the Physical Internet in the city logistics context, proposing the concept of hyperconnected city logistics, while Montreuil (2017) conceptualized the complementary instantiation of the Physical Internet in omnichannel business-to-consumer logistics and supply chains. Marcotte, Montreuil, and Coelho (2015) introduced the concept of hyperconnected mobile production, exploiting the Physical Internet as the additive, containerized, distributed, mobile, modular, on-demand, outsourced and hyperconnected production concepts.

Assessment research was next tackled in the literature. It focuses on rigorously sizing the Physical Internet induced opportunity for economical, environmental and societal efficiency and sustainability improvement through analytical, optimization and/or simulation modelling based experiments. The first comprehensive simulation based assessment study focused on the the transportation of consumer goods in France, exploiting data between two top retailers ahd theirs 106 top suppliers, with facets reported in Ballot (2012), Sarraj (2013) and Sarraj et al. (2014). A second large-scale simulation based assessment experiment has focused on the interconnected transportation of semi-trailers using relay-based exchanges at

PI transit centers, using the Québec province of Canada as tested (see Hakimi, Montreuil, and Haiji (2015)). An analytical model based assessment focused on the US supply chain was reported by Meller, Ellis, and Loftis (2012). Results of an optimization model based assessment study of the potential for hyperconnected distribution were reported by Sohrabi (2016), Sohrabi, Montreuil, and Klibi (2016a, 2016b).

As the PI concept was further elaborated and its potentiality assessed, solutions design research was next addressed in the literature. It starts by asking questions about why industry is not in a position to do it now and then engages in generating solutions for filling the gaps. It focuses on designing, engineering and testing the methodologies and technologies enabling the implementation and exploitation of the Physical Internet in industry across the world. There have been two main interlaced threads of solutions design research.

2.4 Transport System

Transport represents the most important element in the logistics cost in the majority of the companies. In general, freight comprises a considerable part of the logistics costs and is an important component of the gross domestic product. Developing countries usually have production and consumption occurring at the same place, with most of the labour force involved in agricultural production and a less percentage of the population living in urban areas. As cheaper transport services are made available, an economic structure begins to resemble to that of an industrialized country: big cities result from population migration; geographic regions are limited to producing a smaller variety of items; and the level of mean life expectancy begins to increase. Specifically, a better transport system contributes to 1) increase market competition, 2) ensure production scale economy, and 3) reduce the prices of goods (NOVAES, 1989).

In Brazil, after the development stage followed by neo-liberal approaches, the model of economic development converges into a new paradigm: the logistics. This paradigm admits the strategy of mitigating the Brazilian regional disparities through a territorial integration towards the productive connection generated by infrastructure, energy and communications. These integration pathways created to strengthen both industrial activity and productive outlets are called development corridors, which are responsible for overcoming the national logistics bottlenecks. All these aspects prepare the country internally for a more active global insertion and with less vulnerability (SILVA; BORGES; HERREROS, 2014-2015).

When there is no good transport system, the market expansion becomes very limited to the local production. Unless the production costs are much lower in a second production unit to the point that the cost difference can offset the transport costs regarding a second market, there is no significant margin for market competition. However, with better transport services, the costs of products traded in remote markets may compete with the costs of other products being sold in the same markets (NOVAES, 1989).

In addition to encouraging direct competition, a cheaper transport system promotes indirect competitiveness as it enables goods to be available in a market where they otherwise would never be so. Various fruits and vegetables are example of this. When the local production of these goods is off-season, shipments from other regions can meet the local market demand. This increases the general availability of goods beyond local production and can have a stabilizing effect on the prices of all goods (NOVAES, 1989).

The domestic transport system refers to the whole set of work, facilities and resources comprising the cargo-handling capacity in the economy. This capacity implies the handling of people and goods, which may also include distribution of intangible goods such as telephone calls, electrical energy and medical services. Most of the cargo-handling is performed by five basic inter-urban transports (i.e. railways, motorways, waterway, pipeline and airways) and by several transport agencies, which facilitate and co-ordinate the cargo-handling procedures (i.e. transport agents, transporters, export associations) (BALLOU, 1993).

It is fundamental to have a detailed view of the main components of logistics in terms of study and planning, namely: stocks, locations and transports. As sustainability, logistics is also based on a tripod: social, economic and environmental. The twenty-first century's new approaches to corporate logistics are aimed at preserving the environment. In this new era, managers are concerned not only with the flow of products towards the final consumers, but also with the opposite flow direction, the so-called reverse logistics (RODRIGUES et al., 2011).

The relative importance of each transport mode and the changes in their relative participation are partially explained by both cargo transported and transport mode's inherent advantage. For example, let's consider the pipeline mode. This transport mode is a highly efficient method for transporting liquid or gas products over long distances. Therefore, pipelines tend to be limited to liquid cargo (almost always oil and derivatives), large gas volumes and some products which can remain suspended in liquid media and handled as fluids. The handling costs are low, but the kind of products transported are limited (NOVAES, 1989).

In contrast to this situation, the air transport mode is not so limited in its scope regarding technical problems, but its freight rates are relatively higher compared to other transport modes. This had been made air transport restricted to products which can effectively compensate their high costs with a better service. In general, the air-transported products are electrical equipment, optical instruments, fine manufactures, machine parts, and collected flowers. These products have high value compared to their volume or weight, or they need to be distributed quickly (BALLOU, 1993).

Water transport mode operates mainly with bulk products, such as coal, ores, coke, sand, oil, semi-processed iron and steel, with cement and grains comprising more than 90% of the American waterways. Water-based maritime container transportation that supports most of industrial and commercial intercontinental trade. On the other hand, because air transported goods have low specific value and are non-perishable, their stock costs are not excessive and thus they use seasonal transport services, despite being slow, in exchange for low freight rates (BALLOU, 1993).

Finally, there remain the rail and road transport modes, which handle the majority of the manufactured goods and more than two-thirds tons of miles generated between urban centers. The profile differences in the products transported by trains or freight lorries are not so great compared to the above-mentioned cases. In the United States, railways and motorways compete essentially in the same routes with similar freight rates. Freight lorries have been effective competitors since 1929 and their presence as alternative transport service can partially explain the decline of the railway’s participation in the transport, together with the rise of road transport services. The goods carried by each of these transport modes are basically divided depending on compensations between cost and service level. Trains, whose freight rates are cheaper and overall performance is slightly inferior, are focused on cargos with lower value: weight or value: volume ratio (specific value). Chemical, metallurgical and plastic products are examples of cargos usually found in railways, whereas the opposite is true regarding road cargos (NOVAES, 1989).

By comparing the relative importance of the several transport modes in terms of passenger traffic, one can see that the results show a clear contrast with cargo transport. As for the inter-urban traffic, with exception of automobiles, airways companies transport the great majority of passengers. The problem is to find the most efficient routes in order to provide the clients with a given amount of vehicles, production units, logistics platforms and multi-modal network (CONFESSORE et al., 2013).

2.4.1 Rail Network

The Dom Pedro II railway was inaugurated in 29th March 1858, with an initial stretch of 47 km from Court station to the town of Queimados, Rio de Janeiro. This railway is one of the most important engineering works in Brazil as it managed to surpass the 412-metre height of the Serra do Mar by means of colossal cuts, landfills and tunnels, including the Great Tunnel, constructed in 1864 and being the then longest tunnel in Brazil, with an extension of 2, 236 meters (MINISTÉRIO DOS TRANSPORTES, 2015).

The Dom Pedro II railway, through the dynamic work by technicians and labourers, later became the Central do Brasil railway in 1889, one of the country's main development axis. One of the most important facts in the history of railway development in Brazil happened on 8th July 1877 with the Rio-São Paulo line, linking the two most important cities of the country, when the São Paulo railway (inaugurated in 1867) was connected to the Dom Pedro II one (MINISTÉRIO DOS TRANSPORTES, 2015).

The policy of incentives for railway constructions, adopted by the Imperial Government of Brazil, brought some consequences to the country's railway system and which last until today, such as:

- Great diversity of gauge tracks, which has been making operational integration between railways difficult;
- Excessively winding and long railway tracks;
- Railways located across the country on a dispersed and isolated basis.

Until the end of the nineteenth century, other concessions for railway operations with metric gauge track were granted, highlighting in table 1 - brazilian railways, in it can be seen railways and their dates of inauguration.

Table 1 - Brazilian Railways

Railway	**Date of Inauguration**
Companhia Mogiana	03/05/1875
Companhia Sorocabana	10/07/1875
Santo Amaro	02/12/1880
Paranaguá a Curitiba	19/12/1883
Dona Tereza Cristina	04/09/1884
Corcovado	09/10/1884

Source: Ministério dos Transportes (2014).

Amongst the above-cited railways, one can highlight the construction of the Paranaguá-Curitiba railway, which is a hallmark for the Brazilian railway engineering as it was considered unachievable by European technicians at the time. Its construction lasted less than five years, despite the difficulties faced along of the 110-km extension. On 17th November 1883, regular train traffic between Paranaguá and Morretes was inaugurated. This railway has 420 engineering works of art, including today 14 tunnels, 30 bridges and several overpass viaducts, in which the highest point is 955 meters above the sea level. Other lines were connected to the pioneer stretch of the railway, thus enabling the progress of the present states of Paraná and Santa Catarina (MINISTÉRIO DOS TRANSPORTES, 2015).

In 1884, the Dona Teresa Cristina railway was concluded in the then province of Santa Catarina, with an extension of 112 km, after concession obtained by the Viscount of Barbacena in order to transport coal to the Port of Imbituba (MINISTÉRIO DOS TRANSPORTES, 2015).

2.4.2 Rail Network in São Paulo

It is important to emphasize that in the state of São Paulo the railways were the natural result of agricultural exports. One can state that there is a natural relationship between expansion of coffee production in the Vale do Paraíba and construction of railways in that region. The construction of railways in São Paulo started after the first half of the nineteenth century, forming a true coffee catchment network converging towards the Port of Santos. From 1867 to the 1930s, there were 18 railways and half of these had lengths shorter than 100 km as they served as cargo catchment branches for large and medium-sized companies, namely:

- Sorocabana Railway, with 2,074 km;
- Companhia Mogiana Railway, with 1,954 km;
- Noroeste do Brasil Railway, with 1,539km;
- Companhia Paulista Railway, with 1,536 km;
- Araraquara Railway, with 379 km;
- São Paulo Railway, with 246 km, which until the 1930s consisted of a single connection from the Paulista plateau to the Port of Santos.

The Northwest of Brasil railway, cited earlier, should also be highlighted. Initiated on 16th July 1905, this railway connected Bauru to Porto Esperança in 1914 before crossing the state of São Paulo and the present state of Mato Grosso do Sul to the city of Corumbá, at the border with Bolivia, which included the construction of the railway bridge on River Paraguay in 1947.

2.4.3 Establishment of FEPASA

In 1971, the Government of the State of São Paulo decided to unify their five railways into only one company according to state law number 10410/SP. At that time, the Companhia Paulista Railway, Sorocana Railway, Araraquara Railway, Companhia Mogiana Railway and São Paulo-Minas Railway belonged to the State of São Paulo. Therefore, as a result of this unification, the Paulista Railway S.A. FEPASA was established in order to control approximately 5,000 km of railways (MINISTÉRIO DOS TRANSPORTES, 2015).

Privatization Process

From 1980 to 1992, the railways systems belonging to the Federal Railway Network S.A (RFFSA) and Paulista Railway S.A. (FEPASA) were dramatically affected as the former’s number of investors fell significantly in 1989, with only 19% of investment being applied to railways in the entire decade of the 1980s. In 1984, the RFFSA could no longer generate enough resources to afford the debts contracted over time. The company was suffering from serious imbalance in its technical-operational services as a result of degradation of the infrastructure of the main metric gauge tracks and delay in undercarriage maintenance, causing significant loss of market for the rail transport (MINISTÉRIO DOS TRANSPORTES, 2015).

An institutional measure was taken by the federal government to adjust the RFFSA services so that urban transport was no longer offered. On 22nd February 1984, the Brazilian Company of Urban Transport (CBTU) was constituted according to federal law number 89396 in order to provide urban transport services. One can note that, in the majority of the cases, these services were highly unprofitable. With the impossibility to generate resources needed to finance the investments, the federal government put in place measures aimed at granting the private initiative with public cargo transport services (MINISTÉRIO DOS TRANSPORTES, 2015).

The federal law number 8031/90 instituted the National Privatization Program (NPP), with RFFSA being included on 10th March 1992 according to decree-law number 473. The National Bank of Economic and Social Development (*BNDES*) acted as manager in this privatization process, according to decree-law number 1024/94, and elaborated the form and general conditions of the RFFSA concession (MINISTÉRIO DOS TRANSPORTES, 2015).

The privatization process of RFFSA was performed based on federal law number 8987/95, the so-called Law of Concessions. This law established the rights and obligations for the parts involved in the concession process and also defined the maintenance basis of the economic and financial balance, including the users' rights. The process complied with the following chronology (Table 1 - Brazilian Railways).

Table 2 - Privatization of RFFSA

Regional Railways	**Date of Auction**	**Concessionaires**	**Start of Operation**	**Extension (km)**
Western	05.03.1996	Noroeste Railway S.A.	01.07.1996	1,621
Centre-Eastern	14.06.1996	Centro-Atlântica Railway S.A.	01.09.1997	7,080
South-Eastern	20.09.1996	MRS Logística S. A.	01.12.1996	1,674
Tereza Cristina	20.11.1996	Tereza Cristina Railway S.A.	01.02.1997	164
North-Eastern	18.07.1997	Nordeste Company Railway	01.01.1998	4,534
Southern	13.12.1998	Sul-Atlântico Railway S.A. (today ALL Logistics)	01.03.1997	6,586
São Paulo	10.11.1998	Bandeirantes Railway S.A.	01.01.1994	4,236
Total				25,895

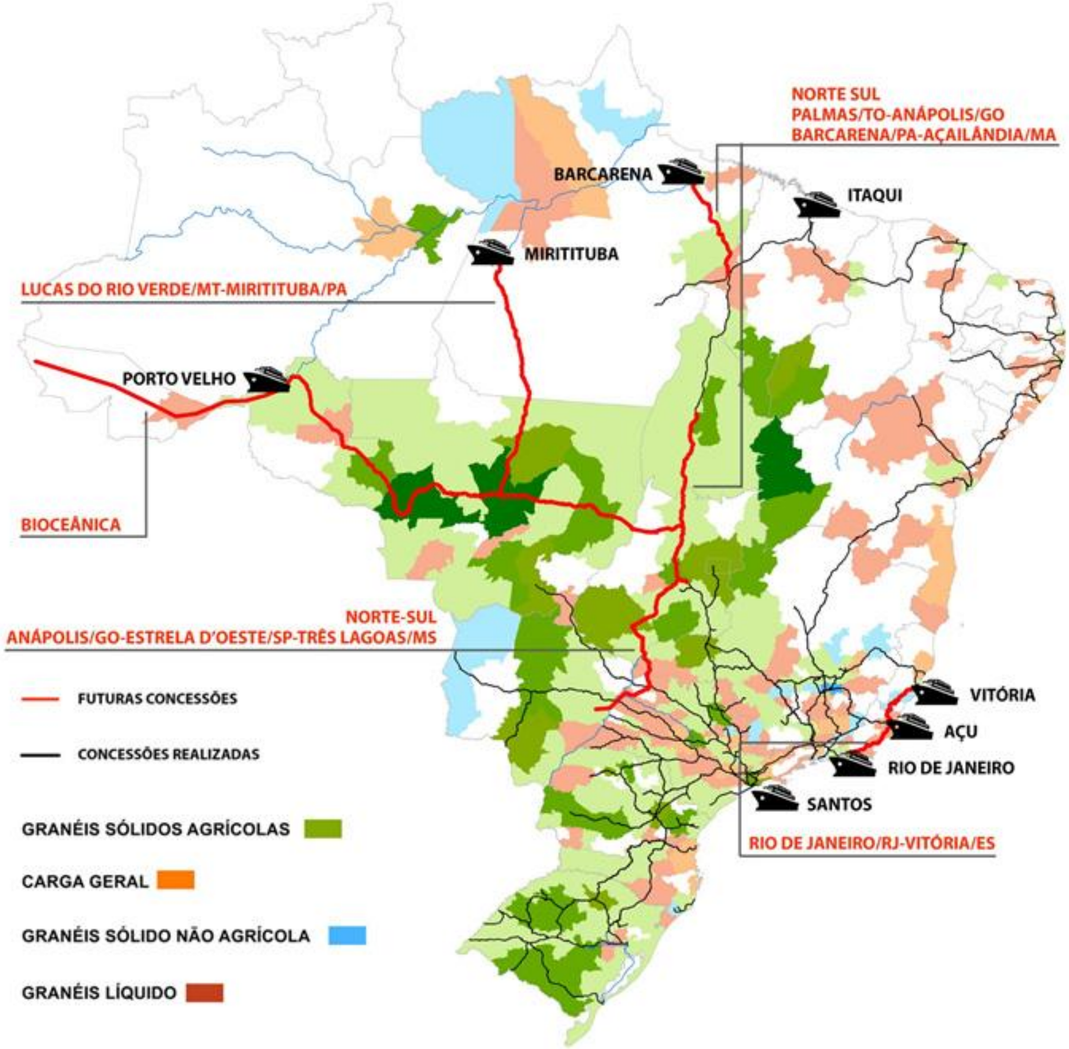
Source: RFFSA (2009) and BNDES (2010).

With the auction of the Paulista railway network (former FEPASA incorporated to RFFSA according to decree-law number 2502 of 18th February 1998), the privatization process of RFFSA was concluded. On 28th June 1997, in its privatization process, the federal government granted to the Vale does Rio Doce Company the exploitation of the Vitória-Minas and Carajás railways. On 7th December 1999, the federal government dissolved, liquidated and terminated the Federal Railway Network S.A. (RFFSA) based on resolution number 12 by the National Privatization Council and decree-law number 3277 (MINISTÉRIO DOS TRANSPORTES, 2015).

This briefly presented information has shown the most import facts of the Brazilian railway history from the early initiatives by the Imperial Government in the nineteenth century to nowadays (MINISTÉRIO DOS TRANSPORTES, 2015). On 15th August 2012, the federal government launched the Program for Investment in Logistics (PIL) in order to widen the scale of investments in infra-structure for motorways, railways, waterway, ports and airports across Brazil. Overall, the program sets guidelines aimed at reestablishing the transport integration planning so that a modern and efficient transport infra-structure network can be implemented to provide more competitiveness as well as to boost economic and social development. On 9th June 2015, the federal government announced the second step of PIL by giving continuity to the modernization process of the Brazilian transport infra-structure and also by resuming the economic growth. As for the railway mode, the program seeks to expand and use the rail cargo transport, to create a modern and integrated railway network, to increase the rail transport capacity and to decrease logistics bottlenecks (MINISTÉRIO DOS TRANSPORTES, 2015).

The program will ensure the use of R$ 86.4 billion for construction, modernization and maintenance of 7,500 km of railway tracks. The concession model holds the premises of broad-gauge railways for high-cargo capacity, optimized tracing and high speed. Therefore, it will be possible to recover the railway transport as a logistics alternative. Additionally, the model's basic premises are the following: to ensure the right of way in order to integrate the existing and newly granted railways; to improve competition in the vertical operator model; to adopt a bidding model through grant or investment sharing; and to use the expression of interest process (EIP) for development of feasibility studies (MINISTÉRIO DOS TRANSPORTES, 2015). It can be seen that in figure 6 new concessions are being made in order to expand the network to reach different points of the country and reach a greater number of people and companies, specially, for agrofood.

Figure 6 - Future Concessions; Granted Concessions; Agricultural Grains; General Cargo; Non-Agricultural Bulk Solids; Bulk Liquids



Source: Ministério dos Transportes (2016).

2.4.4 Waterway Network

The National Traffic System (NTS) is responsible for the waterway infrastructure in the country and plays activities of construction, expansion, recovery, maintenance and operation in rivers and ports under the responsibility of the National Department of Transport Infrastructure (DNIP).

2.4.4.1 Paraná-Tietê Waterway

The Paraná-Tietê waterway crosses the states of São Paulo, Paraná, Mato Grosso of Sul and Minas Gerais. It is integrated with motorways, railways and pipelines at regional and federal levels in a multi-modal outlet system for agricultural production, where almost half of the Brazilian GDP is generated (MINISTÉRIO DOS TRANSPORTES, 2015).

River Paraná is navigable along its length of 1,023 km, with an average width of 120 metres. Under the responsibility of the federal government, the waterway extends between the Itaipú hydroelectric dam in Foz do Iguaçu, State of Paraná, and two dam walls: the São Simão hydroelectric dam at River Paranaíba in the county of São Simão, State of Goiás; and Água Vermelha hydroelectric dam at River Grande in the county of Iturama, State of Minas Gerais (MINISTÉRIO DOS TRANSPORTES, 2015).

Affluent of River Paraná, the River Tietê has a navigable extension of 715 km and minimum depth of three metres. The waterway is managed by the Government of São Paulo through the State Secretary of Logistics and Transport (MINISTÉRIO DOS TRANSPORTES, 2015).

This system is formed by two waterways and eight canal locks, with six at River Tietê, namely, Barra Bonita, Bariri, Ibitinga, Promissão, Nova Avanhadava and Três Irmãos. All of them have 142 metres in length, 12 metres in width and depths between 3 and 4 meters. The other two canal locks are located at River Paraná, namely, Jupiá in the county of Castilho and Porto Primavera in the county of Rosana, both in the State of São Paulo. These canal locks have 210 meters in length, 17 meters in width and 4 meters in depth (MINISTÉRIO DOS TRANSPORTES, 2015).

Navigation

The convoy embarkations used on River Paraná have 200.5 metres in length, with breadth of 16 meters and draught of 3.7 meters, whereas those used on River Tietê have 135 meters in length, with breadth of 11 meters and draught of 2.7 meters. Approximately 6.5 million tons of cargo, mainly soybean, corn and soybean meal, are transported on this waterway systems yearly. Corn, cassava, sugar cane, coal, sand, fertilizer and gravel are also transported (MINISTÉRIO DOS TRANSPORTES, 2015).

2.4.4.2 Três Irmãos Canal Lock (SP)

Located in the county of Pereira Barreto at 650 km from São Paulo City, the Três Irmãos transposition system has two intermediate canal docks measuring 926 meters in length and 70 meters in width. Each canal dock has 142 meters in length, 12.1 meters in height and draught of 3.5 meters. This space can accommodate convoys of up to 137 meters in length and 11 meters in width (MINISTÉRIO DOS TRANSPORTES, 2015).

The intermediate lake has a capacity to store 210,000 m^3 of water, which is enough for four successive canal docks. The system allows embarkations to manoeuvre and operate independently of the canal dock so that they can overcome the unevenness of almost 50 meters. Tietê embarkations are the one mostly using canal docks on this stretch as they consist of a convoy of two barges and one push-tug, totalizing 138.5 meters in length, for width of 11 meters, height above water level of 7 meters and draught of 3 meters. However, there are restrictions for small embarkations as they need prior authorization by the waterway administration (MINISTÉRIO DOS TRANSPORTES, 2015).

On 15th August 2012, the federal government has launched the Program for Investment in Logistics (PIL), which was increased with the inclusion of a set of specific actions for the port sector in December of the same year. The aim was to expand and modernize the infra-structure of Brazilian ports by means of strategic partnerships with the private sector, thus promoting synergies between motorway and railways networks as well as between waterways, airways and ports. The program's main guidelines were: systemic planning, scale gains, increase in competition, port re-organization, and long-term planning. The main objective was to improve the logistics integration between several transport modes in order to bring competitiveness gains to Brazil. It was expected that investment in infra-structure could boost economic growth and promote sustainable development in the country (MINISTÉRIO DOS TRANSPORTES, 2015).

The federal government had announced the second stage of PIL in 2015 by giving continuity to the modernization process of the transport infra-structure, in which investments in the port sector are estimated to be around R$ 37.4 billion, with R$ 11.9 billion for 50 new lease agreements, R$ 14.7 billion for 63 new private usage terminals (PUTs), and R$ 10.8 billion for lease renewals. Leases are divided into parts I and II, with the first one containing 29 terminals. Of this total, three PUTs have been already auctioned in the first phase of part I (one terminal for grains two for cellulose in the Port of Santos).

Of the rest, six terminals complement the first phase of part I (i.e. terminals in the State of Pará) and other 20 terminals are related to the second phase, that is, to be distributed between the ports of Santos and Pará. Auction biddings are also planned for the part II, consisting of 21 terminals distributed between the ports of Suape, Aratu, Rio de Janeiro, São Sebastião, Santos, Paranaguá, São Francisco do Sul, Manaus, Santana and Itaqui (MINISTÉRIO DOS TRANSPORTES, 2015).

2.4.5 Motorway Network

The Road Transport Mode

Road transport is used to transport goods and people by means of motor vehicles (e.g. buses, lorries, automobiles, etc.) As in the majority of the cases, the road transport mode has a freight rate higher than that of waterway and railway modes, despite being adequate for high-value or perishable goods as well as for finished or semi-finished products (MINISTÉRIO DOS TRANSPORTES, 2015).

Characteristics of Road Cargo Transport in Brazil

- Greater representativeness between the existing transport modes;
- Suitable for short and medium distances;
- Initial low-cost implementation;
- High-cost maintenance;
- More pollutant with strong environmental impact;
- More flexibility with large network extension;
- Moderate speed transport;
- Costs increase as distance increases;
- Low cargo capacity in terms of volume and weight;
- Integration of all Brazilian states.

In table 3, the distribution of the network of highways in Brazil, where the number of single roads is greater than the number of double roads. In addition, we highlight the high number of roads under the responsibility of the municipality and of unpaved roads. The information in the table shows the total value (in parentheses) and the percentage of what has already been done: pavedroads, non-pavedroads, plannedroads etc.

Table 3 - Brazil´s Road Network (1,7 million km of roads)

Paved roads	12.9% (221,820 km)
Non-paved roads	79.5% (1,363,740 km)
Planned roads	7.5% (128,904 km)
State motorways	14.8% (255,040 km)
County motorways	78.11% (1,339,260 km)
Federal motorways	7% (119,936 km)
Motorway works	13,830 km
Duplicate motorways	9,522 km
Single motorways	192,569 km

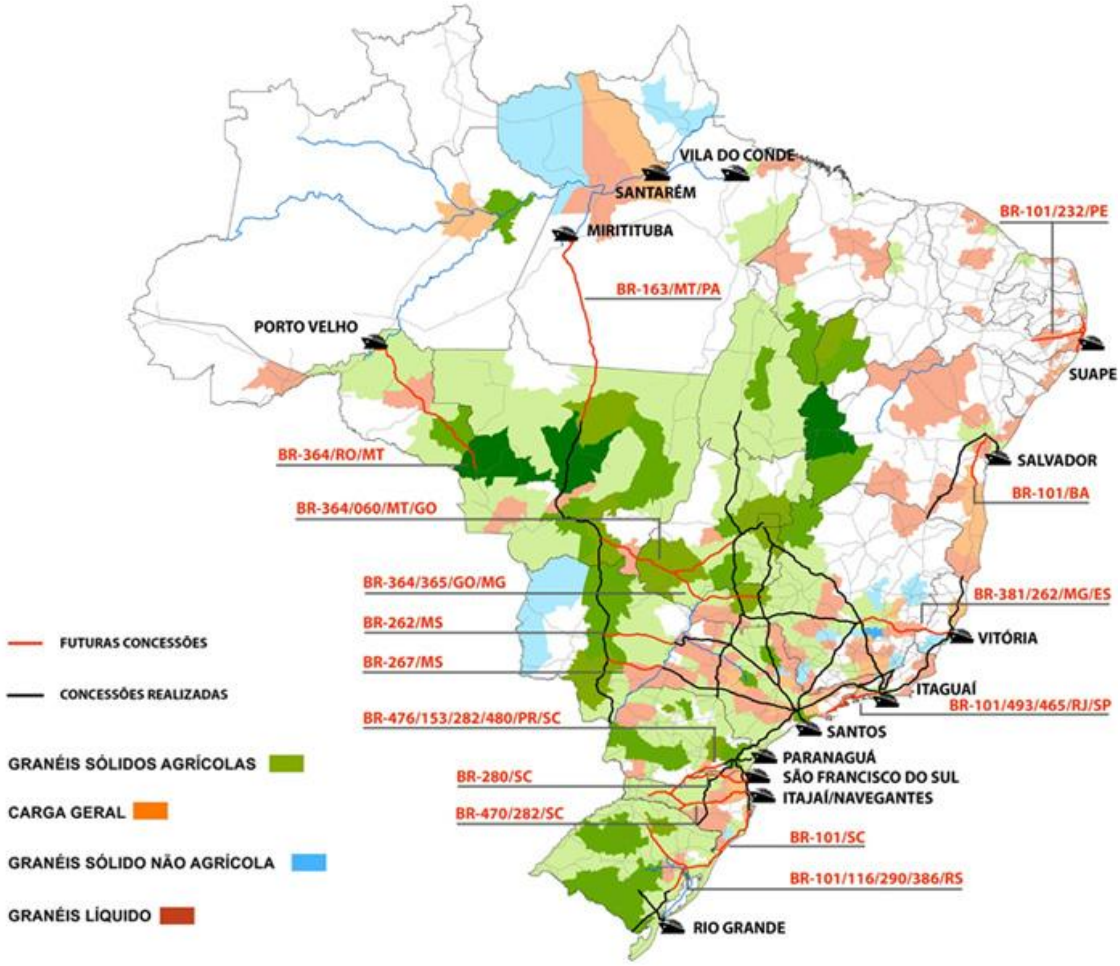
Source: DNIT (Updated in September/2014 – National Traffic System).

Brazil, a continental-sized country, has a road network of approximately 69,000 km where most part of the national economy circulates and, as such, the cargo and passenger road transport plays a relevant role in the Brazilian social-economical development. In order to improve the work conditions for professional drivers of cargo and passenger vehicles, a specific legislation (laws 12619/2012 and 13103/2015) was enacted to regulate, amongst other issues, specific places along motorways for stopping, waiting and resting purposes (MINISTÉRIO DOS TRANSPORTES, 2015).

As mentioned earlier, in 2012 the federal government launched the Program for Investment in Logistics (PIL), which included a set of projects contributing to the development of a modern and efficient transport system. These projects will be conducted by means of strategic partnerships with the private sector, thus promoting synergies between motorway, railway, waterway, airway and ports. As for the motorway network, the program aims at the following: to provide a broad, modern and integrated network of motorways; to enable efficient and competitive supply chains; and to allow tariff modality. In the first phase, from May 2014 to September 2015, the program granted concessions for 4,890 km of motorways and more than 288 km of duplicate motorways (roads with two lanes to transit) were already handed to users. The aim is to duplicate all the motorways under concession in a space of four years after issuing the installation license. The estimated investment is of R$ 46 billion (MINISTÉRIO DOS TRANSPORTES, 2015).

The second stage of PIL was announced by the federal government on 9th June 2015, which aims to give continuity to the modernization process of the national transport infra-structure and to resume the economic growth. This stage anticipates concessions involving approximately 7,000 km of motorways. The investment will be in the order of R$ 66.1 billion for increasing capacity and improving conditions and safe of the motorways, with R$ 50.8 billion being for new concessions to be granted over 2015 and 2016 and R$ 15.3 billion for new investment in already existing concessions. Figure 7 shows future concessions for railways in Brazil. (MINISTÉRIO DOS TRANSPORTES, 2015).

Figure 7 - Future Concessions; Granted Concessions; Agricultural Grains; General Cargo; Non-Agricultural Bulk Solids; Bulk Liquids



Source: Ministério dos Transportes (2016).

According to the legislation, places for waiting, stopping and resting are: bus stations, accommodation facilities, hotels, petrol station, and others. On July 2015, in order to improve the conditions and services they provide, the Ministry of Labour and Employment issued the ordinance number 944 defining security, sanitation and comfort conditions the rest stops must meet to satisfy the needs of professional drivers and other users as well as to be recognized by official agencies as stop and resting points (SRPs) (MINISTÉRIO DOS TRANSPORTES, 2015).

Those facilities interested in becoming a SRP can request the official agencies for such recognition. It should be also emphasized that SRP is a free initiative (MINISTÉRIO DOS TRANSPORTES, 2015).

2.4.5.1 Motorways – The New Stage of PIL

According to the Ministry of Transport, the implementation of SRPs will bring benefits not only to the professionals, but also to facilities and society. Amongst the advantages, one can highlight the following: reduction of accidents due to human failure (e.g. tiredness); reduction of theft; discouragement of prostitution and drug usage; and stimulus for modernization of the facilities. Giving continuity to the program launched in August 2012, the motorway concessions to private sector will follow the lower-tariff auction model (MINISTÉRIO DOS TRANSPORTES, 2015).

Four project auctions initiated in 2014 are expected to occur: BR-476/153/282/480/PR/SP; BR-163/MT/PA; BR-364/060/MT/GO and BR-364/GO/MG. The auction of the Rio-Niteroi Bridge (23 km), whose project was also initiated in 2014, occurred on 18th March 2015. Six companies took part in the auction process, with the winner presenting a proposal of 36-percent discount. The new contract allowed a reduction of R$ 1.50 on the toll rate, that is, from R$ 5.20 to R$ 3.70 (MINISTÉRIO DOS TRANSPORTES, 2015). The four auctions for 2015, including the renewal of the Rio-Niteroi concession, totalized R$ 19.6 billion in investments. In the second phase of the program, 11 new motorway concession projects covering 4,371 km added R$ 31.2 billion, in addition to new investments in existing concessions (R$ 15.3 billion). The economic-financial re-balancing of concession contracts will be negotiated case by case (MINISTÉRIO DOS TRANSPORTES, 2015).

2.4.5.2 Planned Motorway Concessions

On 15th August 2012, the Brazilian Government launched the Program for Investments in Logistics (PIL). The program included a set of projects which will contribute to the development of a modern and efficient transport system by means of strategic partnerships with the private sector, thus promoting synergies between motorway, railway, waterway, airway and ports (MINISTÉRIO DOS TRANSPORTES, 2015).

In the motorway sector, the program predicts the concession of 7,000 km of motorways with an estimated investment of R$ 46 billion. The motorway program is aimed at the following: to provide a broad, modern and integrated network of motorways; to enable efficient and competitive supply chains; and to allow tariff modality (MINISTÉRIO DOS TRANSPORTES, 2015).

Investments

The program plans to invest R$ 144 billion for up to 30 years, with the largest part of the investment to be made for 25 concessions in the first four years after environmental licensing as follows (MINISTÉRIO DOS TRANSPORTES, 2015).:

- R$ 91 billion: construction of 16 stretches, totalizing 11,500 km of railways; R$ 56 billion to be invested in the first four years after environmental license; and R$ 35 billion over 30 years of operation.
- R$ 51.6 billion: recovery, operation, maintenance, monitoring, conservation, improvement, capacity enhancement and service level maintenance of nine motorway stretches, totalizing 7,000 km. R$ 26.3 billion are to be invested in motorways in the first five years, and R$ 25.3 billion over 25 years. These figures may also be altered as the Union Accounting Tribunal (TCU) is still analyzing four concession lots, while the BR-040 and BR-116 contracts are being revised.

Objectives of the Program of Investments in Logistics

- To increase investments in transport infra-structure by giving the country a broad and modern network with low rates.
- To enhance the state's planning capacity and to promote integration between motorways, railways, waterways, airways and ports in articulation with productive chains.
- To create the bases for a sustainable growth in the next 50 years, giving rise to a continuous process of planning and development of its logistics infra-structure.

- To reduce costs and enhance the country's transport capacity, resulting in efficiency and competitiveness (MINISTÉRIO DOS TRANSPORTES, 2015).

Motorway Concessions (PIL)

In 2013, five motorway stretches were granted for concessions by means of PIL, namely: BR-050/GO/MG, BR-163/MT, BR-060/153/262/DF/GO/MG, BR-163/MS and BR-040/DF/GO/MG. The discounted toll rates ranged from 42.28% to 61.13%. The BR-050/GO/MG stretch was auctioned on 18th September, and the Consórcio Planalto was the winner by offering a tariff of R$ 0.04534 *per* kilometer of motorway, meaning a discount of 42.38% compared to the maximum tariff on the auction notice, that is, R$ 0.07987. This stretch from Cristalina (GO) to the border of Minas Gerais and São Paulo has 436.6 km of extension, with an investment of approximately R$ 3 billion over 30 years (MINISTÉRIO DOS TRANSPORTES, 2015).

The BR-163/MT stretch was auctioned on 27th November. Oberbrecht S.A. won the auction after offering a tariff of R$ 0.02638 *per* kilometer of motorway with a discount of 52.03% compared to R$ 0.0550 on the auction notice. This stretch from Brasilia (DF) to Betim (MG) has 1,176,5 km, whereas the stretch from Sinop (MT) to the border of Mato Grosso and Mato Grosso do Sul has 850.9 km. Investments of R$ 4.6 billion are estimated over a contract period of 30 years (MINISTÉRIO DOS TRANSPORTES, 2015).

The concession lot regarding the BR-060/153/262/DF/GO/MG stretch was granted on 4th December. Triunfo Participações & Investimentos won the auction by offering a tariff of R$ 0.02851 *per* kilometer of motorway, meaning a discount of 52% compared to the maximum tariff on the auction notice, which was R$ 0.0594. This stretch involves the BR-060 and BR-153 motorways from the BR-251/DF junction to the border of Minas Gerais to São Paulo, totalizing 630.2 km, including 546.3 km of the BR-262 motorway from the BR-153/MG junction to the BR-381/MG junction. It is estimated that R$ 7.15 billion will be invested during the 30-year contract (MINISTÉRIO DOS TRANSPORTES, 2015).

The BR-163/MS was auctioned on 17th December and Companhia de Participações em Concessões, a company belonging to the Companhia de Concessões Rodoviárias (CCR), was the winner by offering a discount of 52.74%. The maximum tariff on the auction notice was set at R$ 0.0927, with CCR offering R$ 0.04381 *per* kilometre of motorway. The stretch from the border of Mato Grosso and Mato Grosso do Sul to the border of Mato Grosso do Sul and Paraná has 847.2 km. Investments of R$ 2.05 billion during a 30-year contract are expected.

The auction of the BR-040/DF/GO/MG stretch was performed on 27th December, with Investimentos e Participações em Infraestrutura S.A (Invepar) being the winner by offering a toll rate of R$ 3.22. That bid meant a discount of 61.13% compared to the maximum tariff of R$ 8.29763 set on the auction notice (MINISTÉRIO DOS TRANSPORTES, 2015).

2.4.5.3 Motorway Concessions Planned in the PIL

On 31st January 2014, the Brazilian Government announced an investment of more than R$ 17.8 billion, totalizing R$ 50 billion, resources coming from the private sector. The Ministry of Transport authorized private companies to carry out studies on motorway stretches, including the Rio-Niteroi Bridge. These studies aim at concessions of the BR-364/060/MT/GO stretch (703.7 km) from Rondonópolis (MT) to Goiânia (GO); BR-364/GO/MG stretch (439.2 km) from Jataí (GO) to the BR-153/MG junction; and BR-476/153/282/480 stretch (493.3 km) from Lapa (PR) to the border of Santa Catarina and Rio Grande do Sul, passing by Chapecó (SC) (MINISTÉRIO DOS TRANSPORTES, 2015).

The deadline for elaboration and presentation of complementary technical studies on the four motorway stretches for future concessions would be on 17th November 2014, but according to ordinance number 396 by the Ministry of Transport, it was extended to January 2015 after request by the authorized companies (MINISTÉRIO DOS TRANSPORTES, 2015).

Studies have to consider demand, engineering, operation, traffic flow, environment and economic-financial modelling, including support for elaboration of document drafts. A selection commission, formed by members of Ministry of Transport, National Agency for Land Transport (*ANTT*) and Planning and Logistics Enterprise (*EPL*), was constituted to support the Ministry of Transport’s decision on technical studies to be selected and amounts due by way of compensation. The studies can be used partially or fully in case of bidding. Both evaluation and selection will be performed according to criteria established in legislation (MINISTÉRIO DOS TRANSPORTES, 2015).

Concessions of BR-364/060/MT/GO; BR-163/230/MT/PA; BR-476/153/282/480/PR/SC and BR-364/GO/MG

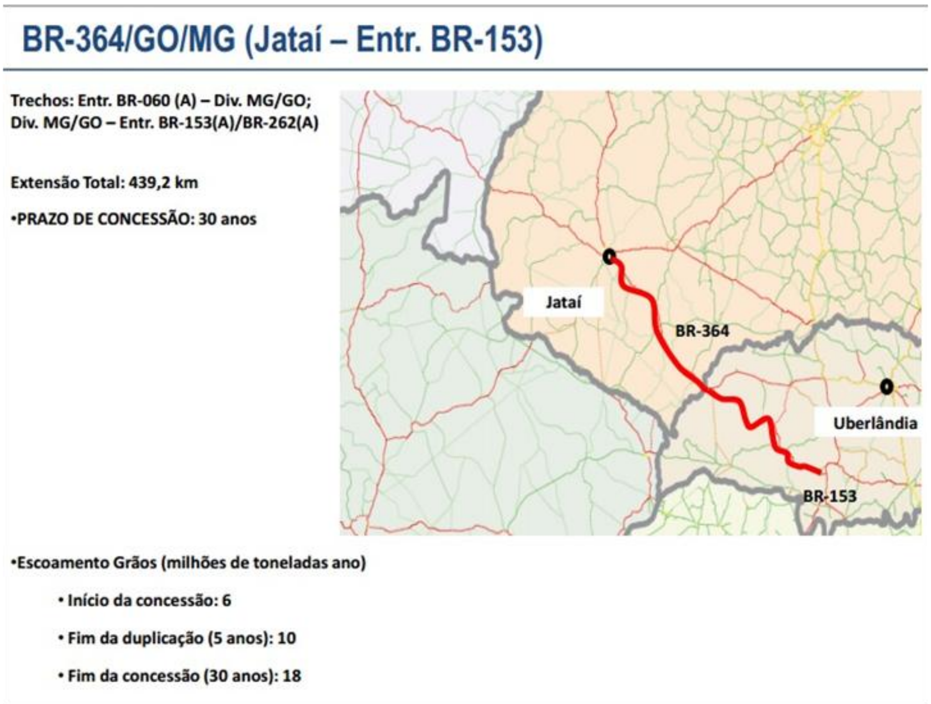
Studies were elaborated for granting period is 30 years, during which the public services for recovery, operation, maintenance, monitoring, conservation, improvements, capacity enhancement and service maintenance level are to be performed for the motorway stretches listed on the maps below (MINISTÉRIO DOS TRANSPORTES, 2015)..

History Records

- **19/05/2014 -** According to the established rules, the authorized companies should deliver a work plan describing in detail the schedule of activities to be performed. On this date, the Secretary for Implementation of Transport Actions of Mato Grosso (*SFAT/MT*) issued the authorization for the companies to deliver the work plan on the established deadline as follows: BR-364/060/MT/GO (8 companies), BR-163/230/MT/PA (7 companies), BR-476/153/282/480/PR/SC (7 companies) and BR-364/GO/MG (5 companies). The other companies had their authorization revoked.
- **28/02/2014 –** The Ministry of Transport authorized studies on concessions of BR-364/060/MT/GO (19 companies), BR-163/230/MT/PA (20 companies), BR-476/153/282/480/PR/SC (18 companies) and BR-364/GO/MG (18 companies).
- **03/02/2014 –** The Ministry of Transport invited companies interested in performing studies on four motorway concessions. The call notice was issued by the Union Official Diary on 3rd February 2014 (MINISTÉRIO DOS TRANSPORTES, 2015).

Figure 8 shows the concession from Goias to Minas Gerais, one of important states in Southeast Region, that makes facilities for product´s transports and shows the stretches; total extension: 439.2 km; Granting period: 30 years; Flow of Grain (million tons/year). Beginning of concession: 6; End of duplication (5 years): 10; End of concession (30 years): 18.

Figure 8 – BR-364 from Goias to Minas Gerais



Source: Ministério dos Transportes (2016).

Rio-Niteroi Bridge

The society's contributions to the public hearings regarding the process of concession of the Rio-Niteroi Bridge are being analyzed. These contributions have already been analyzed and the concession plan was approved by the Minister of Transport on 1st December 2014. The document was sent to the Union Accounting Tribunal (TCU) for assessment before publishing of the call notice. With an extension of 13.2 km, the Rio-Niteroi Bridge (BR-101/RJ) was granted to private initiative on 1st June 1995 for commercial operation and investment in infra-structure for a period of 20 years. The present contract terminates in May 2015 (updated in 17/13/2014) (MINISTÉRIO DOS TRANSPORTES, 2015).

Studies: Complementary studies by CCT on the concession via EIP (expression of interest process) were selected by a technical commission established by the Ministry of Transport.

Concession: The granting period is 30 years, during which commercial operation and public services for operation, maintenance, monitoring and conservation of the bridge are to be performed, including improvements in the access section to Presidente Costa e Silva Bridge in Niteroi and RJ-071 junction (Linha Vermelha) in Rio de Janeiro.

History Records

- **01/12/2014 -** The Ministry of Transport approved the concession plan according to publication on the Union Official Diary. The plan for concession of the Rio-Niteroi Bridge for commercial operation was presented by *ANTT*, being one of the phases of the new concession process regarding the BR-101/RJ stretch, which extends from the access section to Presidente Costa e Silva Bridge in Niteroi to the RJ-071 junction (Linha Vermelha) in Rio de Janeiro. The concession plan has all the details on the stretch to be granted, covering the current situation as well as projections of what should be done to improve it.
- **From 10th to 24th October 2014 -** In this period, the National Agency for Land Transport (*ANTT*) performed public hearings, which received contributions to the concession process. The first hearing (number 12/2014) welcomed suggestions on the drafts of call notice and concession contract, while the second (13/2014) addressed studies on technical and economical feasibilities, Motorway Exploitation Program (MEP) and works of Avenida Portuária. In-person sessions were also held in the cities of Rio de Janeiro (15/10/2014) and Brasília (17/10/2014) (MINISTÉRIO DOS TRANSPORTES, 2015).
- **07/10/2014 -** The Ministry of Transport approved the complementary studies on concession via EIP (expression of interest process) presented by the Companhia de Concessões Rodoviárias (CCR). Authorization was published on the Union Official Diary (MINISTÉRIO DOS TRANSPORTES, 2015).
- **22/09/2014 -** The deadline to deliver the concession studies is over. Three companies were selected to perform studies: CCR, the current concessionaire of the bridge; Invepar; and Planos Engenharia. However, Invepar did not deliver any study, and thus only CCR and Planos Engenharia had their studies sent for evaluation (MINISTÉRIO DOS TRANSPORTES, 2015).
- **27/02/2014 -** The Ministry of Transport authorised 12 companies to perform studies on the concession of the Rio-Niteroi Bridge. In addition to CCR – the current concessionaire of the bridge, the companies Ecorodovias, Estruturadora Brasileira de Projetos (EBP), Construtora Queiroz Galvão, Investimentos e Participações em Infraestrutura S.A (Invepar), Empresa Global de Projetos (EGP), Planos Engenharia, Carioca Christiani-

Nielsen Engenharia, Proficenter Construções, Odebrecht, Construtora Cowan and Saitec Brasil were authorised as well (MINISTÉRIO DOS TRANSPORTES, 2015).

- **29/01/2014 -** The Ministry of Transport invited companies interested in performing studies on the concession of the Rio-Niteroi Bridge. The call notice was issued by the Union Official Diary on 29th January 2014 (MINISTÉRIO DOS TRANSPORTES, 2015).

Concessions of Motorways

The Federal Roads Concession Program covers 11,191 km of motorways and it is unfolded into concessions promoted by the Ministry of Transport and state governments by means of delegations based on law number 9.277/96 as well as by the National Agency of Land Transport (*ANTT*). Currently, *ANTT* manages 21 motorway concessions, totalizing 9,969 km. Five of these concessions were contracted by the Ministry of Transports between 1994 and 1997, one by the Government of Rio Grande do Sul in 1998 (with later Delegation Agreement for Motorways denounced and contract subrogated to the federal government), eight regarding phases I (2008) and II (2009) of the second stage, one regarding phase II (2013) of the third stage, and, finally, six concessions regarding phase III (2013 and 2014) of the third stage, all belonging to the Program for Investments in Logistics (MINISTÉRIO DOS TRANSPORTES, 2015).

In table 4, one can verify the concessions for motorways in Minas Gerais and Rio de Janeiro. These concessions refer to stretches that cover a greater number of points between cities. That the objective is to increase investment in motorways, or better, investment in a polluter modal of transportation.

Table 4 - List of Motorway Concessions

Nova Dutra	BR-116/RJ/SP, stretch from Rio de Janeiro to São Paulo
Ponte Presidente Costa e Silva:	BR-101/RJ, stretch from Rio de Janeiro to Niterói
CONCER:	BR 040/MG/RJ, stretch from Juiz de Fora (MG) to Rio de Janeiro (RJ)
CRT	BR-116/RJ, stretch from Além Paraíba to Teresópolis (BR-040/RJ junction)
Autopista Régis Bittencourt	BR-116/SP/PR, stretch from São Paulo to Curitiba
Autopista Fernão Dias	BR-381/MG/SP, stretch from Belo Horizonte to São Paulo
Autopista Fluminense	BR-101/RJ, stretch from the border of RJ/ES to the Presidente Costa e Silva bridge
Rodovia Transbrasiliana	BR-153/SP, stretch from the border of MG/SP to the border of SP/PR
Rodovia do Aço	BR-393/RJ, stretch from the border MG/RJ to the BR-116 junction

Source: Ministério dos Transportes (2014).

2.4.6 Airway Network

The program for federal airport concession began in 2011 with the auction of the São Gonçalo do Amarante airport in the state of Rio Grande do Norte. In February 2012, the federal government performed another concession round in which the airports of Brasília (DF), Guarulhos (SP) and Campinas (SP) were granted to private initiative. In December of the same year, the federal government had launched the PIL for airports in order to improve the quality of the services as well as the infra-structure, increase the supply of air transport to the population in Brazil. Amongst these measures, one can cite the concessions of airports of Galeão (RJ) and Confins (MG) and programs of investments for regional airports (MINISTÉRIO DOS TRANSPORTES, 2015).

On 9th June 2015, a new stage of the Program for Investment in Logistics (2015-2018) was launched. In the airport sector, the program aims to increase the infra-structure, improve the quality of services, bring more innovation and experience from international operators, boost tourism, improve cargo transport, and create new regional hubs by means of concessions of the airports. Further R$ 78 billion will be invested in concessions of regional airports in Araras (SP), Bragaça Paulista (SP), Campinas/Amarais (SP), Itanhaém (SP), Jundiaí (SP) and Ubatuba (SP) (MINISTÉRIO DOS TRANSPORTES, 2015).

In the stage of EIP, the deadline was ended on 10/07/2015, with 100 expressions of interest being obtained from 30 different companies registered. Each company had 90 days for finishing their studies and presenting them on 26th October 2015. Seven studies were presented as follows: only one consortium delivered studies on the four airports; other delivered studies on the airports of Salvador and Fortaleza; and one delivered a study on the airport of Fortaleza. The best studies were selected for each airport based on evaluation made by a commission of technicians of the Secretary of Civil Aviation SCA), and the list of the winner companies was published on 15th November 2015(MINISTÉRIO DOS TRANSPORTES, 2015).

In table 5, the five stages to granted a railway in Brazil like a process to make road transport viable.

Table 5 - The Five Stages of Concession

• FIRST STAGE: (STUDIES ON TECHNICAL, ECONOMIC AND ENVIRONMENTAL FEASIBILITIES)	• Public call notice by the Secretary of Civil Aviation for presentation of companies interested in performing studies on technical, economic and environmental feasibility for concessions via expression of interest process (EIP); • Execution and delivery of studies on technical, economic and environmental feasibility; • Analysis and selection of studies by the Secretary of Civil Aviation before assessment by ANAC and TCU; • Average Deadline: 140 days
• SECOND STAGE (TCU – Phase I)	• Assessment of studies on technical, economic and environmental feasibility • Agreement – Approval of the studies. • Average Deadline: 45 days
• THIRD STAGE (Public Hearing)	• Elaboration of auction call notice and draft of contract • Public hearing for discussion on auction and contract elaborated by ANAC • Reception of contributions • Average Deadline: 65 days
• FOURTH STAGE (Call Notice Publication)	• Adjustments in the call notice and contract based on both contributions from the public hearing and judicial opinion by ANAC • Average Deadline: 30 days
• FIFTH STAGE (Auction process)	• Deadline to ask for clarification regarding the call notice • Publication of the minutes regarding clarifications by ANAC • Judgment of challenges regarding the call notice • Receipt of envelopes • Analysis of the proposed guarantees • Auction • Average Deadline: 60 days

Source: Adapted from Ministério dos Transportes (2016).

3 THE STATE OF SOUTHEAST BRAZILIAN LOGISTICS

The current moment of the national economy, many companies that have distribution centers are choosing to lease logistic sheds, allowing the reduction of operating costs, releasing capital for retail activities. Among the main companies that are looking for logistics alternatives such as leasing are the large retailers, including e-commerce and multinationals. The Southeast has the most extensive and diversified transportation network in the country. However, for goods to move around the region, either internally or for export, it is necessary to improve existing routes and create new outlets for cargoes produced to reduce transport costs and improve the competitiveness of the economy. Figure 9 shows Southeast composition, it has four states: MG – Minas Gerais, ES – Espírito Santo, SP – São Paulo e RJ – Rio de Janeiro.

Figure 9 – Brazilian Southeast

Source: Anjos (2017).

Characteristics of Southeast states:

Espírito Santo:

Capital – Vitória.

Territorial Extension – 46.098,571 km².

Number of Municipalities – 78.

Population – 3.514.952 population.

Demographic Density – 76,2 hab/km².

Participation in regional GDP – 4%.

Human Deveploment Index – 0,802 (7° national position).

(IBGE, 2017)

Minas Gerais:

Capital – Belo Horizonte.

Territorial Extension – 586.520,368 km².

Number of Municipalities – 853.

Population – 19.597.330 population.

Demographic Density – 33,4 hab/km².

Participation in regional GDP – 16,1%.

Human Deveploment Index – 0,800 (10° national position).

(IBGE, 2017)

Rio de Janeiro:

Capital – Rio de Janeiro.

Territorial Extension – 43.780,157 km².

Number of Municipalities – 92.

Population – 15.989.929 population

Demographic Density – 365,2 hab/km².

Participation in regional GDP – 19,8%.

Human Deveploment Index – 0,832 (4° national position).

(IBGE, 2017)

São Paulo:

Capital – São Paulo.

Territorial Extension – 248.196,960 km².

Number of Municipalities – 645.

Population – 41.262.199 population

Demographic Density – 166,2 hab/km².

Participation in regional GDP – 60,1%.

Human Deveploment Index – 0,833 (3° national position)

(IBGE, 2017)

From the characteristics of the region one can verify that the four states are responsible for a significant participation in the gross domestic product of the country. The state of São Paulo participates with about 60%. For this reason, studying this region and the improvements that logistics can bring becomes preponderant.

The Southeast is the most developed in the country Economic concentration and regional imbalances remain high, with the Southeast and South retaining most of the country's wealth. Even with the maintenance of these disparities, there is a tendency to reduce the income share of these regions towards peripheral ones. However, this process occurred mainly in the North and Central-West regions, considering that the Brazilian Northeast had a share of the country's GDP in 2011 lower than that held in 1960. However, since 1970, the loss of participation of the Southeast Region is visible, with a drop of 10.1 pp in total. An important relative loss, however small and insufficient to reverse the historical picture of regional imbalances. It should be noted that the relative reduction of São Paulo represented about 80.0% of the decrease in the share of the Southeast in the Brazilian GDP (MACEDO et al., 2017).

In the last three decades, the pace of growth of the Brazilian economy has been quite different, influencing the regional productive deconcentration rhythm in the country, as described by Cano (2008). GDP grew at a rate of 1.6% pa between 1980 and 1990; 2.5% a.a. between 1990 and 2000 and 3.6% a.a. between 2000 and 2010. Between 2003 and 2012, when determinants of domestic policy and the pace of commodity exports generated dynamic effects on the regional economies, especially in the Northeast, Midwest and North of the country, the Brazilian average grew by 3.9 % aa. As a result, GDP per capita varied over the same periods on average -0.4% a.a. (1980-1990), 0.9% a.a. (1990-2000), 2.4% (2000-2010) and 2.8% a.a. (2003-2012). In 2000, GDP per capita in real terms was only 4.8% higher than in 1980, which confirms the poor performance of the country's economy in the last two decades of the 20th century (MACEDO et al., 2017).

Despite this low performance, productive deconcentration continued, however, the difference between regional GDP per capita remains great, especially when a comparison is made between the North and Northeast regions, both in relation to Brazil and the Southeast region. It is important to note that in the first decade of the 21st century there is a small decrease in these differences due to social policies, real wage growth, employment generation and greater formalization, which tend to have a more favorable impact on the areas where poverty presents itself, which are located in the two regions mentioned above, especially in their rural areas. It was also important to recover economic growth, as it increased real income in the country, which had more favorable repercussions in less developed regions, especially through increased consumption. This was also influenced by the expansion of the credit and financing modalities that emerged in the post-2003 period, more rapidly expanding the retail trade of these two regions (MACEDO et al., 2017).

The role of productive public expenditure and gross capital formation is also worth mentioning, since the resumption of growth after 2003 and the location of investments - public and private - outside the Southeast also played an important role in this process of relative reduction of regional disparities which, despite this, remain high. The Gross Capital Formation - FBK for the aggregate Brazil, in fact, grew in this century, at average annual rates in a rhythm higher than the last two decades of the twentieth century, although the FBK / GDP ratio did not grow very expressively. The relative growth of public investments is observed. It is important to emphasize, that public investment - other than private investment - can be driven by criteria other than those of the market, fulfilling an important role for the dynamics of less developed regions (MACEDO et al., 2017).

Public spending has always been an important element for the socioeconomic dynamics of the Brazilian regions and for their transformation, often exerting greater influence than the regional development policies themselves. These, after all, usually functioned as real levers for capitalist accumulation outside the Southeast, without taking into account the specificities of the target regions. In general, regional policies, while important for productive deconcentration, have legitimized market logic by financing investments in those areas that were already the most densely populated in the policy regions: major state economies and state capitals. Public expenditures, especially those of a social nature, because they are broader and not necessarily subject to market decisions, as well as private investments that are financed by regional policies, often end up being the main determinant of socio-spatial dynamics of less economically densely populated areas (MACEDO et al., 2017).

In relation to public investments, it is observed that PAC (Growth Accelaration Program) works are disconcerting in character, as the participation of the North and Northeast regions in the investment portfolio surpasses their participation in the Brazilian GDP. In regions with worse social and infrastructural indicators, this direction represents a positive action in order to reduce regional inequalities. However, from the socio-environmental point of view, the negative effects of many of these investments, mainly in energy infrastructure in the Northern Region, are the object of denunciations in academic, journalistic and public prosecution. This indicates a possible worsening in the quality of life of populations living in areas close to these investments (MACEDO et al., 2017).

The deconcentration that takes place in the Brazilian economy manifests itself in all its sectors. As highlighted in the country's regional literature, 1970 marks the peak of the economic concentration process in São Paulo, when its industrial production reaches 58.2% of the country's total, according to information from the extinct Industrial Census of the Brazilian Institute of Geography and Statistics (IBGE). From this point of view, there is a process of industrial deconcentration, but also of other sectors, motivated by several factors, whose manifestations occur with distinct temporalities and are highlighted later (MACEDO et al., 2017).

Data from the latest versions of the Annual Industrial Survey (PIA) and the Regional Accounts (CR) - both from IBGE - confirm the continuation of regional economic deconcentration in Brazil, which began in the late 1960s and early 1970s. The most evident mark of this period is the loss of participation of the state of São Paulo in both GDP and, mainly, in the manufacturing industry (MACEDO et al., 2017).

The main factors of economic deconcentration manifested in a different rhythm and of temporally distinct forms in the last four decades (MACEDO et al., 2017), as:

• the deconcentrated base of natural resources, which became more demanded by the policy of intensification of extractive industries, and which displaced a series of investments outside the South and Southeast regions;

• the role of the State through direct investment in the periphery, especially by the former state-owned companies until the 1980s. This role was partly recovered in the post-2003 period by the deconcentrating investments of Petrobrás, as can be seen, for example, in Pernambuco;

• the regional development policies, which until the early 1980s stimulated investments in the areas of the extinct SUDENE and SUDAM;

• the integration of the national market, creating new spaces for investment, especially the industrial;

• the expansion of the agricultural frontier in areas with large extensions and land, which stimulated, in addition to agricultural investments, agroindustrial investments linked to the primary production base;

• the low growth rate of the Brazilian economy in the 1980s and 1990s would have affected São Paulo's economy more than the less developed areas, which would have demonstrated statistical desconcentration;

• policies to encourage exports and rural credit in the 1970s and 1980s that benefited investments outside the industrial center;

• the fiscal war, especially since 1994, which attracted investments to the North, Northeast and Central West regions and to the state of Espírito Santo;

• the diseconomies of urbanization of the Metropolitan Region of São Paulo, making investments in this area more expensive and promoting a process of industrial deconcentration towards the interior of the state of São Paulo and to other federal units. This movement was important to redefine the territorial division of labor in Brazil and reaffirm the role of the capital of São Paulo and its metropolitan region as the main and most diversified locus of the country's tertiary;

• the economies of agglomeration in new regions and medium cities that present costs to locate productive investments smaller than the metropolis of São Paulo;

• the deconcentrated profile of the Brazilian urban system that allowed investments to be made in urban centers scattered throughout the Brazilian cities network and stimulated by the expansion of the road network in the post-1960 period;

• the trade opening that favored exporting centers outside the industrial nucleus, as will be discussed in the last part of this chapter;

• the resumption of public and private investments, directing a significant portion of them outside the South and Southeast. When it´s observed the pattern of socio-spatial organization in Brazil at the beginning of the XXI century some aspects stand out:

• the generalization of urbanization that affected practically the entire Brazilian territory and stimulated civil construction in more internalized areas, not just metropolitan areas;

• greater internalization of economic growth, derived mainly from the model of foreign commercial insertion of the country;

• a larger growth of medium-sized cities with an increase in the supply of services and commercial activities outside the metropolitan areas;

• more diversified and complex economic structures in the North, Northeast and Center-West regions resulting from the productive deconcentration that had been stimulated by multiple determinants since the end of the last century, export effort; and to the effects of the post-2003 Brazilian economic movement;

• a greater differentiation of the territory with areas whose productive structures connect to the consumer and production markets of Brazil and abroad and others that are excluded from this process, as will be highlighted in the next two sections.

Its economy is the most developed and industrialized among the economies of the five Brazilian regions, concentrating more than half of the national production.

Driven by the largest automakers and steelmakers in the country, industrial production is diversified. São Paulo concentrates the largest industrial park and participates with 36.5% of GDP (reference: 1999). Although the footwear and textile industries are the most heated, at the end of the 1990s there was a relative drop in investments in the industrial sector, mainly due to the fiscal incentives adopted by other regions. Even so, the Southeast manages to keep its share of industrial GDP high. In the course of the decade, the interior of São Paulo emerged as one of the main centers of investment attraction (IPEADATA, 2016).

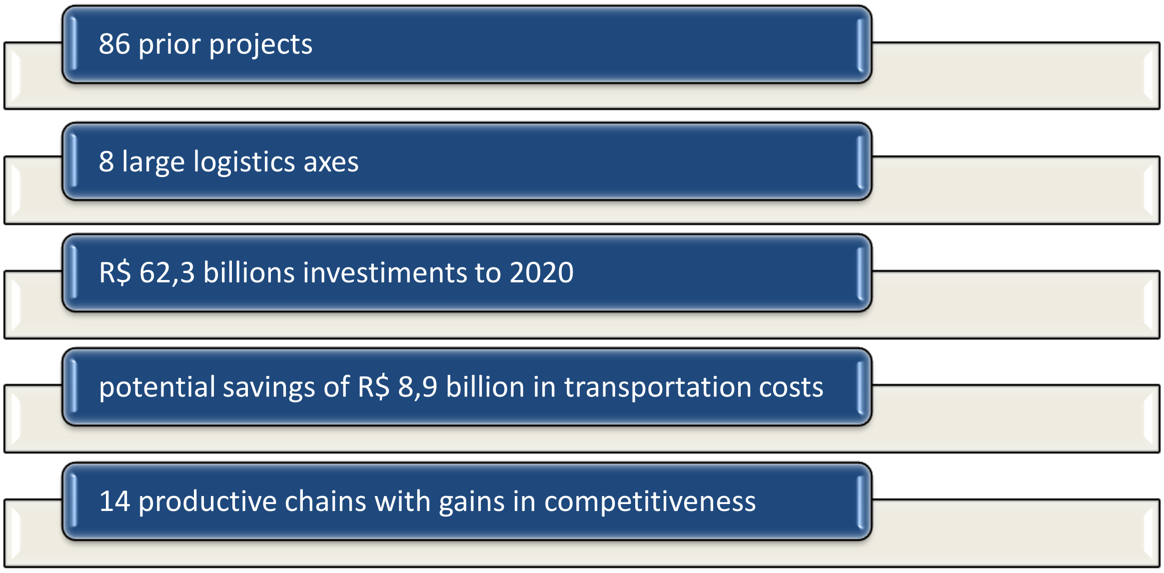
Agriculture demonstrates high technical standards and good productivity. The production of coffee, orange, sugar cane and fruit is among the most important in the country. In livestock production, the share of agricultural GDP fell from 38.9% in 1985 to 36.3% in 1998. In Minas Gerais, a large variety of ores - especially the iron and manganese reserves in the Espinhaço -, and the Campos Basin, in Rio de Janeiro, leaves most of the Brazilian oil (IPEADATA, 2016).

Housing 42.5% of the Brazilian population and responsible for 58.7% of the national GDP (327.5 billion dollars in 1999), the Southeast presents great contrasts. At the same time that it concentrates the greater part of the national wealth, it is the region that most suffers with unemployment and the growth of violence. Even so, its social indicators show the best in the country: illiteracy in the region is 8.1%, treated water benefits 95.9% of households and sewage is collected in 83.8% of the homes. In Brazil, these rates were 14.7%, 78.8% and 63.9%, respectively (IPEADATA, 2016).

The service sector is the main segment of activity and accounts for most of the wealth of the Southeast. The agriculture is very dynamic and diversified, stands out the cultivation of coffee, orange and sugar cane. Mining is another important economic activity: Minas Gerais has large reserves of iron and manganese; Most of the oil produced in the country is extracted from the Campos basin in Rio de Janeiro (CNI, 2016).

In order to ensure the agile and efficient flow of production, in the domestic market or for export, the Southeast region needs US$ 19.15 billion in investments in the transportation network. This is the value needed to execute, by 2020, 86 priority projects to modernize and integrate the logistics system of Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo (CNI, 2016). Once completed, the works will provide an annual savings of up to US$ 2.70 billion with freight transport to the productive sector, based on the projected movement towards the end of the decade. There are main measures to make logistics in the Southeast region more competitive that can be seen in figure 10.

Figure 10 - Southeast Competitive Project



Source: CNI (2016).

The conclusions are from the Southeast Competitive Project, prepared by the National Confederation of Industry (CNI), in partnership with the industry federations of the states of the region, in Belo Horizonte (MG). With the document, the CNI closes the series of works that traces a diagnosis of the national transport network and identifies and points to the public power the logistical axes that can most increase the efficiency of transportation, optimizing investment resources (CNI, 2016).

To reach the priority projects, 337 works of expansion and modernization of ports, airports, railways, highways, waterways and pipelines were analyzed. Completing them would mean investing R $ 219.1 billion, by 2020, with an annual reduction of R $ 13.4 billion in transportation expenses. To optimize the application of resources, the Southeast Competitive selected the set of projects that, with the lowest cost, will reach the largest economy. Thus, with 28.8% of resources (R $ 63.2 billion), it reaches 66% of the potential economy (R $ 8.9 billion) projected for 2020 (CNI, 2016).

About logistics cost, the consolidation of the logistics axes will have a significant impact on the competitiveness of the productive sector in the Southeast. The region currently spends R $ 108.4 billion in transportation costs - including freight, tolls, transhipment and terminal costs, port tariffs and maritime freight, which corresponds to 4.5% of the region's

GDP. If nothing is done, this value will reach R $ 162.8 billion in 2020. On the other hand, when the priority projects are completed, the transportation cost paid by the Southeast productive sector can be reduced by up to 5.4% (CNI, 2016).

For the country, it would mean speeding up and cheapening the flow of products in the region that represents more than half of the Brazilian GDP and shelters the densest industrial park in the country, as well as important agricultural and cattle-raising industries. In 2012, industrial production in the Southeast totaled R $ 1.08 trillion, of which 60% is concentrated in 14 production chains, which will benefit from the reduction in the cost of transportation to receive inputs and to dispose of its production, internally or for export (CNI, 2016).

The 86 priority projects constitute eight major logistical axes, great routes capable of integrating the Southeast with the neighboring states and ensuring agile and efficient movement of inputs and merchandise. The CNI considers the execution of the urgent works, under risk of aggravation of stretches already congested and consequent increase of costs for the productive sector. Half of these strategic routes already exist and require improvements, such as expansion and modernization. The others need to be planned and executed quickly. The main logistical results can be seen in table 5.

Table 5 - Logistics Axes to Competitive Southeastern

Existing Axes	**Potencial Economy in million (U$)***	**News Axes**	**Potencial Economy million (U$)***
1. MotorwayBR-153 Sul: Goiás via Ourinhos (SP)	74	1. Ferrovia EF 354: Anápolis (GO) - Ipatinga (MG) - Açu/Central (RJ)	128
Railway ALL: Mato Grosso – Santos (SP)	112	2. Pipeline: Morro do Pilar (MG) - Naque (MG) - Linhares (ES)	62
Motorway BR-050: Brasilia (DF) – Santos (SP) BR	263	Railway: Grao Mogol (MG) – Sao Mateus (ES)	9
Motorway BR-116 Sul-Nordeste: Via Dutra and Rio de Janeiro	217	Railway MRS and Iron Road 118: Suzano (SP) - Vitória (ES)	63

Source: Projects Competitive Southeastern (CONSELHO NACIONAL DA INDÚSTRIA, 2016).

*Anual Economy, based cargo projection to 2020.

According to the Competitive Southeast, the expansion and improvement of the railway network is a priority to improve the logistics system of the region, with most of the investments. By 2020, the modal requires R $ 30.7 billion in investments, or 48.5% total projected by the Project, to connect important productive centers in the interior of the states to ports, mainly. The maritime terminals, in turn, account for 22 urgent projects, which require R $ 16.6 billion in construction, expansion and improvement works to improve the competitiveness of the region's productive sector (see table 6).

Table 6 - Projects and investments for types of transportation

Modal	Number of projects	% total	Investiment (US$)	% total
Railway	32	37,2	9,3 billions	48,5
Road	31	36	4,45 billions	23,4
Port	22	25,6	5 billions	26,2
Pipeline	01	1,2	36 millions	1,9
	86		19 billlions	

Source: Project Competitive Southeastern (CNI, 2016).

The Competitive Southeast notes the urgent need to accelerate the planning and execution of infrastructure works in the region. According to the study, only 16 of the 86 priority works are in progress. Another 70 are in the planning stage, planning or only in the plans of the public power, without having entered the initial stage of elaboration of the basic project. These projects need, in the view of the CNI, to be accelerated under penalty of aggravating the saturation already faced by the companies to sell their production. In São Paulo, for example, the BR-116 (Via Dutra) operates almost twice its capacity in multiple stretches of the highway. In Minas Gerais, the BR-262 route between Bela Vista and Belo Horizonte receives 32% more cargo than it does at peak times (CNI, 2016).

The Southeast Competitive Project is the latest publication of the Regional Competitiveness Studies series, sponsored by CNI and state industry federations. The North (July 2011), the South (August 2012), the Northeast (October 2012) and the Midwest Competitive (October 2013) were presented. Regional studies provide subsidies for the government to plan the future of the logistics system, optimize resources and reduce transportation costs in Brazil (CNI, 2016).

4 SUGARCANE PRODUCTION

Today, Brazil is the world's largest sugar producer and as the terminal is located in one of the main producing regions of our country, more than 30 mills use the transport of sugar by train to the Port of Santos, where the product is shipped to export. Rail freight, besides having a more competitive cost, brings a great environmental benefit, reducing the number of truck trips and the emission of greenhouse gases, as well as unloading the traffic on the highways that lead to the port.

Currently, more than 130 countries produce either sugarcane or sugar beet, and ten of these produce sugar from both cane and beet crops. Sugarcane, on average, accounts for 80% of global sugar production. Production has become increasingly concentrated. In 1980 the top ten producing countries accounted for 56 % of global, whereas in 2014 the top ten accounted for 75%. The top ten sugar producers are listed below in table 7. Brazil is most large sugar producer in the world. So, it represents a important role in sugar commodity:

Table 7- Largest Sugar Producers in World

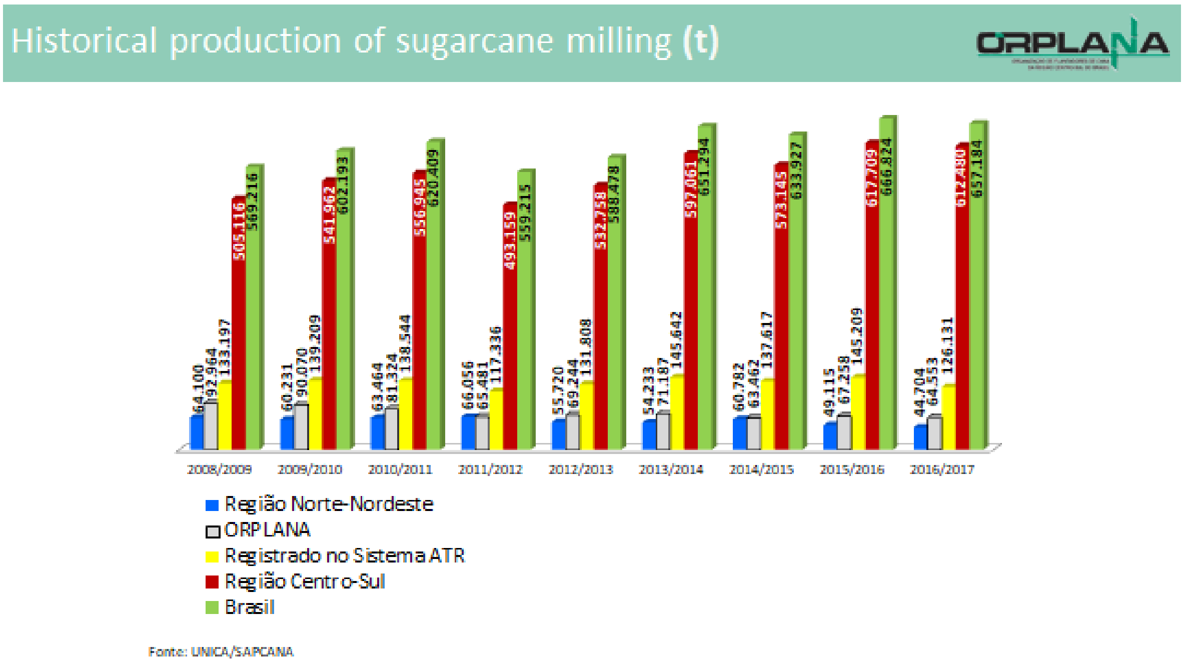
Position	Country	(mln t)
1	Brazil	34.24
2	India	28.87
3	EU – 28	15.30
4	Thailand	11.00
5	China	10.26
6	United States	7.70
7	Pakistan	6.13
8	Mexico	5.88
9	Russian Fed.	5.10
10	Australia	4.82
	World	169.083

Source: ISO Sugar Yearbook (2015).

It can be verified that Brazil occupies a prominent position among the largest sugar producers. This is basically due to the fact that Brazil has, historically, a culture rooted in the cultivation of agrofood, such as sugar cane and coffee, from the European colonizers in past centuries. In addition, the favorable climatic conditions and Brazilian soil quality. This has made Brazil one of the great highlights in the commercialization of commodities for many years and until the present day.

Figure 11 shows historical production of sugarcane during last ten years. It was observed that the red column represents center-south region of Brazil and it´s the main. Its performance is increasing over time analyzed. The green one represents the total of Brazil. The gray one represents Organization of Cane Producers in the Center-South Region of Brazil and the yellow one represents agricultural controller for sugarcane producers, both are localized in south and southeast regions.

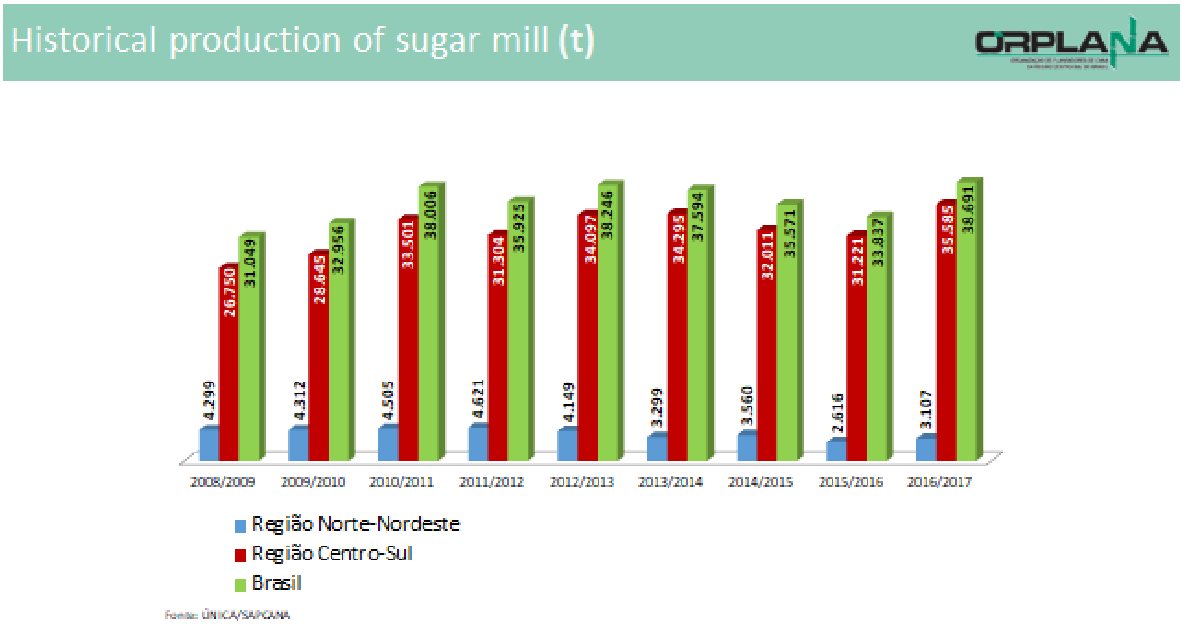
Figure 11- Historical Production of Sugarcane



Source: UNICA/SAPCANA (2017).

Figure 12 shows a historical production of sugar mill from 2008 to 2017. The green one column shows total production of Brazil. The red one shows South-Center Region production and the blue one shows North-Northeast production. Again, once again, the south-southeast region deserves to be highlighted in the production of sugar, confirming the position of great importance in the national production. Once again, the south-southeast region deserves to be highlighted in the production of sugar, confirming the position of great importance in the national production.

Figure 12 - Historical Production of Sugar Mill



Source: UNICA/SAPCANA (2017).

5 SUGAR TRANSPORT

The main objective of transport is to move products from a place of origin to a specific destination while minimizing financial, temporal and environmental costs. The expenses of losses and damages should also be minimized. At the same time, the movement must meet the customers' expectations regarding the performance of deliveries and the availability of information on the cargoes transported (BOWERSOX; CLOSS, 2001).

The modalities of transport are: rail, road, waterway, pipeline and air and the decision of a user to move their cargo depends basically on costs and the operational characteristics of each modal. Of the five existing transport modes, only three are used in the sugar disposal. Aerial mode is not feasible for commodity transport and the pipeline mode is not used due to the physical characteristics of the product. Thus, sugar is transported via highways, railroads and waterways (KUSSANO; BATALHA, 2009).

The main means used in the country until arrival at the port is the road mode followed by the railway mode. The highway is still the most used medium due to the inability of the railroads to transport the demand offered. According to Faria (2007), the choice of mode of transport is influenced by the factors costs, transit time from origin to destination, risk (involving the integrity of the cargo) and frequency (regularity of transport). Usually, the cost factor is the most important in economic and financial terms, but the other factors can also compromise the definition of the mode of transport, being related to the service level required (KUSSANO; BATALHA, 2009).

The cost of transportation is the most representative of logistics costs. Within this cost the most important factor is freight. If you transport outsourced pain, your costs are seasonal due to competition in certain periods with crops from other crops even with those from other sugar mills. But in addition to shipping freight, it is important to consider other variables that affect sugar handling. An important variable to be studied when analyzing sugar transport is the loss during the transportation process. The amount of cargo lost depends on the mode used, type of product packaging, state of the fleet and roads. Packaged products do not present loss in expecting order of magnitude expectations of losses, even in bulk the loss is significant (KUSSANO; BATALHA, 2009).

5.1 Transfer costs at terminals

Intermodality is achieved when there is more than one mode of transport. That is, the merchandise is transport from its point of origin to its final destination by different modalities.

In intermodality, a transportation knowledge is issued for each modal and the responsibility is divided among the transporters. In multimodality, on the other hand, there is the emission of only one transport knowledge, covering the total route of the cargo, from its point of origin to its destination. This document is issued by the Multimodal Transport Operator (OTM), which assumes full responsibility for the cargo transported (KUSSANO; BATALHA, 2009).

In intermodal operations, the terminals play a fundamental role in the economic viability of the alternative. The most worrying thing is that it is precisely the terminals, one of the main barriers to the development of intermodalism in Brazil. Studies have shown a high standard of inefficiency in transport operations, especially in loading and unloading activities, where waiting times are generally very high compared to other countries' standards. This characteristic results in high transhipment costs, which, in many situations, end up making an intermodal operation unfeasible (ANGÊLO, 2005)

The cost of transhipment refers to the costs of transferring loads and modes of transport. The transhipment rates are defined by each specific terminal and are generally established according to the type of packaging of the product, eg bulk, general cargo, containers. According to Ângelo (2005), the rates charged by trans-shipment terminals, railroad, waterway and railways are difficult to raise, since there are many charging terminals that are negotiable values. But it can be considered that they are lower rates than those charged by the port terminals, where there is greater complexity in the movement of the port.

Transhipment operations may result in a significant physical loss of the goods, representing a cost of up to 1% in the price of the product and, consequently, a break in transportation, as well as implying a greater probability of having a stationary vehicle (CAIXETA-FILHO; GAMEIRO, 2011).

5.2 Storage Costs and Stocks

According to Ballou (2002), the cost of storage is the sum of the principal components that the company must pay for the storage system or the fees charged by an external company that offers the service. Therefore, it refers to the cost associated with the administration and operation of this space and not the cost of the product itself, property, plant and equipment.

In own deposits, annual depreciation expense must be appropriated by standard rate per square meter per cubic meter. The annual occupancy cost for a given product may be appropriate by multiplying the number of days that the physical space was used at the current standard rate for the year. The calculated value can then be divided by the total number of units of the product processed in the warehouse to determine the average storage cost per unit of the product. (BOWERSOX; CLOSS, 2001)

Inventory costs are those generated from the need to stock materials. In this category, the most expressive is the Opportunity Cost, which is the value that the company loses by immobilizing the capital stock instead of applying it in the financial market, and is remunerated by interest. There are other inventory costs, such as loss and theft, material depreciation itself and obsolescence. But in the case of grains these last cost factors are not relevant. The capital cost or opportunity cost of capital refers to the cost of money invested in the stock. According to Ballou (2002) this cost can represent 80% of the cost of maintenance in stock.

5.3 Port Costs

In the case of agroindustrial products, it is necessary to consider that the production peaks, coupled with an inadequate storage structure, have forced producers to dispose of their harvests immediately after harvesting, which leads to long queues in ports. The port of Paranaguá, for example, faced serious problems in the outflow of the harvest of the first half of 2004. The main consequences were the great congestion, both on land and at sea; the queue of trucks that was formed in the port for unloading reached more than 120 km and the waiting time of ships was excessive, with cases of ships that waited up to 60 days in the port (HIJJAR, 2004).

Based on this, when studying the logistics aspects of these products, one should consider the opportunity cost of the transit stock in the truck, since it is common for a truck to lose several days waiting to unload. Depending on the situation, the carrier may be reimbursed by means of freight complement mechanisms, such as the so-called pay per stay (CAIXETA_FILHO; GAMEIRO, 2001).

According to Faria; Costa (2012), the composition of the port costs refers only to the part of the terrestrial port infrastructure, that is, to the tariffs charged by CODESP (port authority) that include: the part of the labor force; and the reception, storage and lifting (loading) of sugar, charged by the private terminals. This set of services is also called "market rates" for shipment of products. Therefore, they are excluded: the terminal's remuneration; maritime agency; customs clearance; land transport to the port; storage at source; either the part of maritime transport (FARIA; COSTA, 2012).

In the case of sugar, the logistic cost is divided into six main costs as can be seen in table 8, following:

Table 8 - Total Logistic Cost of Sugar

Packing Cost	Package cost (sac, big bags)
Transport Cost	Shipping + Breaking + Opportunity cost of transit stock
Overrun cost at terminals	Intermediate transhipment rate (terminals) and ports + Breaks
Storage Cost	Storage rate in terminals and ports
Stock Cost	Opportunity cost of warehouse stock
Port Costs	Port taxes + remuneration per stay + Opportunity cost in transit

Source: Costa (2007).

Sugar moves a large amount of resources, but because it is a product of low added value it is necessary to optimize production, transportation and storage. Just as the expansion of sugarcane is moving to the interior of the country farther away from the main export corridors, the need to improve the logistics structure becomes even greater (KUSSANO; BATALHA, 2009).

6 PHYSICAL INTERNET CONTRIBUTIONS

As the PI concept was further elaborated and its potentiality assessed, solutions design research was next addressed in the literature. It starts by asking questions about why industry is not a position to do it now and then engages in generating solutions for filling the key gaps. It focuses on designing, engineering and testing methodologies and technologies enabling the implementation and exploiting of Physical Internet in industry across the world. There have been two main interlaced threads of solutions design research (PAN et al., 2017).

The first thread focuses on designing key Physical Internet components. Physical internet transportation network design was first tackled by Ballot, Gobet and Montreuil (2012). Designing Physical Internet container sets has been addressed by Lin et al. (2014) focusing on container dimensions, Gazzard and Montreuil (2015) on functional container design, Landschützer, Ehrentraut and Jodin (2015) on container requirements and engineering design, Sallez et al. (2016) on container intelligence and Montreuil, Ballot, and Tremblay (2016) on container types. Physical Internet facilities and material handling systems design has been addressed first by Montreuil, Meller and Ballot (2010), then by Ballot, Montreuil and Thivierge (2014), Meller (et al. (2014) and Montreuil et al. (2014), respectively, focusing on roadrail bimodal hubs, semi-trailer transit centers and road-based cross-docking hubs (PAN et al., 2017).

The second thread focuses on methodologies and models for addressing key Physical Internet induced planning and operations decisions in logistic networks. Sarraj et al. (2014) introduced protocols for PI transportation. Sallez et al. (2015) addressed container routing in a PI cross-docking hub. Exploiting mechanism design, Xu (2013) proposed a mechanism design model for transportation service procurement, then Qiao, Pan, and Ballot (forthcoming) proposed an dynamic pricing optimization model for transportation service providers in PI. Chen et al. (2016) provided a PI-inspired crowdsourcing solution for collecting E-commerce reverse flows (PAN et al. 2017).

In the context of hyperconnected mobile production, Marcotte, Montreuil, and Coelho (2015) introduced a deterministic optimization model for planning make-to-order production module transshipment. Inventory management in the Physical Internet context has been addressed by Pan et al. (2015) focusing on inventory control model and assessment, and Yang, Pan, and Ballot (2016) introducing PI focused inventory management models and assessing their impact on resilience, Naccache (2016) introducing a E-commerce focused hyperconnected distribution planning methodology (PAN et al., 2017).

Business model innovation induced by the Physical Internet has first been addressed by Montreuil et al. (2012). Cimon (2014) addressed implementation issues for PI and business models while Oktaei, Lehoux and Montreuil (2014) introduced a business model framework for PI logistics service providers focusing on logistics facilities such as transit centers (PAN et al., 2017).

Validation research focuses on performing case studies, field pilot studies, virtual pilot studies and living labs so as learn from industry anchored Physical Internet endeavours and to guide the implementation roadmap. This research is its early infancy. Hambleton and Mannix (2015) have reported on the case study of ES3´s openly collaborative distribution model. Part of European FP7 Programme, the recent Modulushca project on the Physical Internet in the consumer goods industry resulted in a stream of validation contributions, available at this point through its project report series. For example, Ballot and Montreuil (2016) reported on a validated 2030 vision and roadmap towards interconnected logistics in the fast moving consumer goods industry (PAN et al., 2017).

So, in Brazil, it can be done in the same way. Based on the explicit theoretical framework, it can be seen that the Brazilian logistics presents serious problems of infrastructure, maintenance, management, investment, multimodality, sustainability, transport, handle, storage, realized and supplied. All these problems are involved in the concepts of Physical Internet.

Brazil is among the leading developing countries with the highest growth potential in the world. It is currently among the twenty largest exporters in the world and only does not perform better due to lack of physical infrastructure. In this sense, the great brake of growth is the lack of quality of transport modes. The country has a good infrastructure of information, but it does not want to be in the physical infrastructure, especially with regard to the railway, road and maritime system.

The current framework of the country's cargo transportation structure has presented many limitations to the expansion of economic growth. With an existing transportation problem, the country is wasting billions of Reais, with cargo thefts, operational inefficiencies, resulting in a significant loss of competitiveness. The inappropriate use of the modalities ended up generating a great dependence on the modal road, due to the low prices of the freights. Despite the huge coast and navigable rivers, the highways have a prominent role.

According to the Ministério dos Transportes (2016), about 60% of national cargo is transported by highways (PAN et al., 2017).

The logistical problems are mainly concentrated in a discontinuous, disintegrated system with few technological resources. The concept of Physical Internet seems to address the key points of Brazilian logistics problems because in logistics, Physical Internet is an open global logistics system founded on physical, digital, and operational interconnectivity, trough encapsulation, interfaces and protocols. The Physical Internet does not manipulate physical goods directly, whether they are materials, parts, merchandises or yet products. It manipulates exclusively containers that are explicitly designed for the Physical Internet and that encapsulate physical goods within them (PAN et al., 2017).

It was aimed that the road-rail π-hub is to efficiently and sustainably transfer containers from trains from one line to trains from another line or from and to trucks. The basic idea showed of the road-rail π-hub is: 1) to never dismantle trains to avoid very strict safety constraints; 2) to enable a real network with many destinations available with short lead-times; 3) to smoothly interconnect with truck services (PAN et al., 2017).

Physical Internet is an open standard set of collaborative and routing protocols. Modularized containers are much easier to route through transport networks as individual “black-box” loads instead of heterogeneous loads of different sized cases and pallets that are used today in Brazil. But the efficient routing of modular containers over a collaborative network can only be realized if there is a standard set of routing and digital protocols, as well as business and legal conventions that apply across a community of users. Scale gains can be achieved when the standardized container dispatch products in a continuous flow without the need to stand in the port waiting for release for shipment. In Brazil, this wait can reach 120 days, which will burden the logistics process as a whole (HAKIMI et. al, 2012).

Beyond of handling and digital interfaces are needed to ensure reliability, security, and transparency as well as that the quality of the product being handled is not compromised through its movements. These interfaces cannot be proscribed, but the functional requirements need to be so that innovative interfaces may be developed (HAKIMI et. al, 2012).

Conception like the vision of the Physical Internet involves encapsulating goods in smart, ecofriendly and modular containers ranging from the size of a maritime container to the size of a small box would be good for Brazil. It thus generalizes the maritime container that succeeded to support globalization and shaped ships and ports, and extends containerization to logistics services in general. The other like the Physical Internet moves the border of the private space to be inside of the container instead of the warehouse or the truck is good too.

These modular containers would be continuously monitored and routed, exploiting their digital interconnection through the Internet of Things. (HAKIMI et. al, 2012).

Although this is a compelling vision for the future of logistics, there are any reasons that some ponderations should be done to deploy the Physical Internet today, specially in Brazil, where there are some infrastructure and financial obstacles to implement some improvement in some specific sector. First, there is no agreed-upon standard for various container sizes outside of the international shipping containers. This, and the lack of standard contracts and other operational issues, mean that hyperconnected distribution is difficult to initiate and maintain. And expanding hyperconnected distribution is limited by the fact that there is not a centralized exchange for freight based on a standardized specification of a load, with the lack of standardized specification of a load due to the lack of standard containers. Other arguments on the use of the rail system, due to the currently time-inefficient design of switch yards, the lack of innovation due to the difficulty in justifying innovation when what is handled is so diverse, and the inability to construct facilities that will act as the backbone of the PI until there are users of the PI, all mean that there are a number of research questions and business issues that must be addressed before the Physical Internet is to become a reality (HAKIMI et. al, 2012).

It is observed that one of the major Brazilian deficiencies in agribusiness is the lack of adequate infrastructure to move these products from the field to the final customer. Brazil has a matrix of modal inadequate for its dimensions. Our ports present several problems, and the access, efficiency and productivity of the terminals and the adequate draft are the main bottlenecks.

The southeastern region is responsible for the largest production and consumption of sugarcane in Brazil, home to prominent poles such as the states of São Paulo and Minas Gerais, strategically located for the domestic market and also to meet the flow through the Port of Santos.

Considering the following Brazilian logistic characteristics:

1. Increased level of transport service;
2. Expansion of the railway network, deteriorated during the period of public monopoly;
3. Increase capacity and efficiency of port terminals;
4. Accessibility to Ports;
5. Expansion of the storage system, including for stock control purposes;
6. Expansion of waterway and pipeline activities (for ethanol, mainly);

7. Balancing the transport matrix;
8. Balance when assessing the environmental impacts resulting from logistical interventions

It is observed that the Physical Internet concepts are applicable to the Brazilian logistic context, either in the need to enable the transport of products, or in the standardization of modular containers, in multimodality, or in sustainability, which is intrinsic to the proposed model.

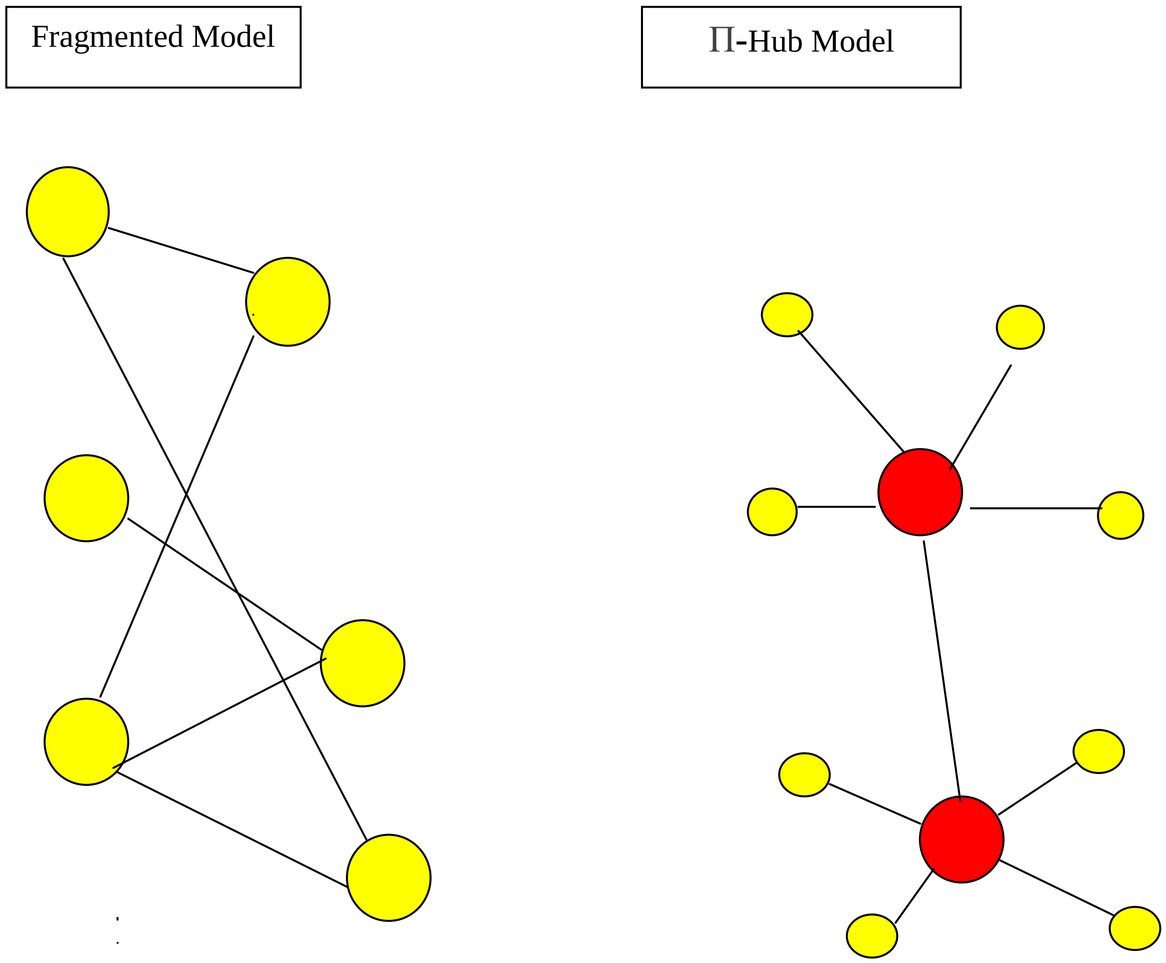
Studies can be done to raise the main deficiency points of the logistic system and apply the physical internet based on simulations that indicate results that can be applied by the main Brazilian stakeholders.

As an alternative to solve sugar´s distrbution demand, rises The Physical Internet (PI, π) that was presented by Montreuil as a response to the Global Logistics Sustainability Grand Challenge. It covered three aspects of sustainability: economic, environmental and social, using symptoms from today´s logistics system as evidence of unsustainability of our present system.

Applying to local perspective of a road-rail π-hub is to efficiently and sustainably transfer containers from trains from one line to trains from another line or from and to trucks. The basic idea of the road-rail π-hub is: 1) to never dismantle trains to avoid very strict safety constraints; 2) to enable a real network with many destinations available with short lead-times; 3) to smoothly interconnect with truck services.

To reach these goals, the mission of a road-rail π-hub is: 1) to receive trucks and handle their inbound π-containers so they can be loaded in time in their assigned train and railcar so as to move them to their next rail-based π-node; 2) to receive trains and handle their inbound π-containers so they can be loaded as pertinent either on a truck called to pick them up or on a subsequent train so as to move them to their next π-node or their final destination; 3) to handle and sort π-containers in connection with either a truck or another train.

Figure 13 – Logistics Model



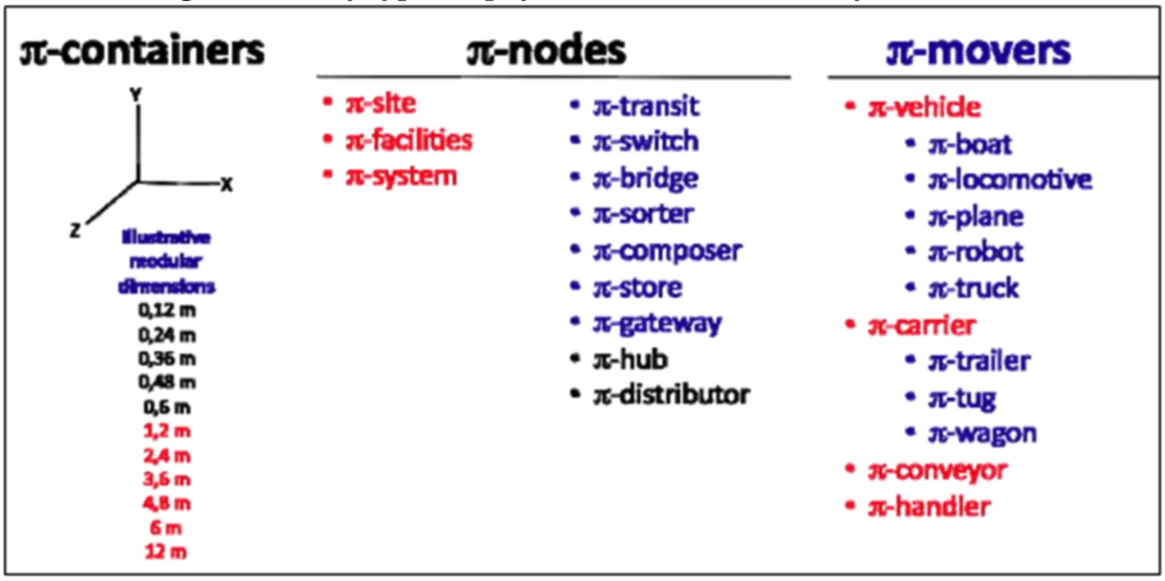
Source: by author.

The fragmented model shows in figure 14 that the flow is inefficient and can spend more time that the π-hub model, why the first one must be change for the hub model configuration. Each π -hub is a logistics platform and it can allow concentration of flows on each platform and can be sent to each location from the next available, located by the manager of each π -hub. If it is provided with terminals multimodal technologies could lead to transfer of cargo to railway wagons or for which will carry out the more "legs" that connect the π-hubs.

6.1 Physical Elements of the Physical Internet

The three key types of physical elements enabling the Physical Internet introduced in this paper are the containers, the nodes and the movers, as can be seen in Figure 15.

Figure 14 - Key types of physical elements of the Physical Internet



Source: Montreuil; Ballot; Tremblay (2014).

Containers are the fundamental unit loads that are moved, handled and stored in the Physical Internet. As illustrated in Figure 15, Physical Internet containers come in modular dimensions. The nodes correspond to the sites, facilities and physical systems of the Physical Internet. Figure 16 identifies a set of node types. The movers transport, convey or handle containers within and between nodes of the Physical Internet. They also come in a variety of types, as highlighted in Figure 16. Containers, movers and nodes are respectively addressed in sections three to five (MONTREUIL; BALLOT; TREMBLAY, 2014).

The physical elements are described in the next sections in their accomplished form for simplicity of presentation purposes. Yet it must be clear that the presented elements do not currently exist and are subject to much further design and engineering. So the stated characteristics of the elements should indeed be perceived as original functional design and engineering specifications (MONTREUIL; BALLOT; TREMBLAY, 2014).

6.2 The π -containers of the Physical Internet

The Physical Internet does not manipulate physical goods directly, whether they be materials, parts, merchandises or yet products. It manipulates exclusively containers that are explicitly designed for the Physical Internet and that encapsulate physical goods within them. These containers designed for the Physical Internet are called π -containers (MONTREUIL et al., 2010).

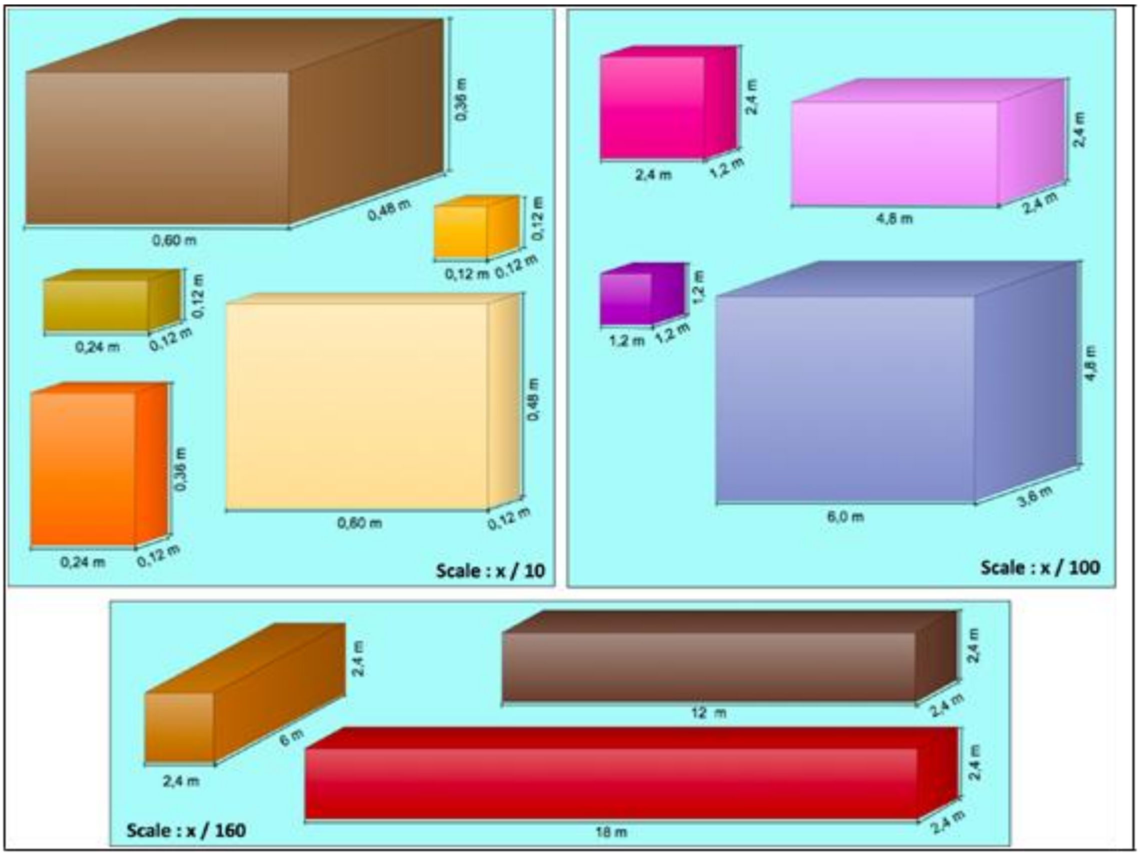
The π-containers are the unit loads that are manipulated, stored and routed through the systems and infrastructures of the Physical Internet. They must be logistics modules standardized worldwide and defined according to open norms. They must be designed to facilitate their handling and storage in the physical nodes of the Physical Internet, as well as their transport between these nodes and of course to protect goods. They act as packets in the digital Internet. They have an information part analogous to the header in the digital Internet. Yet contrary to the digital Internet packets, the π- containers have a physical content and structure rather than being purely informational (MONTREUIL et al., 2010).

6.2.1 Physical description of π-containers

From a physical perspective, π-containers must be easy to handle, store, transport, seal, snap to a structure, interlock together, load, unload, build and dismantle. They may contain individual physical goods, as well as π-containers of lesser sizes, or yet smaller private objects not designed for the Physical Internet. The π-containers encapsulate their content, making the contents irrelevant to the Physical Internet (MONTREUIL; BALLOT; TREMBLAY, 2014).

As highlighted in Figure 16, π-containers are fundamentally conceived to come in a variety of modular sizes. For illustrative purposes, the dimensional modularity of π-containers can be expressed in height, width and depth through combinations of the following dimensions: 0.12m, 0.24m, 0.36m, 0.48m, 0.6m, 1.2m, 2.4m, 3.6m, 4.8m, 6m, 12m and 18m. Actual modular dimensions will be the subjects of evolving international standards. The work of defining the precise sizes and strengths are to be of the most importance (MONTREUIL; BALLOT; TREMBLAY, 2014).

Figure 15 - Illustrating some potential modular dimensions for π-containers



Source: Montreuil; Ballot; Tremblay (2014).

The modularity and the interlocking capabilities of π-containers combine to allow the easy composition of composite π-containers from sets of smaller π-containers. The composite π-containers can later be easily decomposed so as to allow the individualized treatment of its constituent π-containers. Such composition is subject to validation of the structural integrity of the resulting composite π-container, depending on its shape and layout, as well as on the structural strength of its embedded π-containers and of the interlocking mechanisms (MONTREUIL; BALLOT; TREMBLAY, 2014).

The π-containers must have a minimal footprint when out of service, allowing their on-demand dismantling and assembling. They should be as environment friendly as possible, in line with sustainability principles. They must come in a variety of structural grades, adapted to the weight and characteristics of the loads it has to contain, while being as light as possible. They can also have conditioning capabilities such as temperature, humidity and vibration control (MONTREUIL; BALLOT; TREMBLAY, 2014).

6.2.2 Informational description of π-containers

From an informational perspective, each π-container has a unique worldwide identifier, such as the MAC address in the Ethernet network and the digital Internet. This identifier is attached to each π-container both physically and digitally for insuring identification robustness and efficiency. A smart tag is attached to each π-container to act as its representing agent. It contributes to insuring π-container identification, integrity, routing, conditioning, monitoring, traceability and security through the Physical Internet. Such smart tagging enables the distributed automation of a wide variety of handling, storage and routing operations (MONTREUIL et al., 2010).

Technically, RFID and/or GPS technologies are currently perceived as being adequate to equip the π-container tags. Yet as with all other elements of the Physical Internet, this will evolve with technological innovations (MONTREUIL et al., 2010).

Examples of information expected to be in the smart tag of a π-container include:

- Unique identifier of the π-container through the Physical Internet;
- Identifier of the client using the π-container;
- Identifier of the logistician (or of its representative software agent) currently responsible for the π-container;
- Dimensions of the π-container (volume and weight);
- Internal and stack loading structural capacity;
- Functionalities (for handling, storage, etc.);
- Conditioning requirements;
- Identifier of the contract associated with the π-container;
- Status of the π-container (failure/integrity/sealing signals and identifiers);
- Treatment specifications for the π-container (transport from an origin to a destination within some time window, etc.);
- Detailed confidential (or not) information on the content, notably identifying smaller contained π-containers;
- Geo-positioning by GPS or GPRS (when appropriate).

In order to deal adequately with privacy and competitiveness concerns within the Physical Internet, the smart tag of a π-container strictly restricts information access by pertinent parties. The informational contents of π-container tags are protected by a encryption/decryption key for security purposes. Only the information necessary for the routing of π-containers through the Physical Internet are accessible without this key. The π-container is a key element of the Physical Internet and therefore a lot of research and design work have to be conducted in order to define them for the best fit with π-movers and treatment in π-nodes. This work should build upon contemporary innovative projects on container materials, dimensions and smart tag technologies (MONTREUIL; BALLOT; TREMBLAY, 2014).

6.3 The π-movers of the Physical Internet

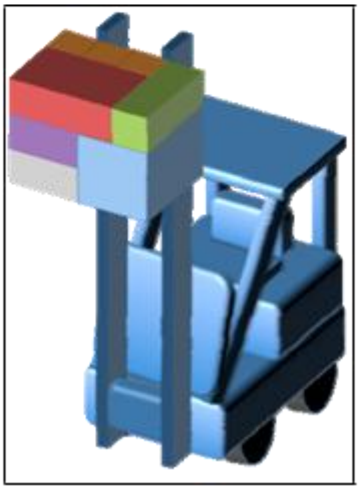
In the Physical Internet, π-containers are generically moved around by π-movers. Moving is used here as a generic equivalent to verbs such as transporting, conveying, handling, lifting and manipulating. The main types of π-movers include π-transporters, π-conveyors and π-handlers. The latter are humans that are qualified for moving π-containers. All π-movers may temporarily store π-containers even though this is not their primary mission. The set of π-transporters conceptually includes π-vehicles and π-carriers. These are respectively vehicles and carriers specifically designed for enabling easy, secure and efficient moving of π-containers. They are differentiated by the fact that π-vehicles are self-propelled while π-carriers have to be pushed or pulled by π-vehicles or by π- handlers (MONTREUIL et al., 2010).

The set of π-vehicles notably includes π-trucks, π-locomotives, π-boats, π-planes, π-lifts and π-robots. These all have contemporary equivalents, yet they differ by the key fact that they are habilitated to operate within the Physical Internet. Similarly, the set of π-carriers includes notably π-trailers, π-carts, π-barges and π-wagons (MONTREUIL; BALLOT; TREMBLAY, 2014).

Consider the most typical kind of vehicle used in a facility: the ubiquitous lift truck. Such a lift truck takes its reason for existence from the fact that moving goods stacked on a pallet is widely used in current operations. In the Physical Internet, the pallet as we currently know it loses its purpose due to the fact that π-lift-trucks only move and store π-containers that are designed-for-handling, stackable, inter-lockable, and so on. Such π-containers thus have the means to attach themselves to a π-mover without having to be placed on a platform. Thus, the need for forks as currently used to support pallets of goods is removed. π-trucks will gain from innovations exploiting the standard modular π-containers. As an illustration, Figure 17 conceptually depicts a π-lift-truck currently lifting a composite π-container without reliance on a pallet and forks. It exploits a structural frame with gears lockable on the π-container, allowing to hold it and to lift it as desired (MONTREUIL; BALLOT; TREMBLAY, 2014).

Figure 17 further illustrates how the nature of π-containers may allow simple yet efficient innovations. It depicts a composite π-container with four wheels snapped underneath it so as to allow its manual displacement by a π-handler. The set of four wheels could also be motorized and smart-sensor enabled so as to allow its autonomous travel from origin to destination within the π-facility or π-site (MONTREUIL; BALLOT; TREMBLAY, 2014).

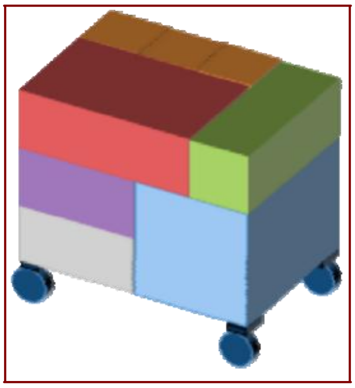
Figure 16 - π-lift-truck lifting a composite π-container without pallet and forks



Source: Montreuil; Ballot; Tremblay (2014).

Either manual or automated, it is key to remark that as for the π-lift-truck of Figure 18 there is no reliance whatsoever on a pallet because the π-container is structurally sound and designed for allowing the snapping of handling devices (MONTREUILet al., 2010).

Figure 17 - Simple illustrative π-mover used for moving a composite π-container

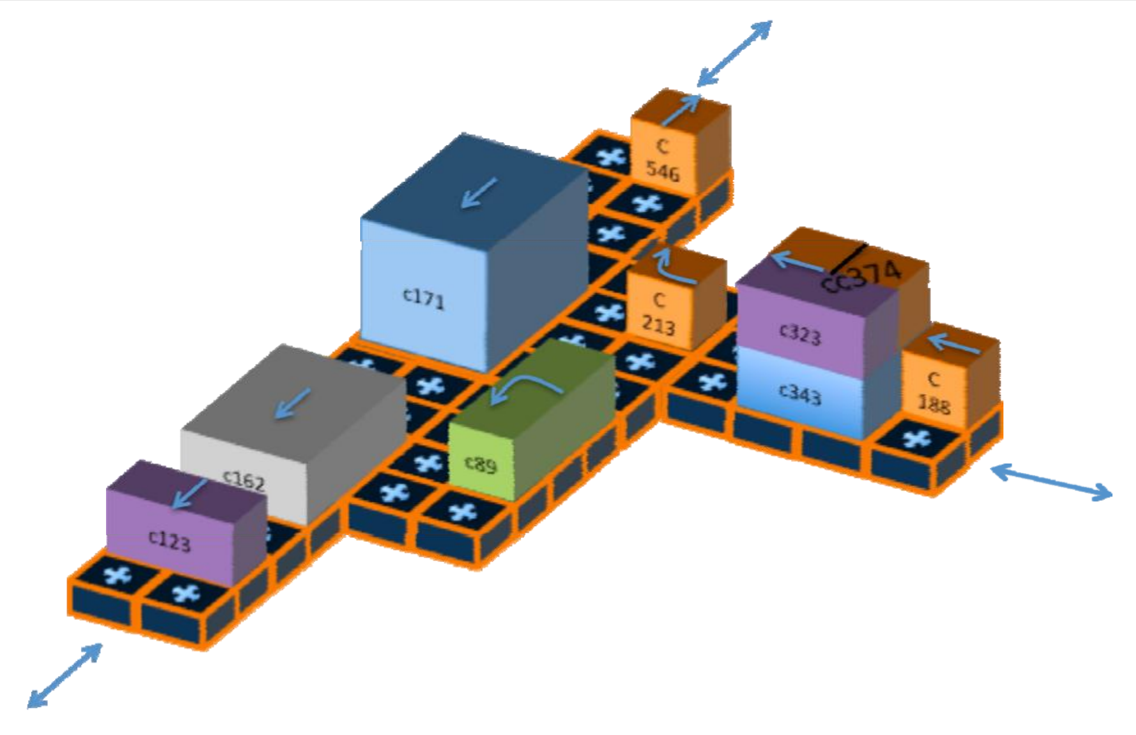


Source: Montreuil; Ballot; Tremblay (2014).

Complementary to π-vehicles, the π-conveyors are conveyors specialized in the continuous flowing of π-containers along determined paths without using π-vehicles and π-carriers. Contemporary conveyors typically use belts or rollers to support goods during their continuous flow. Such belts and rollers, with their underlying mechanics, represent a significant part of the overall cost and physical footprint of the conveyor. As they are explicitly designed for π-containers, π-conveyors may well differ from contemporary conveyors by not having rollers nor belts, the π-containers simply clipping themselves to the π-conveyor gears so as to be towed. They indeed only need an interface to connect themselves to the tracking mechanics of the conveyor core. This simplifies, drastically, the nature of π-conveyors, while leaving a lot of room for innovation from conveying-solution providers. Note that as contemporary conveyors, π- conveyors may or not be motorized. When not motorized they can potentially exploit gravity or π-handlers to ease the moving of π-containers (MONTREUIL; BALLOT; TREMBLAY, 2014).

As an innovative illustration among many possibilities, Figure 20 displays a set of π--conveyors exploiting the recently introduced flex conveyor concept. Here square conveying cells allow moving π-containers in the four cardinal directions. Each cell is dimensioned to the size of the smallest π-container to be conveyed. When only such smallest square π-containers are handled, then each cell autonomously conveys a π- container to one of its up to four neighboring cells.

Figure 18 - π-conveyor grid composed of flexible conveying π-cells



Source: Montreuil; Ballot; Tremblay (2014).

In the example of Figure 19, π - containers of a variety of modular dimensions are conveyed concurrently. This requires coordination of adjacent π -cells for them to act jointly in conveying a large π -container such as π -container c171 occupying a 2X3 grid and having to be conveyed southwestward. Efficient and robust decentralized or centralized algorithms for controlling a grid of such π -conveyors have yet to be developed. However, examining the design of the grid in Figure 20, which conveys π - containers through a T-shape joint, reveals its conceptual elegancy and potential power. It concurrently conveys a variety of unitary and composite π -containers, each capturing a discrete set of π -cells. Currently all π -containers arrive from the southeast and either want to go southwest or northeast. Currently π -container c89 is standing still for some coordination reason, yet without blocking the main southwest traffic. The traffic pattern could be changed from time to time according to workflow needs (MONTREUIL et al., 2010).

6.4 The π-nodes of the Physical Internet

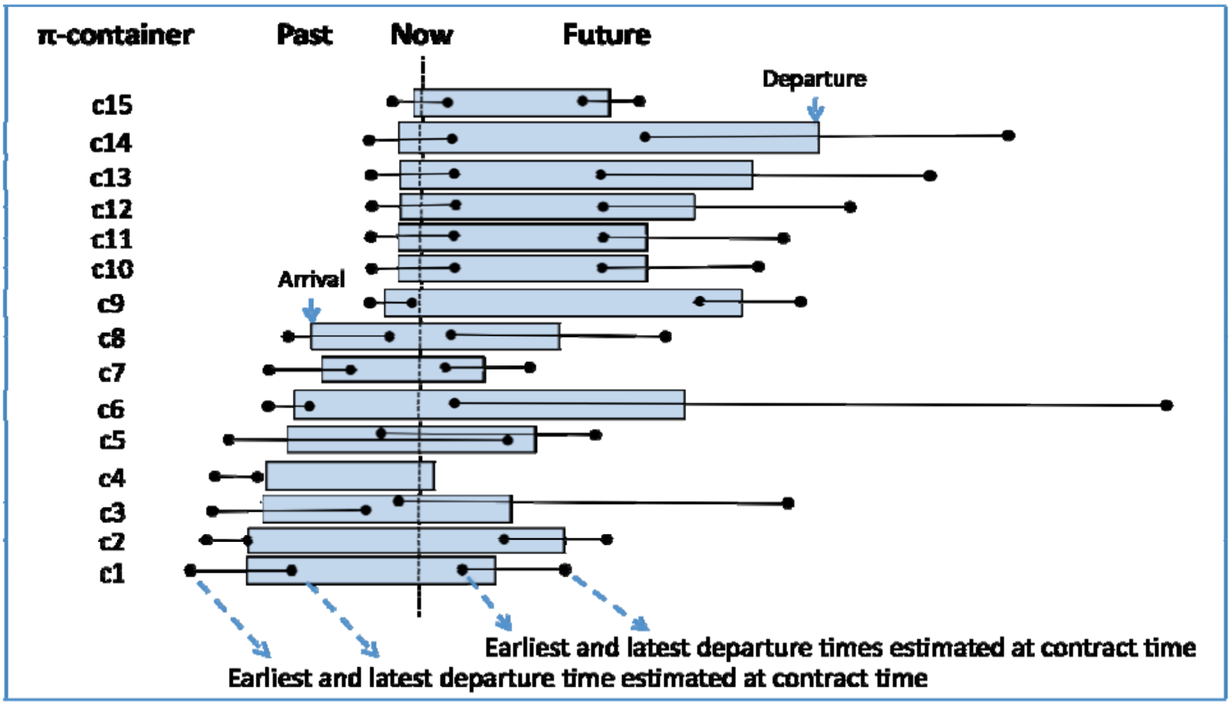
The π-nodes are locations expressly designed to perform operations on π-containers, such as receiving, testing, moving, routing, sorting, handling, placing, storing, picking, monitoring, labeling, paneling, assembling, disassembling, folding, snapping, unsnapping, composing, decomposing and shipping π-containers. There exist a variety of π-nodes delivering services of distinct natures, from the simple transfer of π-carriers between π-vehicles to complex multimodal multiplexing of π-containers (MONTREUIL; BALLOT; TREMBLAY, 2014).

Generically, the π-nodes are locations that are interconnected to the logistics activities. The activities at a π-node may affect physical changes, such as switching from a transportation mode to another. They may result in contractual changes for the π-containers. To each π-node is associated at least one event for each π-container to ensure traceability of its passage through the π-node (MONTREUIL; BALLOT; TREMBLAY, 2014).

The π-nodes are publicly rated on a number of key attributes, such as speed, service level adherence, handled dimensions of π-containers, overall capacity, modal interface and accepted duration of stay. Clients will use this kind of information for decision making relative to π-container deployment. Other pertinent Physical Internet entities will also exploit it for routing purposes, through the Physical Internet routing protocol.

Figure 21 illustrates the dynamics of a π-node by displaying its dynamic occupancy in face of arriving and then departing π-containers. For each π-container, Figure 21 provides its realized arrival and departure times, as well as the estimates provided through the Physical Internet routing protocol on its earliest and latest arrival and departure times to ensure the final delivery on time for the client. Figure 20 makes it clear that in the Physical Internet, π-nodes treat π-containers on an individual basis, each having its own contract (MONTREUIL; BALLOT; TREMBLAY, 2014).

Figure 19 - Illustrating the dynamics of a π-node with uncertain



Source: Montreuil; Ballot; Tremblay (2014).

Generically, π-nodes conceptually encompass π-sites, π-facilities and π-systems that are respectively sites, facilities and systems designed to act as physical nodes of the Physical Internet. Usually, π-sites include π-facilities and external π-systems, while π-facilities contain internal π-systems. The π-node types presented hereafter vary in terms of mission orientation, scope and scale, as well as in terms of capabilities and capacities, yet they all have in common that they are explicitly specialized to treat π-containers at the physical and informational levels (MONTREUIL et al. 2010).

6.5 The π-transits

The π-transits are π-nodes having the mission of enabling and achieving the transfer of π-carriers from their inbound π-vehicles to their outbound π-vehicles. They allow the distributed transport of π-carriers by a series of π-vehicles, each responsible for a segment of the overall route from primary source to final destination. π-transits aim to ensure the efficient, easy, safe and secure execution of these activities for significant flows of π-vehicles and π-trailers. The π-transits are generally either π-sites or π- facilities, requiring low investment in π-systems (MONTREUIL; BALLOT; TREMBLAY, 2014).

In road-based transportation, a π-transit can be as simple as a π-site located nearby the intersection of two highways, where π-trucks carrying π-trailers register their arrival, unhook their π-trailer at an assigned location, then either leave or pick up another assigned π-trailer stationed at a location within the π-transit. In general, π- transits are often unimodal. There can be multi-modal π-transits. For example, π- trailers can be transited from π-trucks to either π-trains or π-boats, and vice-versa (MONTREUIL; BALLOT; TREMBLAY, 2014).

There is a simple π-transit composed of ten π-bays, each allowing the parking of one π-carrier. Each arriving π-vehicle backs up its π-carrier into an assigned π-bay when it becomes available. Then it either departs or moves to attach another assigned π-carrier and then departs with this new π-carrier. A π-vehicle may come in just to pick up an assigned π-carrier. It shows graphically the current state of the illustrative π-transit. It also provides a table indicating both the current physical and informational states of the π-transit. For each π-carrier, it states the π- carrier that brought it, its arrival time, the π-bay it is parked in, the π-carrier expected to pick it up, as well as the estimated earliest, most probable and latest times at which it is to be picked up. The π-transit would also have a similar log of all π-carriers it has a contract for taking care of its transit, but that are not yet arrived. In such a log the arrival time would be an estimate (MONTREUIL; BALLOT; TREMBLAY, 2014).

The π-transits enable distributed transportation of π-carriers. Along the route from origin to final destination, a π-carrier can for example be iteratively transported from its current π-transit to a π-transit located a few hours away. This helps greatly to reduce the pain endured by truck drivers currently having to be far from home for weeks due to long hauls. In the process, they also help reducing the traveling time as the π-carrier only have to wait a coordinating time at each π-transit rather than having to stand still long hours while the driver gets his meals and his sleep. This illustrates that despite their simplicity the π-transits improve logistics performance in many aspects (MONTREUIL; BALLOT; TREMBLAY, 2014).

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6.6 The π-switches and π-bridges

A π-switch is a π-node having for mission to enable and achieve the unimodal transfer of π-containers from an incoming π-mover to a departing π-mover. Examples include rail-rail π-switches and conveyor-conveyor π-switches. There is no multiplexing. There is rather an essentially linear transfer (MONTREUIL; BALLOT; TREMBLAY, 2014).

A π-bridge is a π-node having a mission of the same type as a π-switch, specializing in the one-to-one multimodal transfer of π-containers not involving any multiplexing. An example is a rail-route π-bridge. The main tasks of a π-switch and a π-bridge are double. From a physical perspective, their main role is the efficient, safe, secure and reliable transfer of π- containers from one π-mover to another. From an informational perspective, their main role is ensure that the receiving rr -mover is ready before the rr -container is transferred, that all parties are informed of the transfer, and that the contracts are terminated and activated respectively for the incoming rr -mover and the departing rr –mover (MONTREUIL; BALLOT; TREMBLAY, 2014).

6.7 The π-hubs

The π-hubs are π-nodes having for mission to enable the transfer of π-containers from incoming π-movers to outgoing π-movers. Their mission is conceptually similar to the mission of π-transits, but dealing with π-containers themselves rather than dealing strictly with the π-carriers. They enable unimodal π-container crossdocking operations. Furthermore, π-hubs will be at the core of fast, efficient and reliable multimodal transportation, by allowing ease of transfer of π-containers between combinations of road, rail, water and air transportation (MONTREUIL; BALLOT; TREMBLAY, 2014).

For π-containers come either on a π-boat or on a π-trailer pulled by a π-truck. The π-hub is laid out so that incoming π-boats enter a bay where they are anchored so as to allow π-container loading from one side and π-container unloading from the other. The implemented operational dynamics lead the π-hub operators to prepare π-containers on the appropriate quay for easing their loading prior to their π-boat arrival. Once a π-boat arrives, its π- containers having to be transferred to road based transportation are unloaded and then either routed directly to a waiting π-trailer or to a buffering π-store (here identified as a dark green rectangle) awaiting the arrival of their assigned road based π-mover. When the spatially conflicting π-containers have all been unloaded from the π-boat, then the loading of its assigned π-containers is started, eased by the fact that many have been smartly put aside the π-boat on the quay. From the other direction, when a π-container arrives on a road based π-mover, it is unloaded and routed toward a buffering π-store, its departing quay or yet directly its π-boat (MONTREUIL; BALLOT; TREMBLAY, 2014).

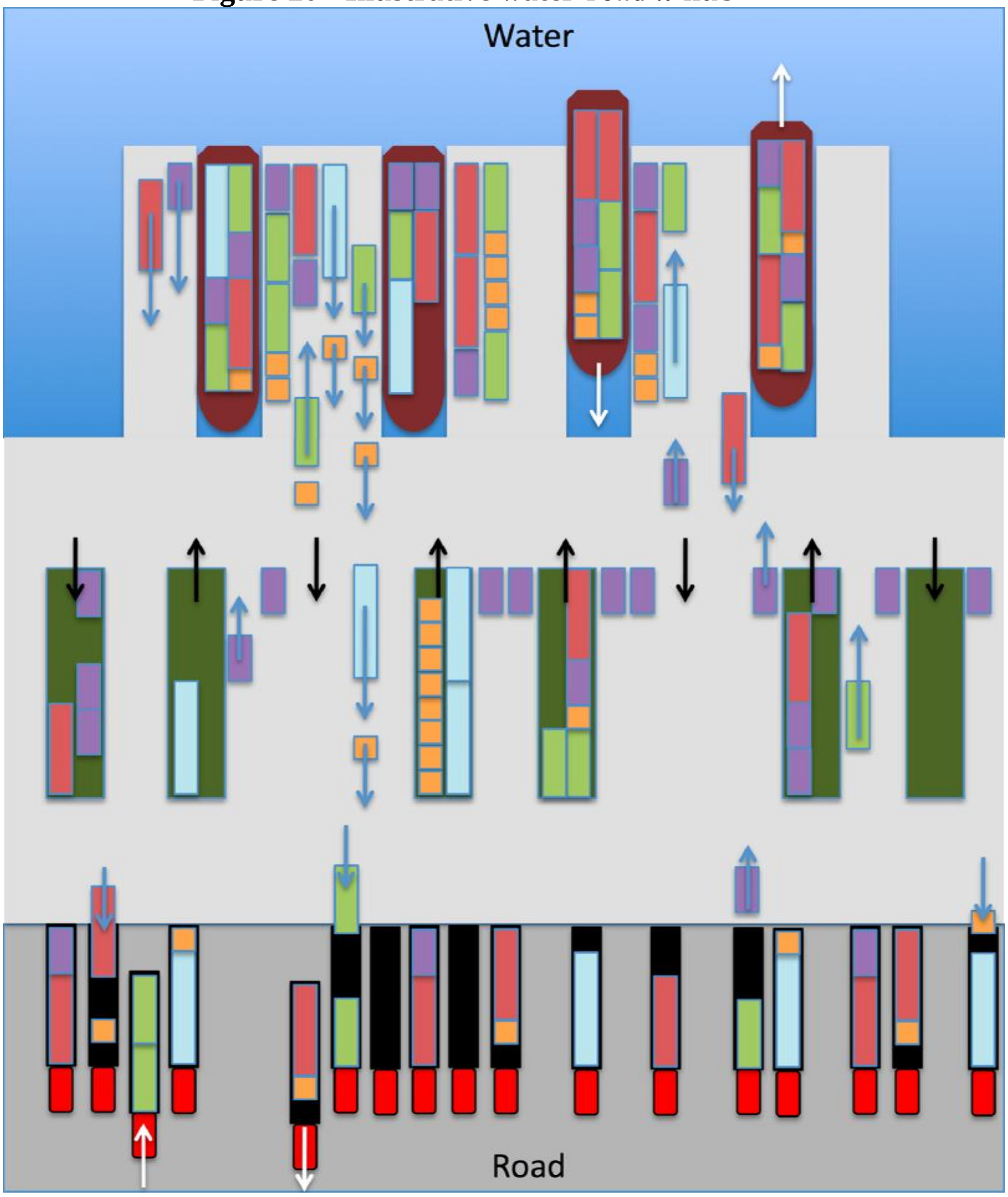
The π-hub is easy to explain and logical to run, yet it represents a type of hub currently not existing. It has three key differentiators, making it a paradigm breaker. One, it is not limited to only two sizes of containers. Second, it purposefully uses small boats rather than huge cargos. Third, its workflow is streamlined and fast enough that some containers may already be gone before their incoming boat is completely unloaded or reloaded.

In general, the simpler π-hubs disembark π-containers from their inbound π-movers and bring them at locations within π-hubs where they are ready to re-embark on their outbound π-movers. Meanwhile, their inbound π-movers are fed with other π-containers and depart from the π-hub. There is thus a continuous flow of inbound, in- transit and outbound π-containers (MONTREUIL; BALLOT; TREMBLAY, 2014).

Some π-hubs, for example those involving rail and water-based transportation, may restrict themselves to handle only larger π-containers. For example, they may state that they only handle π-containers having a width and a height of 2.4m, with lengths of 1.2m, 2.4m, 3.6m, 4.8m, 6m and 12m. Other π-hubs may conversely focus on smaller dimension π-containers, while yet others may aim for comprehensive offerings with minimal dimensional restrictions. These are strategic decisions taken by their owners, based on their business intent (MONTREUIL; BALLOT; TREMBLAY, 2014).

Figure 21 shows a water-road PI-hub. More complex π-hubs embed π-sorters, π-composers and temporary π-stores. First, π-sorters help sorting the incoming π-containers and channeling them to their assigned π-carrier. Second, π-composers allow incoming composite π-containers to be decomposed into sets of smaller π-containers, each with its specific target destination and target departure time and π-mover, and composite π-containers to be composed from inbound π-containers and put on departing π-movers, according to client specifications. Third, temporary π-stores allow flexibility in synchronizing π-container arrivals, consolidations and departures (MONTREUIL; BALLOT; TREMBLAY, 2014).

Figure 20 - Illustrative water-road π-hub



Source: Montreuil; Ballot; Tremblay (2014).

6.8 The π -sorters

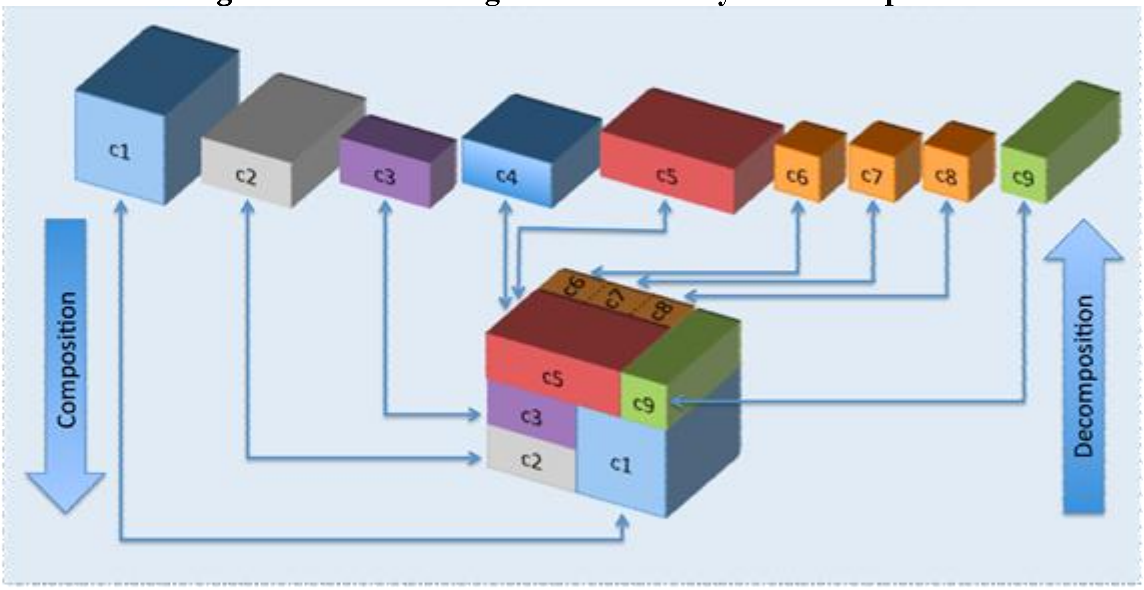
A π-sorter is a π-node receiving π-containers from one or multiple entry points and having to sort them so as to ship each of them from a specified exit point, potentially in a specified order. A π-sorter may incorporate a network of π-conveyors and/or other embedded π-sorters to achieve its mission. The π-sorters are typically embedded within more complex π-nodes, such as π-hubs (MONTREUIL; BALLOT; TREMBLAY, 2014).

6.9 The π -composers

A π -composer is a π -node with the mission of constructing composite π -containers from specified sets of π -containers, usually according to a 3D layout specified by the end customer or for the purpose of improving efficiency within the physical Internet, and/or of dismantling composite π -containers into a number of π -containers that may be either smaller unitary or composite π -containers, according to client specifications. The composition and decomposition of composite π -containers are respectively realized by snapping together (interlocking) and *unsnapping* its smaller constituent π -containers.

Figure 22 provides a conceptual illustration of the functionality of a π -composer, depicting nine π -containers interlocked to compose a composite π -container. The resulting π -container in Figure 22 is a perfect cube with no empty space. Even though spatial modularity of π -containers helps fitting sets of π -containers into a compact composite π -container, it will not be always possible to reach a perfect fit as in Figure 24. In such cases, there are two basic options relative to composition feasibility. First, the holes may be left as such when they are minor and do not impact the structural integrity of the composite π -container. Second, when the holes have significant negative impact on the composition, empty π -container structures can be inserted to fill in the holes. Such modular structures would not need to have closed walls and could be dismantled upon decomposition of the composite π -container.

Figure 21 - Illustrating the functionality of a π-composer



Source: Montreuil; Ballot; Tremblay (2014).

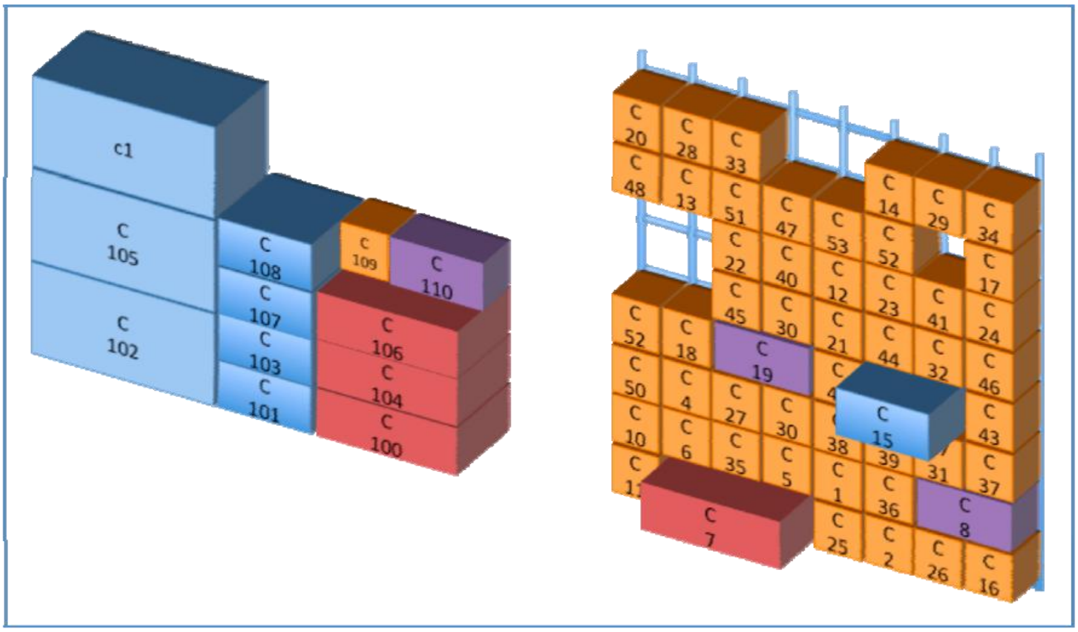
It is anticipated that π-composers will be designed for composing and decomposing composite π-containers at high velocity. For example, it will be normal to require that a π-composer be able to compose in a few minutes (or less) a 1.2x1.2x6 cubic-meter π-container from twenty smaller π-containers. π-composers are prime candidates for automation, notably integrating π-conveyors and π-sorters. They play a role similar to current palletizers and depalletizers, but with standard easy-to-interlock modular π-containers rather than diverse arbitrarily sized objects that are not necessarily easy to handle. Overall, π-composers perform fragmentation and defragmentation operations on composite π-containers, without ever opening a unitary π-container.

6.10 The π-stores

A π-store is a π-node having the mission of enabling and achieving for its clients the storage of π-containers during mutually agreed upon target time windows. These can be very precise or be more probabilistic, shorter or longer term, as best fit the circumstances. π-stores differ from contemporary warehouses and storage systems on two major points. First, they focus strictly on π-containers: they can stack them, interlock them, snap them to a rack, and so on. Second, they do not deal with products as stock-keeping units SKUs), but rather focus on π-containers, each being individually contracted, tracked and managed to ensure service quality and reliability. Figure 24 illustrates the potential stacking and snapping functionalities of a π-store enabled by the fact that it only deals with modular π-containers that are designed for handling and storage (MONTREUIL; BALLOT; TREMBLAY, 2014).

The left of Figure 23 illustrates a stacking π-store. Stacking is functionally identical to what is being done across the world in cargo container ports, with the added flexibility provided by the dimensional modularity and structural strength of π-containers.

Figure 22 - Illustrating stacking and snapping functionalities of a π-store

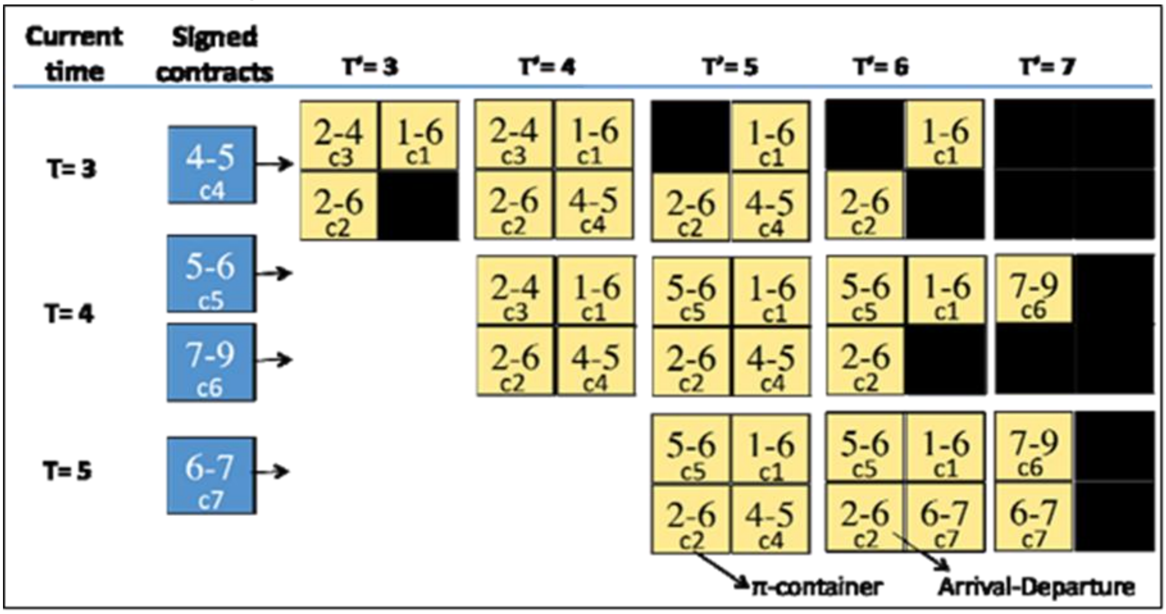


Source: MONTREUIL; BALLOT; TREMBLAY (2014).

Clearly, π-containers can be stored in conventional racks, eased by their modular dimensionality, yet they are to lead to new kinds of π-store technologies exploiting the powerful functional characteristics of π-containers and the dynamics of the Physical Internet. Snapping consists of attaching the π-containers to a grid, exploiting fixtures embedded in the π-containers, without having to deposit the π-containers on a flat surface as in conventional rack based storage. The racking cost can be significantly reduced as compared with conventional racking. Indeed a very significant part of any rack today is the platform in each storage slot, allowing cases and pallets to be deposited in the slot. Such platforms are not necessary in snapping π-stores, opening a wealth of innovation opportunities.

Figure 24 expresses the dynamics of a small π-store with four π-bays. At time 3, it stores three π-containers c1, c2 and c3 and has signed a contract for storing π-container c4 in times 4 and 5. Based on the current knowledge in time 3, the planned state of the π-store is shown for times T' = 4, 5, 6 and 7. It shows that if no further contract is signed, the π-store will be empty in time 7. When time 4 comes, the π-store signs two more contracts for π-containers c5 and c6. Then π-container c7 is signed in time 5. The figure adapts the occupancy plan of the π-store as it progresses from time 3 to 5. Here the targeted π-container arrival and departure times are certain for simplifying the illustration. Note that π-stores are generally subject to more elaborate dynamics in line with the stochastic nature of demand depicted in figure 23.

Figure 23 - Illustrating the dynamics of a small π-store



Source: Montreuil; Ballot; Tremlay (2014).

It is quite possible for a π-store to receive from a client composite π-containers, to have them dismantled, storing its constituent π-containers, then to be requested to ship some combination of the client's π-containers, either independently or jointly as a newly-constructed composite π-container. In such cases, either the π-store embeds a π-composer or exploits a nearby π-composer not part of itself.

In π-stores, capacity and speed for receiving π-containers and shipping them are critical success factors, as well as storage capacity. Their π-container dimensional, security, visibility and conditioning capabilities are other key factors. π-stores come in a multitude of sizes, such as π-storage-systems within facilities, π-storage-facilities, or π-sites storing π-containers outside, such as a π-yard.

6.11 The π-gateways

The π-gateways are π-nodes that either receive π-containers and release them so they and their content can be accessed in a private network not part of the Physical Internet, or receive π-containers from a private network out of the Physical Internet and register them into the Physical Internet, directing them toward their first destination along their journey across the Physical Internet. For example, a factory that is not internally π- enabled may have π-gateways at its receiving and shipping centers.

Generically, π-facilities of various types may embed π-gateways and tightly contained centers that are not explicitly part of the Physical Internet. For example, a π-distributor may have some focused out-of-PI centers doing some personalizing, value- added operations on some types of products embedded in π-containers, according to client specifications. Such centers may open π-containers and actually work on its embedded objects. π-gateways ensure the exit to and reentry from such an out-of-PI center of π-containers.

The π-gateways have both physical and informational mandates. On the physical side, they ensure the physical integrity of π-containers and their efficient, secure and safe physical transfer in and out of π-movers, π-systems and π-facilities. On the informational side, they interact with the π-container agent so as to validate the π- container identity, the contractual agreements, to initiate tracking as pertinent, to validate π-container sealing when appropriate, to be informed of its first destination within the Physical Internet, and so on.

The Physical Internet is both easy to grasp due to its reliance on the analogy with the Digital Internet and difficult to understand due to its complexity and the change of paradigm it implies. It attempted to aid with the understanding by defining and discussing a key set of basic physical elements of the Physical Internet. This set is far from being exhaustive. For example, more complex elements have not been described. For example, π-distributors are the π-equivalent of current distribution centers, yet restricted to π-containers. Potentially, they can embed any combination of the above types of π-nodes. They can perform crossdocking operations such as π-hubs, store π-containers as π-stores, and so on (MONTREUIL; BALLOT; TREMBLAY, 2014).

Although the set is not exhaustive, there are more physical elements yet to be defined, and a more in-depth characterization and modeling required for all elements, we hope the paper provided a stepping stone towards further understanding, investigation and implementation of the Physical Internet. The study also attempted to highlight the great breakthrough innovation opportunity brought forward by the introduction of the Physical Internet. The significant innovation opportunity for material handling technology providers and logistics facilities designers. First, it showed how the current nature of fundamental elements such as lift trucks, conveyors and racks is challenged by the Physical Internet. Second, it introduced new types of systems and facilities necessary for the Physical Internet or enabled by it, such as π-composers. Third, it introduced illustrative instances of π-nodes that challenge the current paradigms, such as the water-route π-hub. Innovation is of paramount importance so as to enable the easy, efficient, robust, safe and secure travel and storage of π-containers through the Physical Internet (MONTREUIL; BALLOT; TREMBLAY, 2014).

The Physical Internet is about networks of networks, each embedding nodes and links between these nodes, with standard modular containers. Its introduction aims toward a radical improvement in the economical, environmental and social sustainability of worldwide transportation, handling, storage, supply, realization and usage of physical goods. It is through this aim that Physical Internet focused material handling system and logistics facility design and innovation should be addressed (MONTREUIL; BALLOT; TREMBLAY, 2014).

Physical Internet helps to uncover a wealth of novel and important research avenues. Indeed, every introduced Physical Internet element requires further characterization, modeling, prototyping and testing. The interplay between π-container, π-mover and π-node design and engineering is also an important research avenue. The interplay between the physical, informational and financial facets is again a promising research avenue. The architecture of π-nodes from the core set introduced here and others as needed is a virgin field of exploration. The same is true at the network level and the networks of networks level, investigating the means and impacts of deploying π-nodes of various types so as to best enable the Physical Internet. Finally, there is significant research required on the gradual transformation of the existing sets of containers, movers, systems, facilities, sites and protocols along a roadmap from the current paradigm towards a full implementation of the Physical Internet (MONTREUIL; BALLOT; TREMBLAY, 2014).

7 RESEARCH METHOD

This research study will be exploratory in nature because this area of investigation is new and vague, and thus it requires an exploration of the problems faced by managers. The objectives of this exploratory case study can be achieved by using various techniques. In this case, qualitative techniques will be applied exclusively. There will be interaction between the researcher and the object of study. This is why the researcher's personal values and view of the world will be part of this process (COOPER; SCHINDLER, 2003).

7.1 Study's objective

The objective of this study is causal, that is, it aims to assess the relation between the variables time, delivery cost (in relation to road, air, water or rail transport, if applicable), routes and the modes of transport used for non-sustainable distribution services.

This study considers some of the main sugar producing areas of southeastern Brazil, their features and their distribution network. The study´s objective is how PI concepts can be applied through simulations. Sustainability indicators such as idle time, excessive use of only one mode of transport, gas emissions, non-cargo trips (returning empty from a delivery), and robberies are variables that we have used to simulate and assess alternative and sustainable modes of transport, since the term "indicator" is a parameter selected and considered separately or in combination with others, and thus reflects the conditions of the system under examination. In general, an indicator is used for the pre-treatment of original data (SICHE et al., 2007).

7.2 Description of the Variables

The variables examined in this study are the time in which sugar can be transported and distributed and alternative routes that would permit more rapid and efficient transport.

7.3 Data Collection

This study is based on sustainability variables. The object of this case study is the Colombo mill of the Caravelas Sugar Company and its distribution of sugar throughout southeastern Brazil. This company is located in the city of Ariranha, in the region of São José do Rio Preto, São Paulo. It was visited on March 1st, 2018 and one of its owners Mr. Sergio Colombo was interviewed.

According to Gil (2011), interviews can be divided into four types: informal, focused, structured and formalized. An informal interview is less structured and is only distinguished from a simple conversation because its main objective is to collect data. This is recommended in explanatory studies that deal with realities that are not well known by the researcher or that offer an approximate vision of the problem under examination. Focused interviews are oriented towards a specific subject, which enables the interviewee to speak freely about the subject, but also allows the interviewer to return to the subject if there are any digressions. They are employed in experimental situations with the objective of deeply exploring an experience that occurs under precise conditions.

This interview was conducted based on a semi-structured interview. The questions were defined ahead of time as can been observed in Appendix A of this work. He explained that this is a family company that was founded in the 1940s and grew with the first mill because the family believed in the growth prospects of this market. Today the company has become one of the largest Brazilian producers of sugar and ethanol. The company is very concerned with environmental issues, but since distribution is performed by transport companies, the company has not had control over the issue of sustainability.

This is why the person responsible for the product’s logistics was invited to join the interview. This individual explained that the company has its own small distribution fleet, but most of the distribution is done by transport companies. There are fifteen of these transport companies that distribute this product. This study prepared the questionnaire that appears in Appendix A and sent it to these transportation companies. Only four responses were received.

Just as was done for the Modulushca Project in Germany, which can be seen in detail in Appendix A, it was possible to verify the development and results of the application of the Physical Internet, mainly in terms of the sustainability indicators proposed in this work.

7.4 Variables and Data Analysis

Inside the Physical Internet vision, there are two sets of key performance indicators (KPIs). One set of KPIs is from the perspective of “clients” and another is from the perspective of the operator of the π-hub. Since this study deals with the main sugar companies, it is the operator perspective that is analyzed. For the operator of a road-based crossdocking π-hub, there is the typical trade-off between capacity and costs. These are the variables. If the operator provides more container handling bays, for example, then the average processing time will decrease, but costs will increase relative to land and handling technology. So, these are the following KPIs that are related to the capacity of the π-hub.

1. Area of the π-hub site and facility
2. Number of outbound gates
3. Number of docks
4. Number of outbound gate queuing places (trucks/trailers)
5. Number of parking bays in the buffer zone (trucks/trailers)
6. Numbers of π-containers that can be processed concurrently within the hub facility
7. Average percentage of trucks/trailers denied entrance due to hub overflow.

In this case, an Anylogic 8 Simulator and a GIS Map were used to simulate several routes with the time variable defined in hours, or in other words, how long the vehicle takes to go from Point A to Point B, tracing the most rapid route in terms of time. The simulator automatically selects this route and indicates how many vehicles can leave to meet a given level of demand (the system's operator can simulate this demand as well).

It was desirable to choose sustainability variables due to our research objective, which is the possibility of improving sustainability. Physical Internet concepts also permit the appearance of sustainability indicators. Given that this distribution is performed by a system that features multiple modes of transport, a decrease in the emission of gases which are emitted exclusively by road transport can be verified, especially in terms of carbon dioxide which directly affects the ozone layer and global warming.

In 2010, 28 internationally renowned scientists gathered in Stockholm, Sweden to arrive at an improved diagnosis of the current environmental crisis. The result was the identification of nine threats to the planet (SOFFIATI, 2012):

- Climate change: Generated by the emission of greenhouse gases, notably CO_2, global warming is causing a rapid change in the climate that could compromise agriculture, livestock and urbanization.

Although the process of ozone depletion has been reversed through new techniques and technologies, it has not entirely halted the deterioration of the ozone layer, a fundamental shield for the continuation of the most complex forms of life on this planet (SOFFIATI, 2012):

To a greater extent than the forests, the oceans fulfill the ecological role of absorbing carbon dioxide from the atmosphere and producing oxygen. However, much of the ocean's absorption of carbon dioxide has led to the acidification of the oceans and the destruction of key ecosystems such as coral reefs and carapace animals (SOFFIATI, 2012):

- Freshwater: Two thirds of the planet is composed of water, but very little of it is fresh water, which is fundamental to agriculture, livestock and humanity. Fresh water is being wasted or used for profit.
- Biodiversity: Despite the erroneous understanding of many who associate it with small plants and animals, the most important aspect of biodiversity is that it guarantees equilibrium in the planet's essential biological processes.
- Nitrogen and phosphorus cycles: Nitrogen and phosphorus production is much greater than normally it would be in nature, and this has increased the eutrophication of fresh and salt water.
- Land use: The conversion of half of all forests, mainly tropical forests, into crops and pastures has harmed the planet's ability to perform vital functions that maintain equilibrium.
- Particles in the atmosphere: At present, the release of particles into the atmosphere has doubled since the industrial revolution. This is extremely harmful to life.
- Chemical Pollution: About 100,000 different chemical compounds produced by industry are harming living beings and humanity around the world.

The basic principles of an environmental indicator systems are as follows:

- Comparability: these indicators should allow comparisons to be made and indicate changes in terms of environmental performance;
- Equilibrium: environmental indicators should distinguish between problematic areas (poor performance) and areas with good prospects (good performance);
- Continuity: indicators should be based on similar criteria and on comparable time frames or units;
- Temporality: the indicators must be updated with sufficient regularity to permit the taking of action;
- Clarity: indicators should be clear and understandable (SOFFIATI, 2012).

Therefore, it was verified that the carriers that transport and distribute the sugar do not systematically control the gases emitted by their fleets, which in this case consist exclusively of road transport. In this case, however, it was not possible to study this aspect because we would need to have previous values for gas emissions to compare with the new simulated values.

7.5 Research Steps

To realize this study, the variables were originally chosen to verify the gains of using the Physical Internet concepts. Since the object of this theory is a hyperconnected network that distributes products in an intelligent, efficient, sustainable and innovative manner, it was necessary to adapt it to the reality of Brazilian logistics infrastructure, and in particular, the sugar industry in southeastern Brazil.

Sugar is an important product in the southeastern region, and it is distributed through road transport. With help from agribusiness professors, the Colombo mill was suggested for this study. The researcher entered into contact with the Columbo Group and quickly scheduled an interview.

The interview was structured to guide the visit. The researcher recorded the interview with the authorization of the interviewee and also collected constant data and photos of the work. The visit extended to the operational mill and the person responsible for the logistics area. He explained how the mill's production and distribution function. He also provided contacts for transport companies that provide services to the mill.

A questionnaire was prepared and sent to the sugar transport firms by email. There was a low level of response. Some route simulations were made to verify the efficiency of sugar delivery. The analyzed results and the study's limitations were verified and can be found at the end of this work.

8 RESULTS AND DISCUSSION

To apply the research method, a sugar producing company from southeastern Brazil was selected, and the distribution of the company's product was analyzed with the PI through the use of a simulator.

8.1 Visit´s Presentation

The Colombo mill of the Caravelas Sugar Company was selected, and it is the second largest producer in Brazil. The researcher went to the city of Ariranha, São Paulo to find out about the production of sugar and how the mill handles its distribution to its end consumers.

The photos that follow were taken during the visit to the Colombo mill. Figure 26 shows the mill from the point of view of the central administration building.

Figure 26 – Colombo Mill – Ariranha/SP

Source: the author

Figure 27 shows part of the Colombo mill's small distribution fleet that only makes deliveries to nearby locations.

Figure 17 - Colombo´s Own Fleet

Source: the author

Figure 28 shows the façade of the central administration building where we can see the names of the founders of the mill in a monument in the form of a caravel, reflecting the brand name of the sugar produced by the Colombo mill.

Figure 28 – Administrative Building

Source: the author

Figure 29 shows the operational mill where sugar is produced by grinding sugar cane.

Figure 29 – Sugar Cane Mill

Source: the author

Part of the volume of sugar distributed to the industry is marketed through a wholesaler, that is, it is not a direct sale from the mill to the industry. Generally, this transaction occurs with wholesalers that are specialized in the industrial segment which in turn sell to small factories. These wholesalers, besides selling to these factories, sometimes pack the sugar and sell it to retailers. Such specificity was not considered in the mapping due to the difficulty of inferring an estimate of the volume traded and the price practiced by this type of wholesaler. This difficulty arises from the fact that no secondary data was found for this situation. The main sugar-consuming industries are soft drinks (20%), chocolates (10%), chemical (10%), and dairy products (7%), with other industries representing 53%. In terms of the consumption of natural sugar, the main type sold is crystal sugar (61%), followed by refined sugar (36%), and refined granulated and other types (4%).

In terms of volume, the central-southern region traded 10.5 million metric tons and the north-northeastern region traded 1.02 million metric tons. Of the production in the central-southern region 60% goes to industry, 28% is for direct sales to retail and 12% is wholesale. For the north-northeastern region's production, these numbers are 53% for retail sales, with 25% going to industry and 22% to wholesale. Sales to the industry totaled 6.5l9 million metric tons of sugar, with direct sales to retail of about 3.5 million metric tons and 1.49 million metric tons going to wholesale.

Freight for the Export of Sugar and Ethanol – the resources mobilized for freight exports of sugar and ethanol amounted to $539.03 million. Of this total, the amount spent on road freight for the export of sugar in the central-southern region was $383.6 million, with the ports of Santos and Paranaguá being the main export routes out of the country in 2008.

The researcher conducted field research at the Colombo mill and interviewed Mr. Sergio Colombo, one of the owners of the mill. The mill was founded by the family in the 1940s and it is still in operation. He runs it along with his siblings and cousins. The business is growing and currently the mill is the second largest producer of sugar in Brazil. The market served is 95% domestic with 5% for export. The types of sugar produced are demerara, refined and special refined, which are sold in packs of 1kg, 5kg and 25kg.

Mr. Colombo says that the sugar is distributed directly from the sugar mill to wholesalers who make the orders. Each service order is forwarded to the logistics sector which verifies which carrier is available for delivery. They work with a small fleet of their own, but the vast majority of their deliveries are performed by third parties. He provided the contacts for three of the most important transport companies to assist this study's investigation of the distribution process.

To begin the process of applying the selected method, the researcher contacted these transport firms and prepared a survey that is available in Appendix A, which was sent by email to the logistics managers.

8.2 Simulation

It is difficult to maintain efficiency in managing your supply chain without new technology. The management of multiple flows of goods and information across complex networks of suppliers, transporters, freight forwarders, and other key players is a sizable task. Simulation modeling can help manage this complexity, increase profitability, and improve customer service to enhance competitiveness (MANUAL ANYLOGIC, 2014).

In this instance, the AnyLogic 8 Simulator was selected because it can provide simulations with these features and because researchers who work with the Physical Internet around the world use this kind of simulator. AnyLogic can provide users and logistics experts with a high degree of decision-making assistance. It can explore a great number of interrelated, dynamic and random events that drive a business. It uses real-time data to develop “what-if” scenarios. One can stress-test a system and optimize strategies – all in a virtual environment. Supply chain management systems equipped with simulation-based decision support permit custom optimization, and can offer increased efficiency, agility and profitability. This system has been used in the United States Military Academy at West Point, Keio University, Arizona State University and the Georgia Tech Research Institute, which is where the researcher used this tool (MANUAL ANYLOGIC, 2014). To observe a presentation, access**:** https://www.youtube.com/watch?v=z4gHwp6D8R4.

Some simulator screenshots will be presented here to give an idea of how it works. The type of simulation used is the GIS Map because it can reproduce any part of the world on a map, and in this case, it used a map of southeastern Brazil to create a sugar simulation.

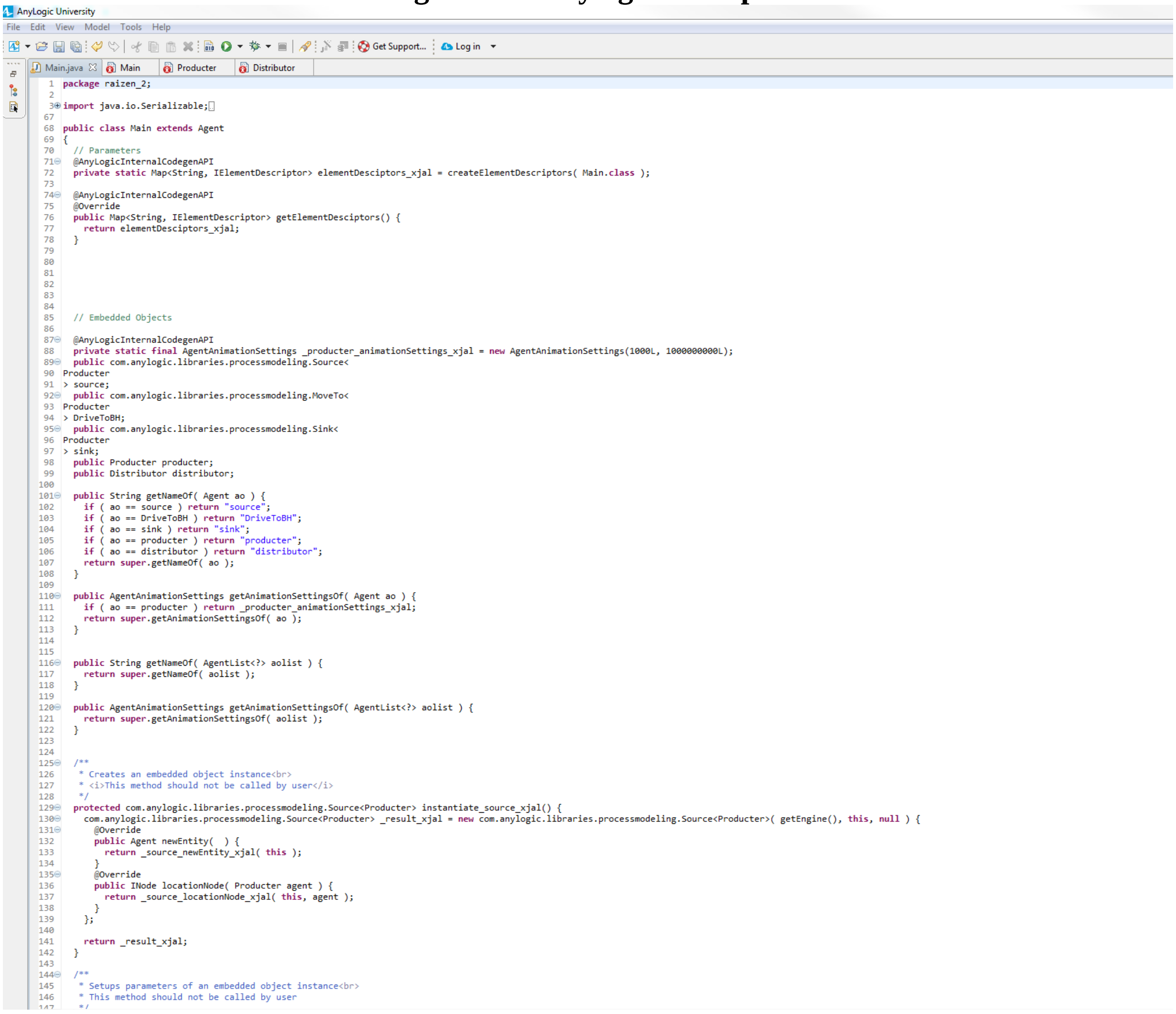
Anylogic 8 – Supply Chain Model

The programming code for the GIS map is displayed in figure 24. This code utilizes the parameters that have been provided in the simulator’s main menu. The gaps don´t need to be filled in. They are filled in by the simulator as the data is input.

The researcher attended the Georgia Institute of Technology for four months to learn the concepts of the Physical Internet and how the simulator uses these concepts. For this study, the GIS Map was used, because it was considered the most appropriate to examine sugar distribution. The Anylogic simulator has many resources for various modes of transport, but it was not this study’s objective to gain a deeper understanding of the simulator, because it is just a tool used to demonstrate how the Physical Internet can be used to resolve logistics problems in the distribution of sugar in southeastern Brazil. With control of the logistics network, there is a greater chance of using sustainability indicators in the logistics context, since it provides information from the entire logistics system.

In Figure 25 it is possible to observe the functioning of the main menu of the GIS Map. This screen displays the simulator’s programming code and the filling in of producer and distributor data and their placement on a map of southeastern Brazil. This data is inserted in the screen below.

Figure 24 - Anylogic 8 - step 1



Source: Anylogic 8 (2017).

The results show that when they receive a request for a delivery from the Colombo mill, they take into account its weight and the client to decide how the delivery will be made. The details include delivery date, vehicle availability, if the client requires scheduling, if the client requires an invoice prior to delivery, the type of vehicle, if a delivery assistant is needed, if you pay for unloading at the location, and what will be the form of payment.

If it is a 28 pallet delivery, they a 32 metric ton truck will be used. If it is a 22 pallet delivery, then they will use a regular truck. In terms of the criteria used to send the product, they consider safety, speed, punctuality, the quantity and weight of the product, the size and suitability of the vehicle (cleaning, tarpaulin, linings, etc.), requested delivery date, the availability of the product for loading, and the availability of the vehicle to load the product.

The deliveries are customized for each client, which means that they use a special kind of delivery for each one. The delivery time depends greatly on the quantity, weight and capacity, and whether someone needs to receive the shipment. The same delivery can be made within an hour after arriving at a destination or more than 8 hours later, depending on factors related to the client. In general, deliveries of 30 kg packages take about 2/3 of the unloading time that is needed for a 10 kg package. If the merchandise is being delivered on pallets where the client has a dock and pallet or at least a forklift, the unloading does not differ between types of packaging because it is on a pallet. Each delivery consists of different types of packages, but the trucks are always loaded to capacity, so they deliver their loads to their clients independently of the type of packaging. So, this means that regardless of whether the truck is full or not, the freight price will be the same. The route chosen is always the one that optimizes transit time and route costs, especially diesel fuel and tolls. Some types of vehicles require a special transit authorization (AET), and it is not always feasible to select the route with the lowest cost per km. Due to time constraints this may end up delaying the delivery.

They only use one route to deliver a product; they don´t have alternatives routes and all of them are made by trucks. For the Colombo mill, for instance, they use routes such as:

1. from Ariranha to Osasco (Washington Luiz Highway / Anhanguera Highway / Rodoanel Beltway);
2. from Ariranha to Porto Alegre (PR092 or BR116);
3. from Ariranha to Caxias do Sul (BR101 or BR 116);
4. from Ariranha to Florianópolis (PR092 or BR116);
5. from Ariranha to Curitiba (PR092 or BR116)

The first one is the only route that exists, because the destination is where the major Brazilian wholesalers of the Colombo mill are located: Carrefour, Pão de Açúcar, Atacadão etc.

The researcher took some of the main routes used to deliver sugar from the Colombo mill to its main buyers. This data was used for the parameters for the Anylogic 8 simulation. The Colombo mill does not have a product delivery routine because purchases occur occasionally and not planned for. There is no systematic sale of parts to buyers and everything depends exclusively on demand. The logistics service receives orders and provides dedicated transport for deliveries. Regardless of whether the truck is full or not, the freight price is the same and the Colombo mill has to pay for it.

Four sugar companies completed surveys. These transport companies do not use sustainability indicators. One of the companies has a consumption indicator (directly connected to the emission of gases) that is measured by trip, per month, per year, per driver. A performance evaluation meeting is held in regard to fuel consumption. The fleet stands out in terms of fuel economy, training, maintenance, exhaust tests and driver assessment. In addition, this fleet is one of the newest in the sugar segment, and because it uses cleaner diesel (s-10) for more than 70% of the fleet together with the correct use of arla-32, it certainly is one of the least polluting fleets in this segment. However, it does not have a formal sustainability indicator.

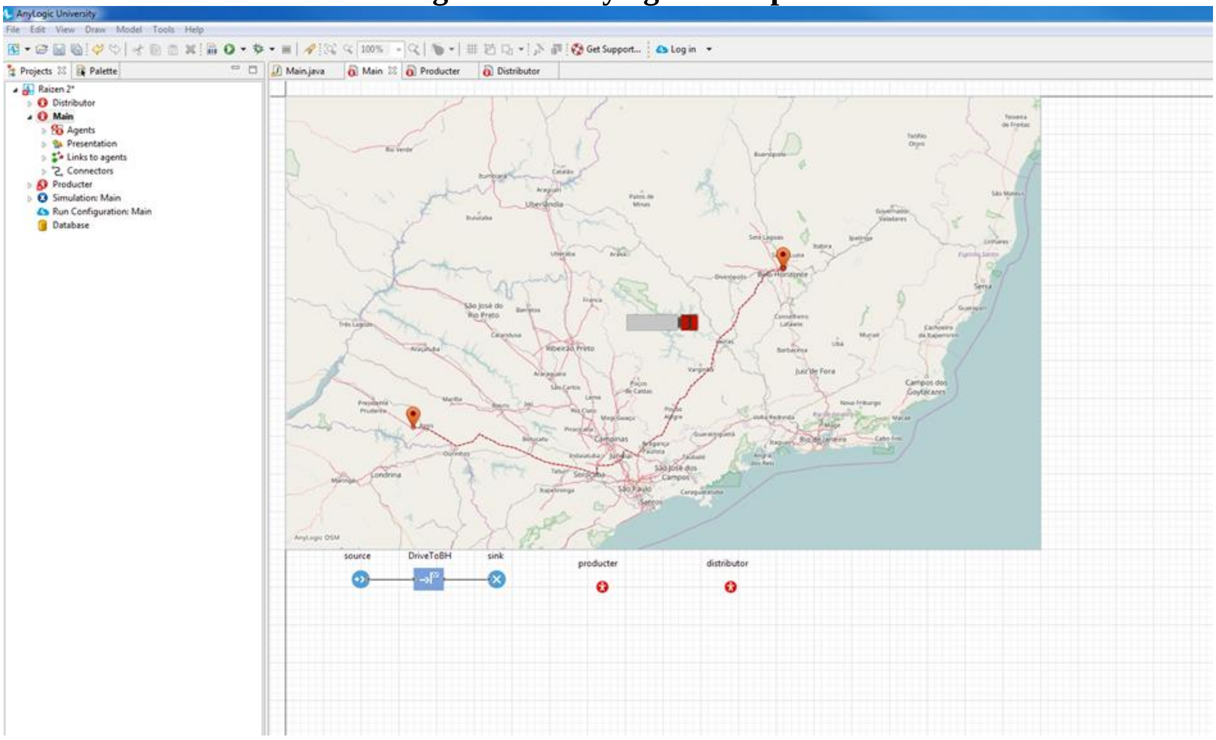
The Colombo mill is in search of solutions such as using freight management software. The solution presented includes GKO FRETE software, which is installed in an outsourced cloud infrastructure, and the allocation of the resources required to implement this solution. GKO FRETE, created by GKO Informática, is a support application for freight management.

GKO FRETE is used by 50 of the 500 largest companies in Brazil including 3 Hearts, Melitta, Gomes da Costa, Kerry, Parmalat, Carrefour, Syngenta, Panasonic, Faber Castell, Volkswagen, Anglo American, Danone, Wall Mart, and Pepsico, among others. Currently, over R $ 6 billion of transport is hired and managed each year using this system, which is estimated to result in savings of at least 5% of this value. This system will allow Colombo to improve its control and the visibility of its production chain, increasing the efficiency of the transportation process, reducing freight and logistics costs, and providing better service to its end customers. The system structures its projects through a PMO (Project Office) with an integrated system for this purpose, where all the projects are monitored in real time.

Through the approval of the Project Plan, the mill and the client can share their vision and definitions of the project at hand, so that the implementation schedule, resource allocation demands, and delivery schedule can all be validated each step of the way. As a result, any changes in scope that arise are also documented and analyzed on a case-by-case basis in order to determine their impacts on the project schedule and costs, and can be approved or rejected.

In Figure 26, the route chosen for simulation was from Point A, the city of Assis, São Paulo to Point B, the city of Belo Horizonte, Minas Gerais. Points A & B on the GIS Map were input into the system and then the simulation was run. The results appear below.

Figure 25 - Anylogic 8 - step 2

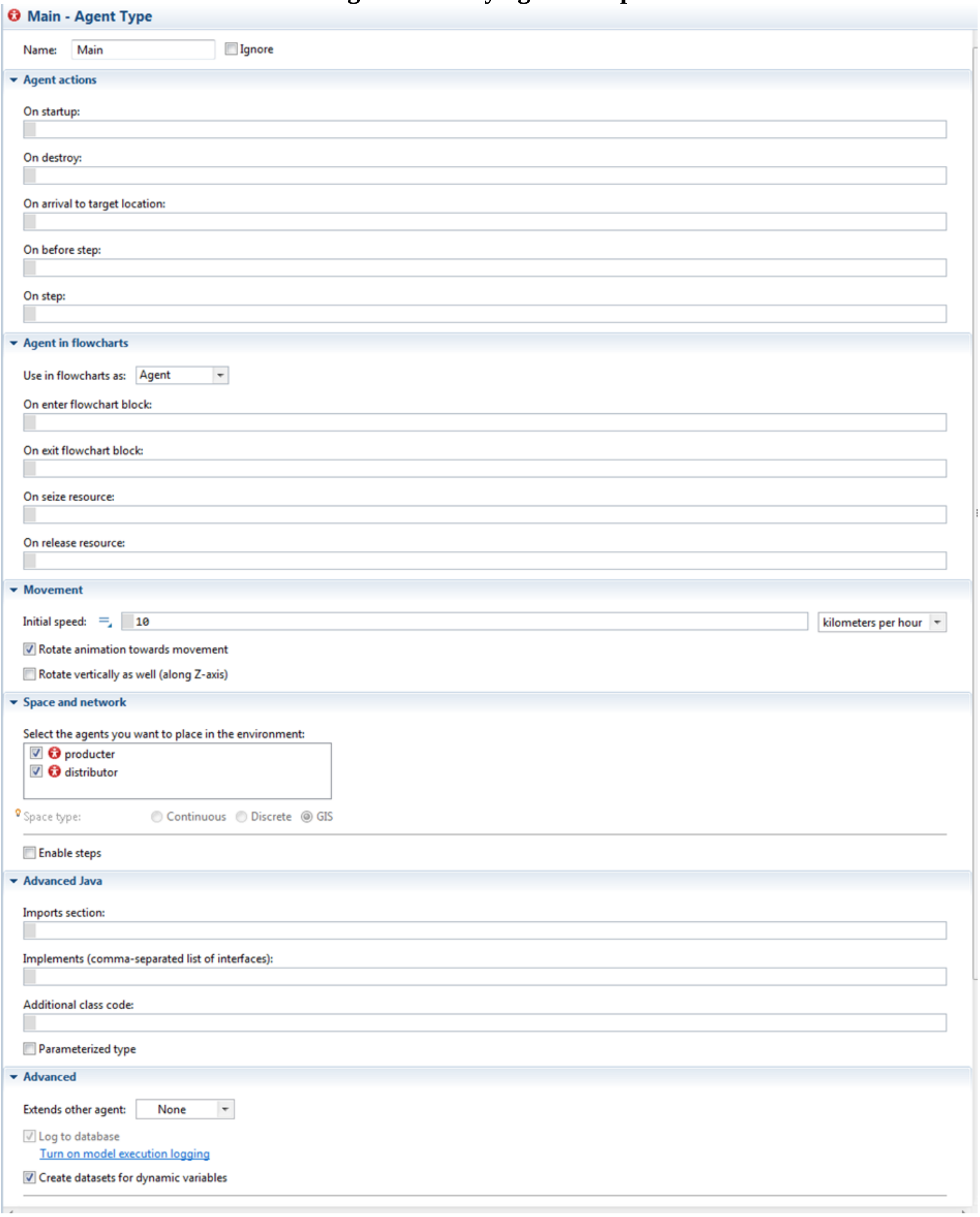


Source: Anylogic 8 (2017).

The simulator works with the existing physical setup. Therefore, the simulator exclusively uses the road mode of transport to reflect the current situation.

In Figure 27**,** data entry is for the main type. In terms of space and the network, Point A was set up as the producer and Point B as the distributor.

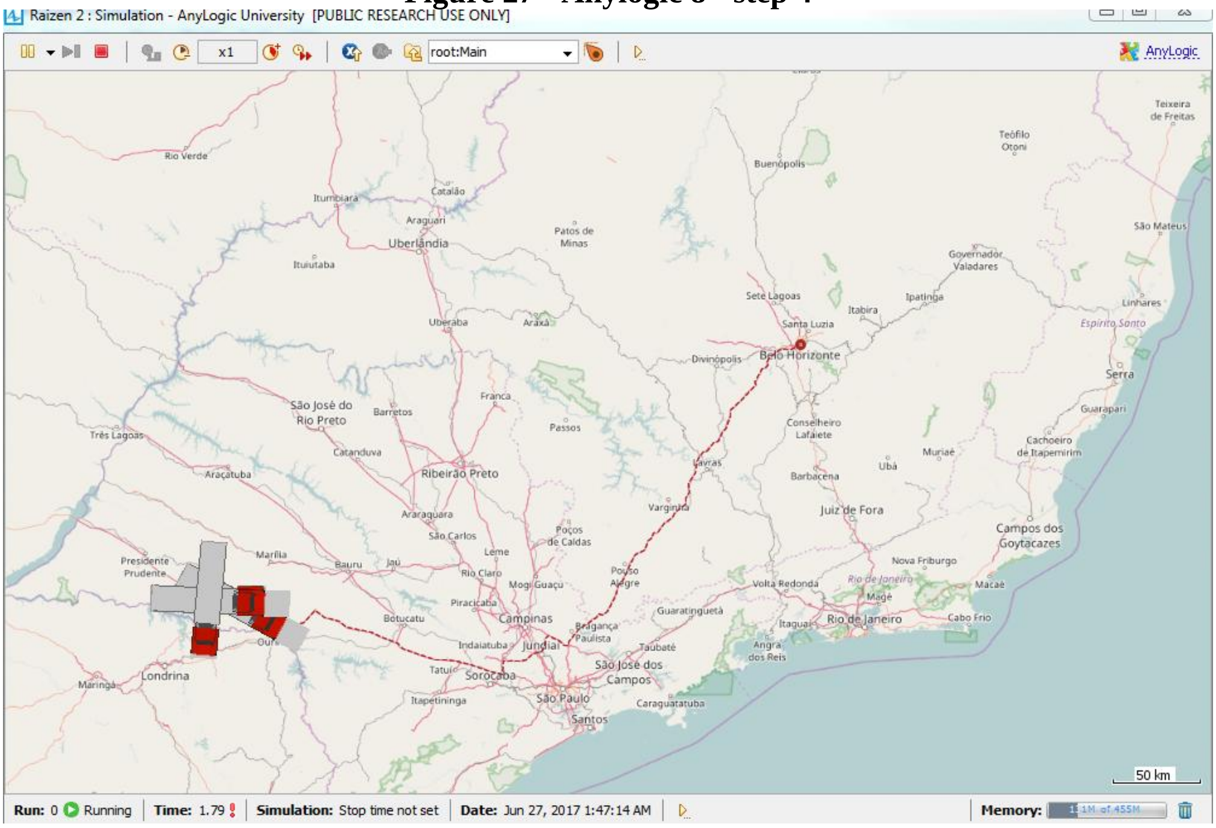
Figure 26 - Anylogic 8 - step 3



Source: Anylogic 8 (2017).

In Figure 28, the departure times for the trucks are selected based on specific hours and then the simulation is run. The trucks may be observed moving dynamically from the start. Parameters can be selected according to the needs of the simulation and the client. The simulator can include variables such as time, route, destination and participants (producer, distributor, warehouse, etc).

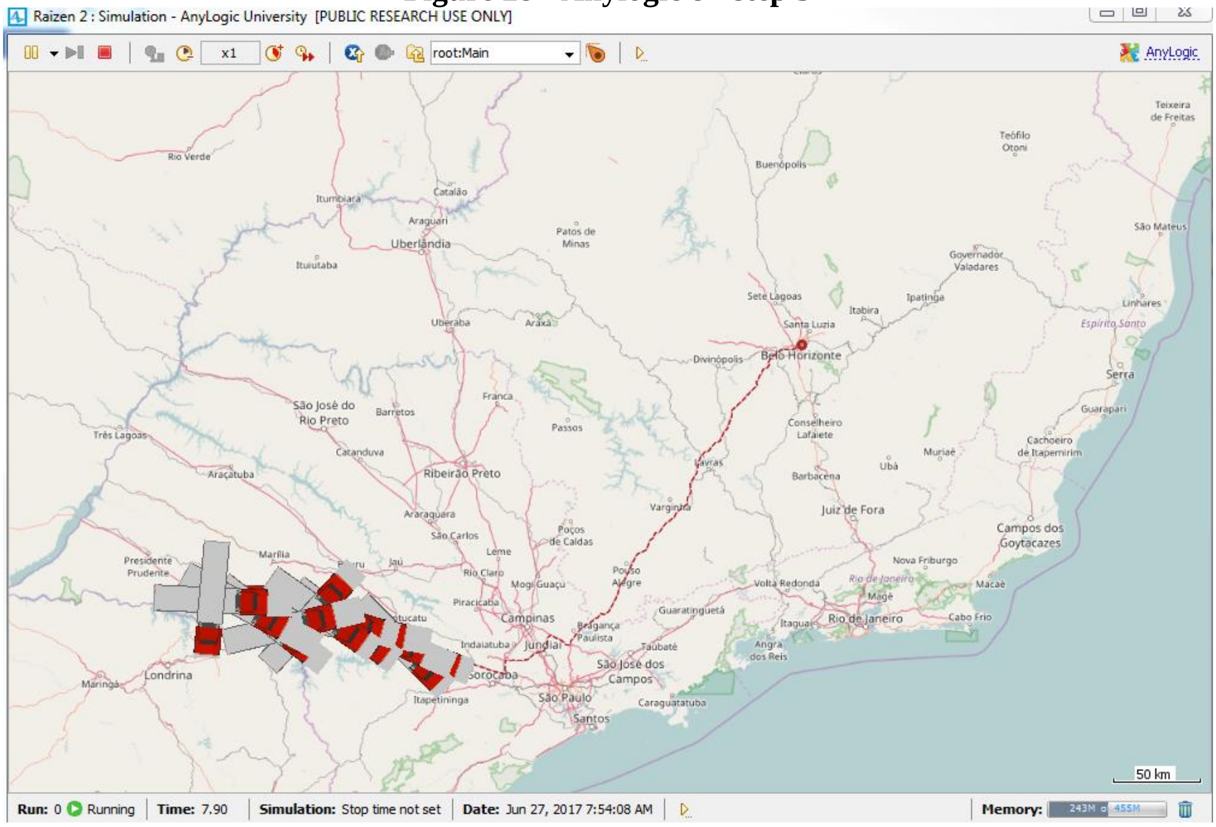
Figure 27 - Anylogic 8 - step 4



Source: Anylogic 8 (2017).

In Figure 29, the trucks can still be seen moving dynamically. This enables the distribution controller to observe the real-time movement of all of the trucks which are making deliveries in this hyperconnected system..

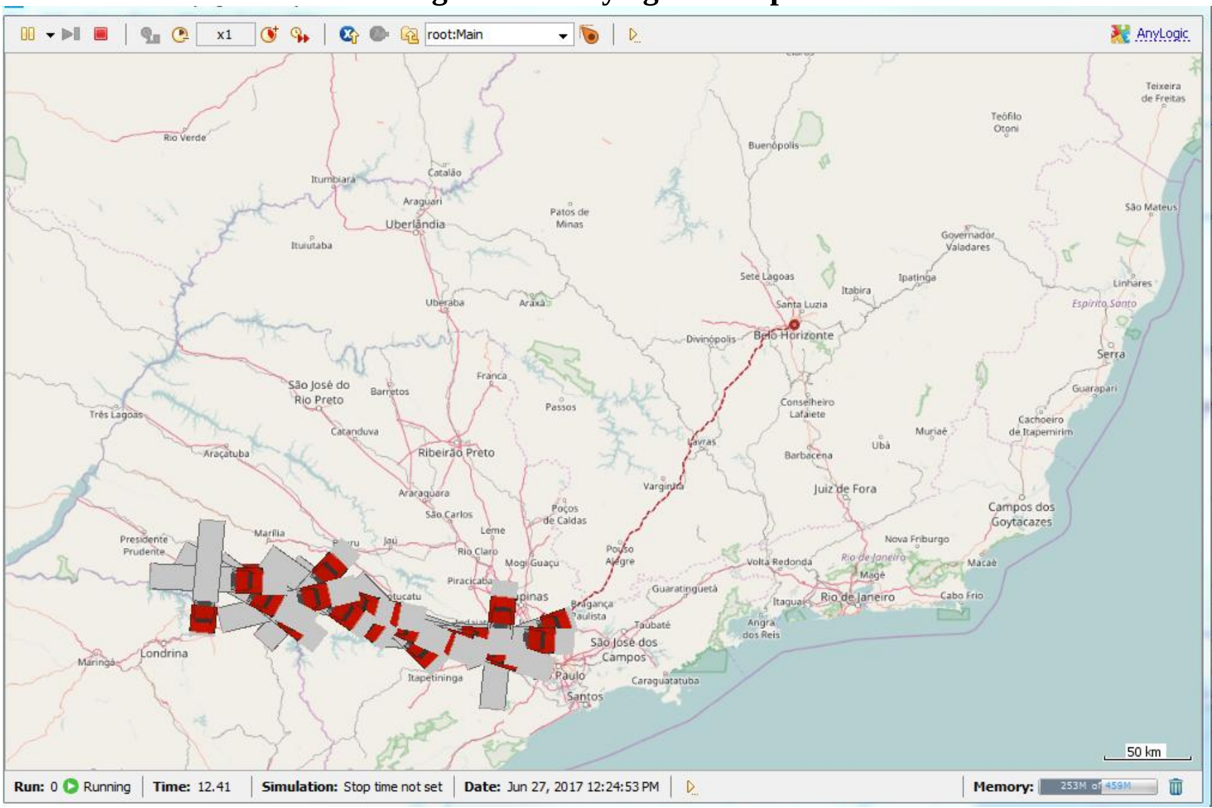
Figure 28 - Anylogic 8 - step 5



Source: Anylogic 8 (2017).

In Figure 30, we can see the trucks moving in a more intensive manner. This illustration serves to show the dynamism of the simulator according to the parameters used.

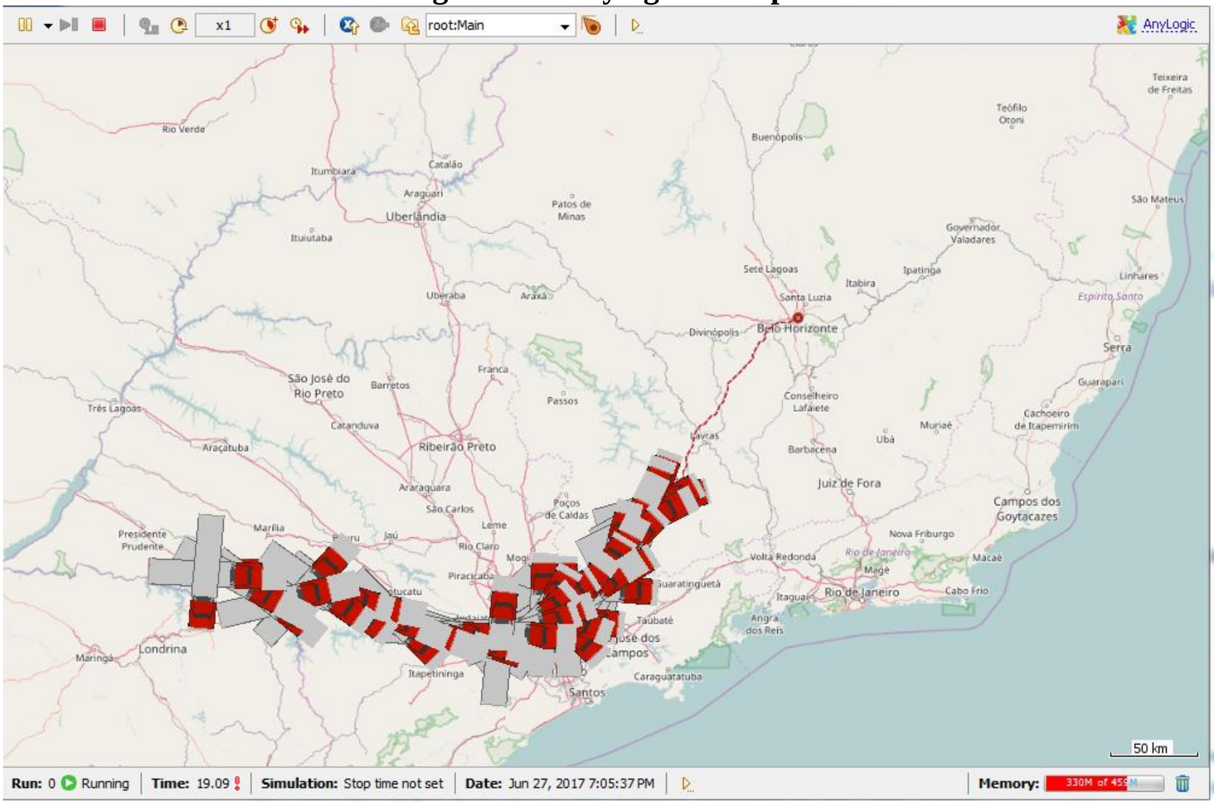
Figure 29 - Anylogic 8 - step 6



Source: Anylogic 8 (2017).

In Figure 31, for each hour you have a truck; the simulator shows all the trucks that are on their way from Point A to Point B.

Figure 30 - Anylogic 8 - step 7

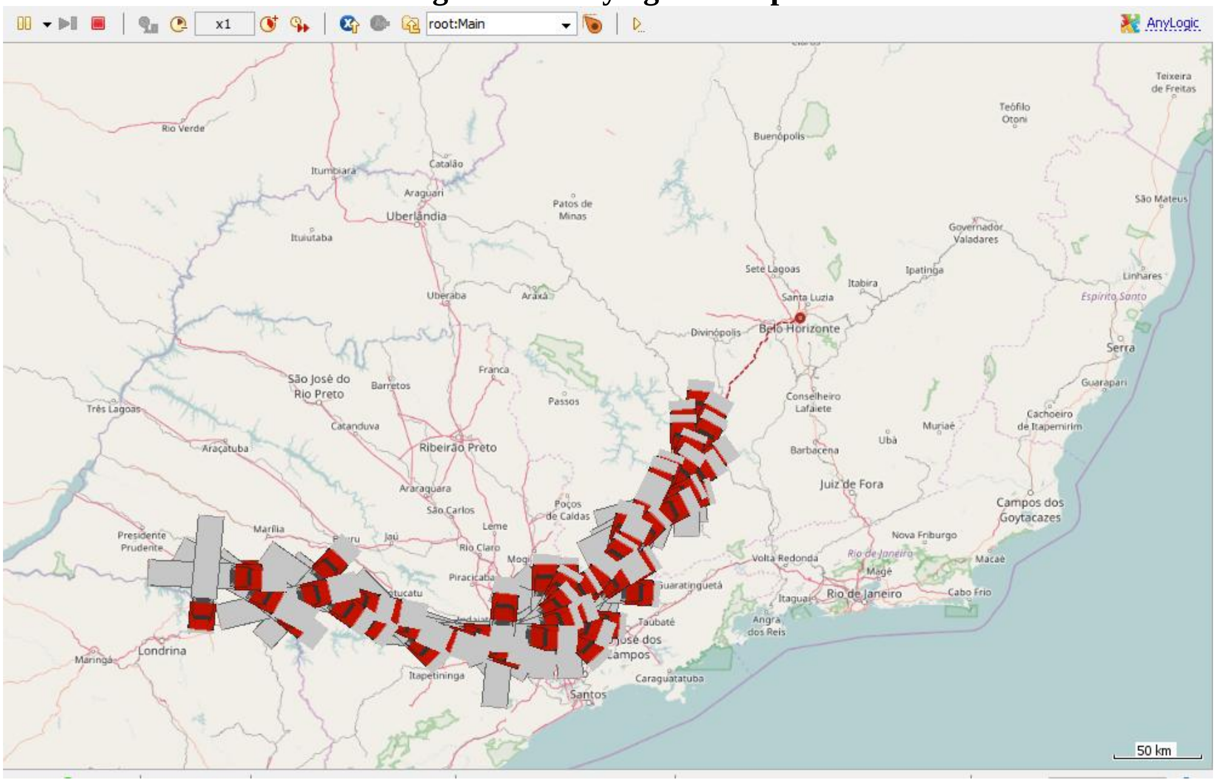


Source: Anylogic 8 (2017).

In Figure 32, shows us more of the dynamic simulator. Each hour a new truck leaves the origin at Point A and proceeds towards its destination at Point B. The simulator makes it possible to conduct simultaneous simulations with other points, and also makes it possible to analyze the real delivery time simultaneously as well, which thus makes it possible to verify the efficiency of the logistics system.

In a system with multiple modes of transport, the simulator could be used to implement the concepts of the Physical Internet, in which every point of logistics distribution would be monitored the entire time, and in this way its efficiency could be verified as well as any gains in sustainability, based on the gas emissions indicator, for example.

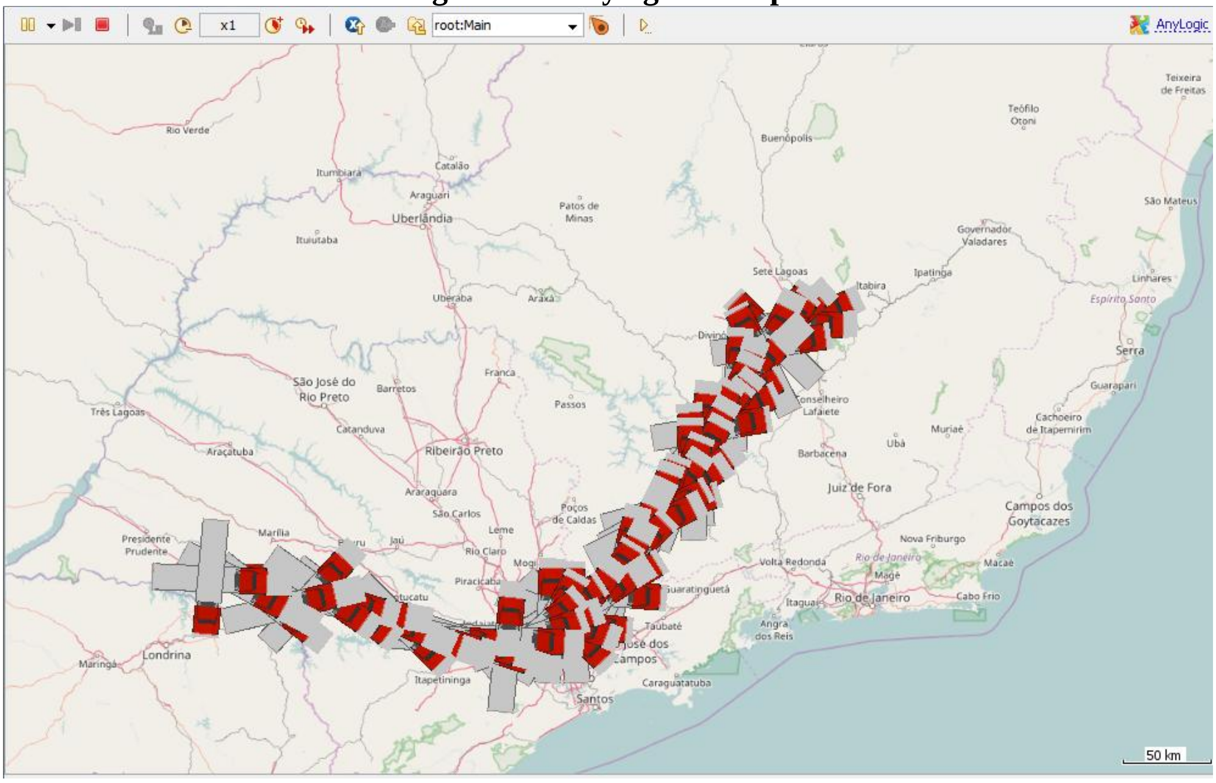
Figure 31 - Anylogic 8 - step 8



Source: Anylogic 8 (2017).

Figure 33 shows the final simulation in which all of the trucks arrive at their final destination with their sugar deliveries.

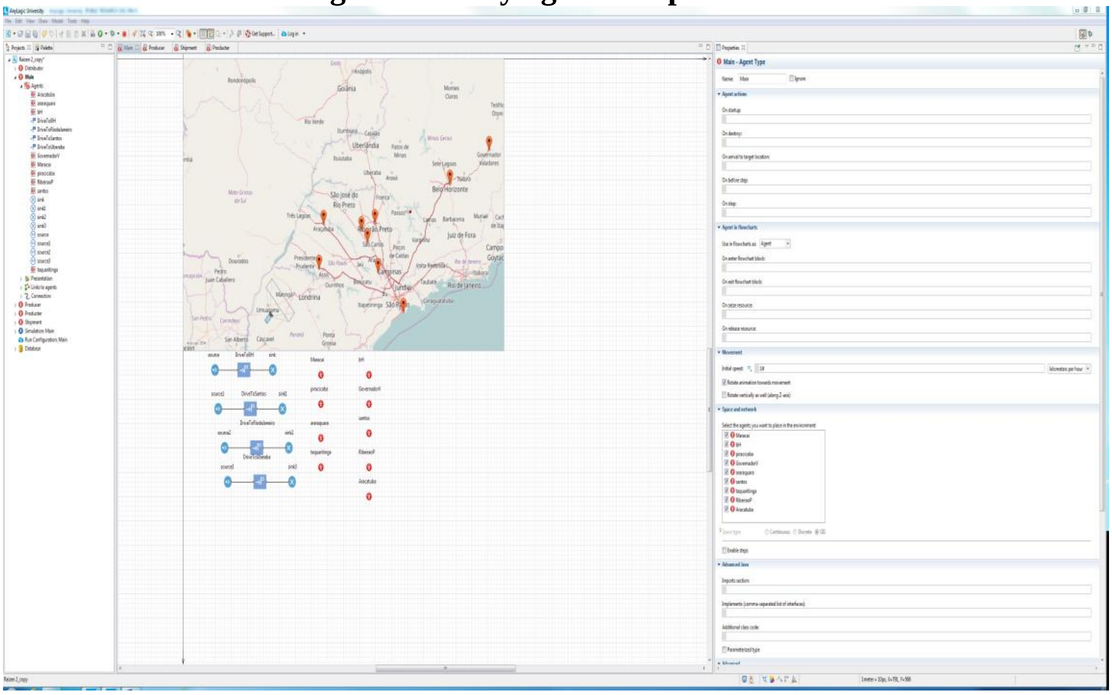
Figure 32 - Anylogic 8 - step 9



Source: Anylogic 8 (2017).

In Figure 34, Scenario 2 was selected. A different kind of simulation was used with various destinations for the sugar deliveries. There are several points for producers and distributors at the same time.

Figure 33 - Anylogic 8 - step 10

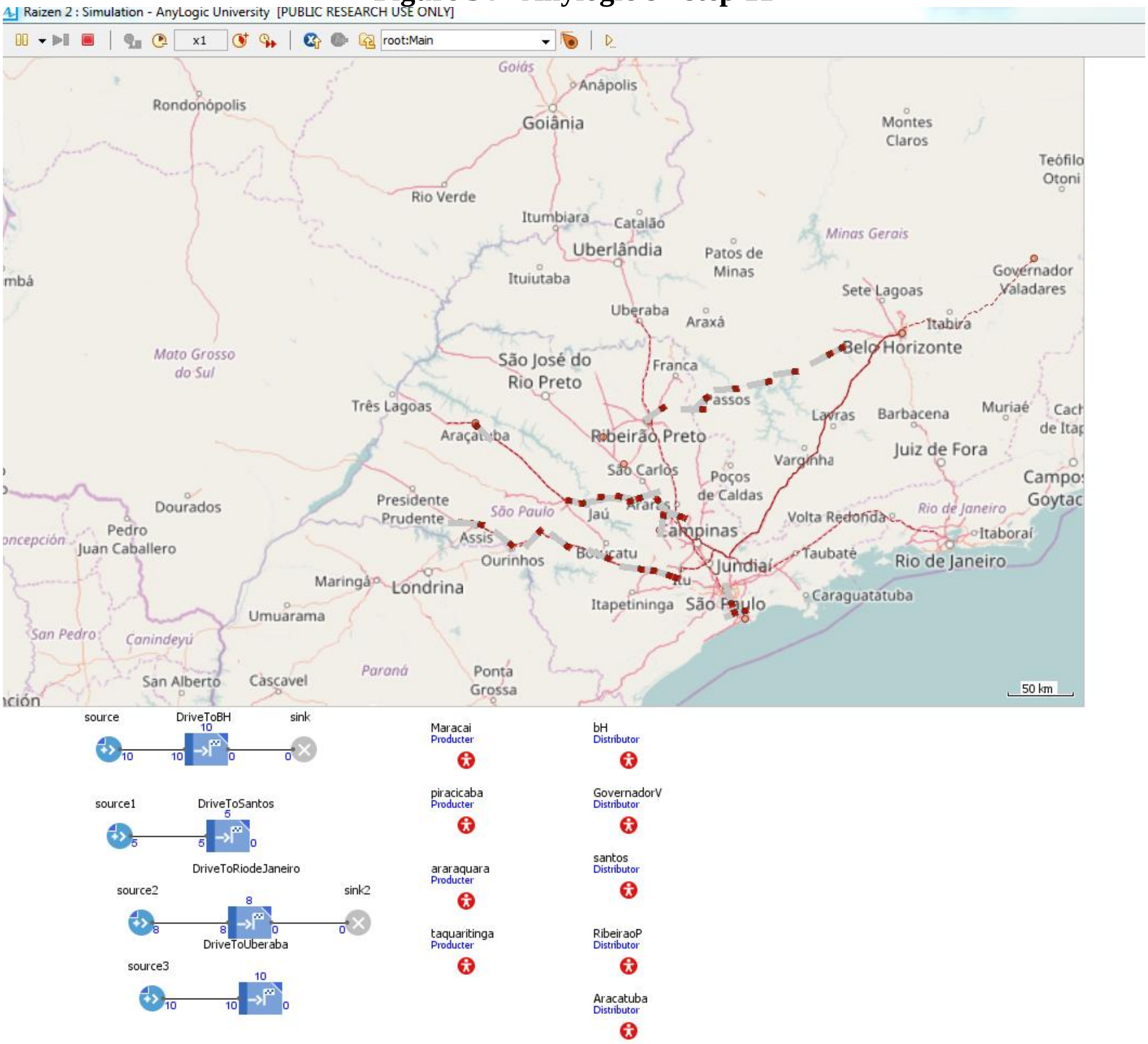


Source: Anylogic 8 (2017).

The selected producer points were the cities of Maracaí (São Paulo), Piracicaba (São Paulo), Araraquara (São Paulo) and Taquaritinga (São Paulo). The selected distributor points were the cities of Belo Horizonte (Minas Gerais), Governador Valadares (Minas Gerais), Santos (São Paulo) and Ribeirão Preto (São Paulo).

In Figure 36, Point A (producer) was Assis (São Paulo) and Point B (distributor) was Santos (São Paulo). Point C (producer) was Araraquara (São Paulo) and Point D (distributor) was Uberaba (Minas Gerais). Point E (producer) was Piracicaba (São Paulo) and Point F (distributor) was Governador Valadares (Minas Gerais).

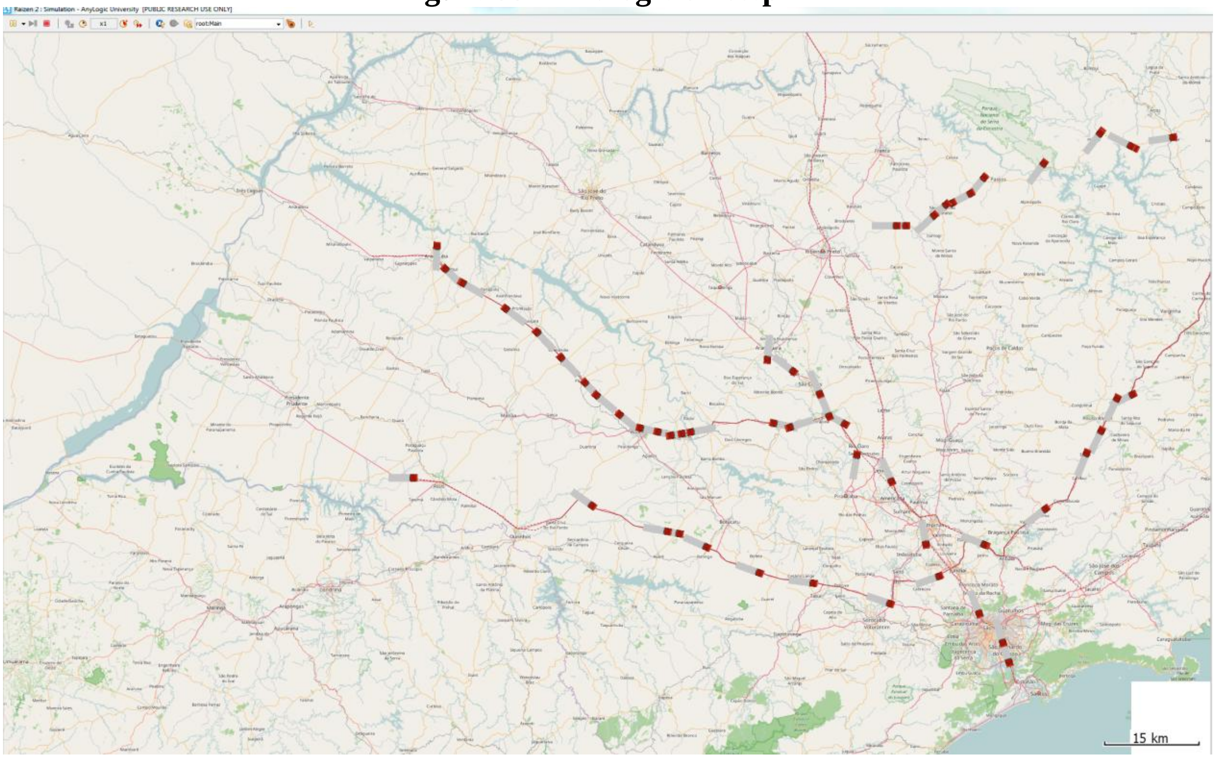
Figure 34 - Anylogic 8 - step 11



Source: Anylogic 8 (2017).

In Figure 36, the simulator is running dynamically. Using the parameters inserted into the simulator, we have all the possible trucks making sugar deliveries from one point to the other. Applying Physical Internet concepts, these products are monitored throughout the distribution process leaving the mill and proceeding to the destination. Sugar transport routes can also be simulated to verify whether there is sufficient capacity for a delivery in a given space and time, which modes of transport can be used, and how much carbon dioxide emissions have been reduced by these system. This is something that still has not been realized in southeastern Brazil according to the surveyed sugar transporters.

Figure 35 - Analogic 8 - step 12



Source: Anylogic 8 (2017).

Based on the examples studied by the simulator, it is possible to verify the functioning of a totally connected distribution system with information from the truck's departure from the producer until its arrival at the wholesaler, with complete transport monitoring, and most importantly control of gas emissions. Other sustainability indicators can be adopted, but within the current context, controlling emissions would be the most significant indicator, given that most of the Brazilian logistics system in based on road transport.

If the Brazilian logistics system were adapted for multiple modes of transport, the simulator could identify which would be the best mode of transport for a single destination and could meet pollution reduction expectations through its delivery flexibility.

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8.3 Final Analysis

Brazil is a continental country with strong agribusiness production that drives the domestic market and is responsible for the large volumes of exports that make Brazil’s trade balance dynamic. In this work, it has been demonstrated that society, the federal government and the stakeholders involved all require efficient and sustainable logistics. The PIL launched by the government seeks to improve efficiency in road routes, but it is still in the execution phase. The project is quite important to the federal budget, but focuses on the road mode of transport that causes a relatively high level of pollution. Historically, Brazil has made use of its railroads, but currently they are in disuse, which is the opposite of what has happened in other continental countries like the United States and Canada.

The southeastern region is one of the most developed and has large sugar cane plantations, with their principal product being sugar, the object of this study. Brazilian logistics for sugar distribution in the southeastern region relies mainly on road transport. This system is not integrated, and the sugar cane mills have individual solutions to their transport needs. Transport contractors provide their services to these mills. Upon receiving delivery orders from these mills, manager´s transport determine how deliveries are made. Unique routes are used, and these trips occur according to the demand of sugar mills, which usually also have other products such as ethanol.

The logistics of this segment, therefore, follow the logic of dedicated services, that is, deliveries are made exclusively for each client. The amount charged is preset regardless of whether the load is completely full or not. Problems such as theft or the misuse of deliveries may also exist, and this has already happened to this company. The reason why owners are looking for a freight management application solution is to solve problems like this.

Transport companies do not work with sustainability indicators, so they do not know the effects that the current delivery system has on the environment and society. There is concern about this environmental issue, but no preventive measures have been taken to control the emission of gas pollutants, for example, since the transportation is carried out entirely by road.

The sugar logistics for the surveyed companies in the southeastern region follow the criterion of speed in delivery. Normally, they do not have warehouses or distribution centers, except in Porto Alegre far away in the South and the port of Santos. However, exports represent a small percentage of the sales of these mills, and they sell primarily to wholesalers in the domestic market. Thus, a single vehicle is loaded at the point of origin and continues on towards its final destination. Multiple modes of transport are not utilized in this survey of this sector in the southeastern region with occasional deliveries in the South. Since deliveries are dedicated, loads are sent to their final destination, and these trucks return to their origin completely empty. Pollutants are being generated without any delivery being made. In addition, the driver of this load has to make an exhausting journey that may have to be repeated several times.

Having identified these inefficiencies in Brazilian sugar distribution and logistics, this work suggests the application of Physical Internet concepts, created by professor Benoit Montreuil. He decided that several lessons could be learned from the way digital information is packaged and moved across the Internet. The application of an open, global logistics system is a contrast to the proprietary or closed systems that are common today. The idea of physical, digital and operational interconnectivity enabled by encapsulation, protocols and smart interfaces for increased efficiency and sustainability would be a better way to deliver sugar to wholesalers in southeastern Brazil. The concepts of the Physical Internet may sound complex, but they can be boiled down to a few simple principles.

Interconnectivity: In the world of logistics today, many countries have unique standards. For example, a 48 x 40-inch pallet may be ubiquitous in the U.S., but there are different standards in Europe and Asia. Similarly, one supplier’s conveyor belt may not connect with another supplier’s conveyor belt. The Physical Internet aims for universal connectivity. Containers should connect with other containers, no matter what product is inside. It should easily fit on the conveyor belt and easily on the lift. Handoffs throughout the supply chain should be easy.

Encapsulation: The Physical Internet does not deal with freight. It only deals with packaged goods, much like ports only deal with containers. Outside of ports, distribution centers and logistics providers are dealing with hundreds of different kinds of boxes and they’re not easy to handle. The Internet, on the other hand, only deals with packets of information that are formatted very precisely.

Montreuil envisions an array of standard sized containers that will be used around the globe. They would begin with standards for maritime containers and truck trailers. Shipping containers and cartons would be sized to maximize the space inside these standard containers and trailers. Regardless of the size, they would be environmentally sustainable, trackable by bar codes or RFID, and would also be modular. Those behind the Physical Internet will also talk to rack and conveyor specialists to come up with containers that are easy to handle and are designed for logistics.

Security: Whatever their size and design, containers used by the Physical Internet will be sealable for security in the same way as a shipping container is sealed today.

So, is the Physical Internet a dream or is it a possibility? Technology is very important to this process. There is no science fiction and nothing to invent in terms of software and data collection. Companies could come up with handling innovations to make this happen very quickly. In Montreuil’s definition, quickly is about a decade in the world. The real challenge is overcoming the reservations that businesses have in terms of collaborating with one another to make the Physical Internet work. Companies will need to come up with new business models. The other challenge is convincing a group of shippers to do it now, rather than later. While it may take a decade to get a global Physical Internet up and running, Montreuil believes that a consortium of companies, or even an entire industry, could do it now. So, this is a possibility if all the players work together.

The biggest hurdle is the reluctance of companies to do this until everything is in place to operate on a global scale. There is a possibility to make it phased in now and then grow incrementally. The trucks that travel on our highways and the delivery trucks that circulate through our cities are on average half empty, if not *completely* empty. Even if it is unrealistic to run at 100% capacity at all times, significant progress can be made. And this progress will provide all the players in the chain with margins by decreasing environmental effects and energy consumption.

There is a lot of the containers and packages that we ship are filled with air. There are far too many empty and/or unnecessary trips, and storage systems are often underutilized because they are scaled for peak usage. Scattered across a multitude of competing systems, the logistics industry suffers from a huge deficit in terms of efficiency. This type of organization would have a tangible effect on prices, urban congestion, traffic, pollution…

The Physical Internet offers a response to all of these challenges by offering large-scale optimization, which is made possible by streamlining the system, standardizing tools (both hardware and software) and the pooling of resources. The basic building block of this system, the equivalent of the packet of information flowing through the Internet, is a smart, standardized container. Such containers are currently being developed, and we still need to imagine the networks that will deliver them. Through the Physical Internet it will be possible to make a delivery using various modes of transport including trucks as part of the trip. This would cause less fatigue and exhaustion for drivers, and it would make it possible to manage the fleet with sustainability indicators in order to lessen the damage done to the environment.

The general objective of this study has been to analyze the existing issues in terms of sugar company logistics in southeastern Brazil, and how Physical Internet concepts can be used to improve logistics using multiple modes of transport with a focus on sustainability. It has been demonstrated by the Colombo mill that it is possible to manage faster and more efficient deliveries and control sustainability indicators such as gas emissions by using alternate routes with roads that are part of a route from one point to another in a hyperconnected way.

The specific objectives of this work have been the following: to list the main structural, environmental and social problems related to logistics in the southeastern region related to sugar transport. As has been noted, there are few modes of transport, and there are problems with pollution and high costs for companies that deliver sugar. The main logistics difficulties that sugar companies face in commercializing their products for national and international trade are: greater representativeness for existing modes of transport for short and medium distances with initial low-cost implementation and high-cost maintenance; more pollutants with a strong environmental impact; the need for more flexibility including a large network extension; implementing moderate speed forms of transport with cost increases as distances increase; low cargo capacity in terms of volume and weight, and the integration of all of the states in Brazil. The modes of transport employed used by sugar companies are roads and highways. In terms of sustainability indicators used in sugar industry logistics, it appears that none are in use. The criteria used for the distribution and delivery of sugar to wholesalers in the Southeast and South are simply speed and efficiency. Finally, this study has identified the nature of logistics today and has verified how the Physical Internet would change the logistics in this region: it would make multiple modes of transport possible and would provide a hyperconnected system that would probably make it easier to deliver sugar and have a sustainable indicator like the emission of gas pollutants, and this would be possible through the employment of a simulator to map routes.

A bibliographic review clearly demonstrates the importance of sustainability in the logistics area. Physical Internet concept clearly indicate the existence of sustainability in the supply chain and logistics area. Researchers from all over the world are concerned with this issue: Siche et al. (2007), Bursztein et al. (1993), Meixell and Gargeya (2005), Porter and Kramer (2011), Gibson et al. (2012), Govindam et al. (2014), Façanha, Silva and Feldmann

(2010), and Montreuil, Meller and Ballot (2012) among others. It has also been confirmed by RODRIGUES et al. (2011) who state that it is:

> […] fundamental to have a detailed view of the main components of logistics in terms of study and planning, namely: stocks, locations and transports. As well as sustainability, logistics is also based on a tripod. The twenty-first century's new approaches to corporate logistics are aimed at preserving the environment. In this new era, managers are concerned not only with the flow of products towards end consumers, but also with the opposite flow direction, so-called reverse logistics.

The theoretical reference tells the history of the transport system. Railroads were significant actors in term of product distribution at first. However, as the Ministry of Transport (2015) has stated, "the privatization process of RFFSA was performed based on Federal law n° 8987/95, the so-called Law of Concessions." The resulting privatization of the management of the Plan of Goals from the '50s confirms that the construction of highways has been considerably favored, and road transport remains the main mode of distribution today for several sectors of the economy, especially the sugar industry, which is the subject of this study.

Brazil's southeastern region is the most important region of the country economically, representing 40% of Brazilian GDP. Sugar cane is an important commodity mainly due to the size of the plantations, and the size of these sugar companies, which accounts for the distribution of the product to wholesalers. Moreover, the main producers are also relevant in assuring the significance of the product in both internal and external markets. Product distribution in internal markets is almost totally carried out through road transport. However, distribution to external markets is accomplished through sea transport. This finding was confirmed during the visit to the Colombo mill. Thus, it was found that sugar is distributed by motorways in Brazil and by waterways to the external market.

This study demonstrates the impact of the Physical Internet, and the simulations allowed us to point out how its concepts can benefit sugar cane distribution in a sustainable way. Due to a hyperconnected network and container standardization, modern transporting enterprises, even with each sugar company working in an isolated way, can operate in a joint, systematic fashion, participating in each stage of distribution using information based on a joint protocol. Current packaging can be replaced by standardized, smart packaging, which will allow clients to follow each delivery stage using a cell phone app, for example. This is confirmed by authors Montreuil; Ballot; Tremblay (2014), who state that "the Physical Internet is a network of networks, each embedding nodes and links between these nodes, with standard modular containers. Its introduction aims toward a radical improvement in the economic, environmental and social sustainability of worldwide transportation, handling, storage, supply, and the production and usage of physical goods. This is why the Physical Internet features a focused material handling system, and logistics facility design and innovation need to be addressed."

The simulator also makes demand estimation possible, which generates less impact when production waste is a possible outcome. This is so because the information system controls each customer order that is placed based on its data. Simulator maps can point out which modes of transport to use, and avoid restricting distribution to a single mode of transport. Events like the recent truck driver strike of May 2018 would have less impact and the system would be less vulnerable system if other modes of transport were in fact used. In the near future, it would be very interesting for the stakeholders to think about the possibility of joining a hyper- connected network reference protocol.

So, southeastern Brazil's current logistics for sugar cane as a final product depends on the highway mode of transport and outsourced transportation enterprises which operate mainly on an exclusive basis, which is customized, expensive and causes more pollution. Sustainable practices in terms of controlling gas emissions have not been adopted by these enterprises according to our data. Freight is very expensive and taxes also contribute to high prices.

Physical Internet concepts can generate efficiencies due to the use of information protocols, standardized and clever packaging and multiple modes of distribution transport. Controlling gas emissions can improve sustainability. Moreover, the Physical Internet can provide faster information for clients concerned about product delivery.

Currently, sugar cane producers in this part of the country are concerned with sustainability and information control. There are enterprises like GKO that have shown interest in the issues presented by the Physical Internet, though they work individually and only try to solve specific company problems, which is what they have been hired to do. This is confirmed by Pan et al's citation (2017):

> The concept of the Physical Internet seems to address the key points of Brazilian logistics problems because in logistics, the Physical Internet is a global open logistics system founded on physical, digital, and operational interconnectivity, trough encapsulation, interfaces and protocols. The Physical Internet does not manipulate physical goods directly, whether they are materials, parts, merchandise or even products. It exclusively manipulates containers that have been explicitly designed for the Physical Internet and that encapsulate physical goods within them.

The purpose of this thesis has been to demonstrate that possibilities exist for improving distribution logistics problems through the use of a clever, integrated network. However, adopting these practices requires a consensus among the main production and distribution system actors. This is already a reality in Canada, France, Germany and the United States. A thesis has to present something new in terms of science, something that is state of the art. This study has presented an innovative concept as Montreuil, Ballot and Tremblay (2014) confirm: “This study also attempts to highlight the great innovative breakthrough that has been presented by the introduction of the Physical Internet. This is a significant innovation opportunity for material handling technology providers and logistics facilities designers.”

The research involved in this thesis is limited because it considers only one product and a unique national region. Brazil is a country of continental proportions in which many other products and commodities are produced and marketed. Furthermore, only one type of simulation has been taken into account and it is based on a GIS map. The Anylogic simulator can also handle other types of simulations such as passenger transport, multiple agents, etc. and depending on the study objective, other aspects can be examined.

In terms of future research, economic aspects and social benefits can be explored, which would benefit from the application of the Physical Internet. An exact measurement of how much it would cost to adopt a connected network protocol and the social benefits this would bring could inform the decision making process of Brazilian producer and distributor logistics specialists in evaluating the Physical Internet.

The simulator also makes it possible to estimate demand, which would have less of an impact on possible production waste, since the information system would control the requests of each database client. The use of the simulator’s map could show which mode should be used, avoiding that a dependence on a single mode of transport. Facts such as the severe truck driver strike in May 2018 would generate less significant impacts and make the system less vulnerable if other modes were used. In the near future, it would be very interesting if key stakeholders thought about joining a hyperconnected referral protocol.

We have concluded that the current logistics in southeastern Brazil for the finished sugar products is dependent on the road mode of transport and outsourced transport companies that currently handle each client in an individualized and expensive manner that leads to greater pollution. Sustainability practices such as gas emission control have not been adopted by the companies surveyed. Freight is expensive and taxes raise the final price of sugar.

The concepts of Physical Internet presented could generate greater efficiency with the use of an information protocol, standardized and intelligent packing, and multiple modes of distribution transport. Gas emission control would improve the sustainability issue and the use of information from the Internet of Things would make it possible to delivery information to clients at a faster and faster rate.

Currently sugar producers in the region have concerns about sustainability and information control. There are companies such as GKO, which has been presented in this study, which have shown interest in the issues that the Physical Internet presents, but they work in isolation, trying to solve the specific problems of the companies that have hired them.

What this study is proposing is that it is possible to improve distribution logistics problems through an integrated and intelligent network, but there would have to be a consensus among the main actors within the production and distribution system. This is a reality in countries like Canada, Germany, the United States and France.

9 CONCLUSION REMARKS

This research addresses the issue of logistics involving the distribution of outbound products in a particular region of Brazil. To make a better assessment, sugar has been chosen because it is an important commodity in this country's internal and external trade agenda.

Environmental, economic and social problems are relevant when it comes to logistics. Brazil is a country that has encouraged road transport throughout its history and has watched its trade increase over time. Normally there has not been logistics planning, and distribution is based on meeting current demands one at a time.

Precarious roads, high toll rates, and fuel pollution are some of the problems that this research has raised. The environmental issue is the most urgent of these, because it directly affects the conditions of the existence of our future generations. Conditions in terms of our climate and sustainability have been the subject of much debate around the world. For this reason, this research has raised the issue of sustainability in terms of logistics.

This study's purpose is to make an effort to encourage the application of the Physical Internet, a tool that has been adopted by first world countries and that has presented significant results in terms of speed, efficiency and sustainability in the delivery of products.

Brazil is a country that faces many problems in terms of politics, economics and financial stability. The adoption of the Physical Internet may seem somewhat audacious and uncertain to Brazilian logistics players. There will be a need for a large amount of investment to adopt an integrated platform, especially for a country the size of Brazil. At the moment, this study's objective is to show that these concepts can be effective in solving the main logistics problems in Brazil. The investment that would need to be made should be dealt with later, when all those involved feel convinced that the proposed solution can be applied and provide improvements in the distribution of products. Other surveys may indicate the costs of its deployment, but for this we need to know all of the benefits of the Physical Internet.

The conclusion, therefore, is that this study demonstrated the possibility of application of the concepts of the Physical Internet and its viability in Brazil provided that the logistics infrastructure is adequate to a hyperconnected, multimodal, systemic and integrated format. Actors of this system can work on the same network. The distribution can be realized in an integrated way, using a platform that communicates through several hubs scattered throughout the country. Simulations can help in the gradual adoption of this system. The results can prove that the logistic problems presented in this research can be solved.

A limitation of this study is that only one product and one Brazilian region have been studied. Brazil is a country of continental size and has many other products which are marketed. In addition, only one type of simulation was used with the GIS map. The Anylogic simulator has many other types of simulation, such as the transport of passengers and multiple agents, among others, depending on what you want to research, and other aspects could be analyzed.

For future studies, economic aspects and social benefits that could come from the application of the Physical Internet could be explored. How much the implementation of the connected network protocol would cost and the measurement of its social benefits could help encourage its adoption by Brazilian producer and distributor logistics operations.

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APPENDIX A

1. How was the company founded?

2. Why did you choose sugar cane?

3. What's involved in producing sugar and what is the market like?

4. How is sugar distributed?

5. Which are the main markets that consume the sugar you produce?

6. What are the main difficulties that your company faces in distributing sugar?

7. Has the company sought a solution to improve the distribution of its product?

8. Has the company adopted a sustainability policy in terms of the product's delivery?

9. Would your company be open to a change involving the improved distribution of sugar based on sustainability?

10. What are your company's expectations in terms of the future distribution of sugar and how would it like to see itself within this scenario?

APPENDIX B

1. When receiving the request for a delivery from the mill, what is taken into account to decide how the delivery will be made?

2. What are the criteria used to send the product?

3. Are your cargo shipments dedicated (consisting only of products from the Colombo mill) or are they shared (the cargo is divided with products from other companies that are going to the same location)?

4. How much time does it take to deliver each type of package on average (and can you explain why) ?

5. How is the route chosen? Is there more than one for the same location? Are only trucks used?

6. Could you give me some examples of routes that are used by the Colombo mill?

7. Are there records of sustainability indicators (such as gas emissions, etc.) for sugar distribution?

ANEXO A

MODULUSHCA Report Summary

Project ID: 314468

Funded
under:
FP7-
TRANSPO
RT

Country:
Germany

Final Report Summary - MODULUSHCA (Modular Logistics Units in Shared Co-modal Networks)

Executive Summary:

The objective of MODULUSHCA was to achieve the first genuine contribution to the development of interconnected logistics at the European level, in close coordination with North American partners and the international Physical Internet Initiative. The goal of the project was to enable operating with developed iso-modular logistics units of sizes adequate for real modal and co- modal flows of fast-moving consumer goods (FMCG), providing a basis for an interconnected logistics system for 2030.

MODULUSHCA integrated five interrelated working fields:

1. developing a vision addressing the user needs for interconnected logistics in the FMCG domain,

2. the development of a set of exchangeable (ISO) modular logistics units providing a building block of smaller units,

3. establishing digital interconnectivity of the units,

4. development of an interconnected logistics operations platform leading to a significant reduction in costs and CO_2 emissions that will be

5. demonstrated in two implementation pilots for interconnected solutions.

Project Context and Objectives:

The objective of MODULUSHCA was to achieve the first genuine contribution to the development of interconnected logistics at the European level, in close coordination with North American partners and the international Physical Internet Initiative. The goal of the project was to enable operating with developed iso-modular logistics units of sizes adequate for real modal and co- modal flows of fast-moving consumer goods (FMCG), providing a basis for an interconnected logistics system for 2030.

MODULUSHCA integrated five interrelated working fields:

6. developing a vision addressing the user needs for interconnected logistics in the FMCG domain,

7. the development of a set of exchangeable (ISO) modular logistics units providing a building block of smaller units,

8. establishing digital interconnectivity of the units,

9. development of an interconnected logistics operations platform leading to a significant

reduction in costs and CO2 emissions that will be

10. demonstrated in two implementation pilots for interconnected solutions.

Project Results:

During the project life time, the main working areas and achievements have been:

- Finalisation of a framework on how Physical Internet can enable an interconnected FMCG logistics system has been developed in several workshops with experts from industry partners, also explaining obstacles and success factors to a Physical Internet enabled system
- Development of modular boxes in the FMCG sector in two versions, version 1 focusing on interlocking mechanism and

ersion 2 made by panels

- Algorithms for digital interconnectivity between different IT systems have been chosen and described as well as a sensoring and communication approach for modular logistics units
- Recommendations have been developed for the standardisation of iso modular containers
- Two implementation pilots have been carried out
- Active promotion of the Physical Internet and MODULUSHCA has been made, accompanied by dedicated dissemination material (brochure, templates, website, internal working space to share information, mailing lists, etc.)
- The Advisory board (Board of Directors) with experts from 13 industry and science institutions has been continued

Potential Impact:

Communication and Dissemination Strategy

The dedicated Communication and Dissemination Strategy was presented as D7.1: Dissemination strategy. It outlines in detail which public and private target groups the project intends to reach, by means of which project communication tools and through which dissemination channels at the European, national and local level. This was used as an alive document and has therefore been constantly updated during the project lifetime.

Website

A dedicated project website was set up ashttp://www.MODULUSHCA.eu/. It allows the internal and external community to follow up on new developments and results.

Figure 12: MODULUSHCA website

A WIKIPEDIA article was developed, improved and can be visited

underhttp://en.wikipedia.org/wiki/Physical_Internet. Figure 13: Wikipedia article about PI and

MODULUSHA

Social Media

2.0 social media web channels have been set up and are used for communication:

- Twitter: @MODULUSHCA
- YouTube: MODULUSHCA
- Facebook: MODULUSHCA
- LinkedIn: Physical Internet Initiative group

Brochure

A project brochure was produced and presented. It shows the project's main objectives and expected results at a glance and has been distributed widely since then. It has been revised and updated during the project lifetime.

Press releases

Four press releases have been distributed to inform interested people about the MODULUSHCA results.

Figure 14: Press releases

Newsletters

After the first newsletter in reporting period one, MODLUSHCA has been produced 5 more between July 2014 and January 2016 to keep the interested project community informed of the project's progress and results. They have been distributed via the mailing list and can be found on the website.

Figure 15: MODULUSHCA newsletters

Conferences:

MODULUSHCA has co-organised the 1st and 2nd International Physical Internet Conference.

The 1st International Physical Internet Conference was held in Quebec City between 28th and 30th of May 2014.

The 2nd International Physical Internet Conference was held in Paris, a three day event between 6th and 8th of July 2015 in

Paris. It was also the final event (see D7.2)

- >250 Registrations for the Conference
- 116 high level speakers
- 3 days

Exploitation

Several actions were taken to exploit the MODULUSHCA results. An exploitation strategy has been developed placing the focus on the following fields

- Box development and bringing it into the market
- Improved network logistics through sharing capacity
- Enhance supply chain co-operation of manufacturer, retail and transport
- Information management for co-operative logistics

Dedicated exploitation approaches have been developed consisting of:

- Awareness creation on the Physical Internet and MODULUSHCA
- Individual exploitation plans towards the exploitation focus of the partners

Within the first half of the project, focus has been given to the awareness making, while individual strategies on technical exploitation has been the focus in the second half of the project. P&G and PTV have presented the project at many occasions.

In parallel, specific meetings with companies/organizations have been organized to identify field of cooperation within the

MODULUSHCA project:

- Siemens AG Infrastructure & Cities Sector Mobility and Logistics Division
- Nestle
- ECR
- Schoeller Allibert
- Utz
- TESCO
- DM
- AXIT

In addition, a close partnership has been established with the sister project in Canada in order to set up a clear and structures framework of cooperation.

Industrial Advisory Board

An Industrial Advisory Group composed of key industrial stakeholders has been established involving now the following external experts:

- Prof. Georges Huang (University of Hong Kong)
- Prof. Dr. J. Rod Franklin (Kuehne & Nagel)
- Mr. Guillaume Tilquin (Renault)
- Mr. Max Winkler (SSI Schäfer)
- Mr. Michiel Nielsen (IRU)
- Mr. Roeland van Boeckel (CEN/TC 320)
- Mr. Dirk Thooft (Holland International Distribution Council)
- Mr. JeanLuc Azzani (P&G)
- Mr. Jean Fortin (SOUTHSHORE)
- Ms. Anna Ivers-Tiffée (DHL)
- Mr. Dave Sheldon (Nestle)
- Mr Ludo Gielen (Schoeller Allibert)
- Mr. Christof Weis (IFCO)

Three Advisory Board meetings have been carried out:

The first one in Munich on the 4th of June 2013 on the Transport Logistics 2013, the International Exhibition for Logistics, Mobility, IT and Supply Chain Management

The second Advisory Board meeting with 29 participants has been carried out on 7th of March 2014 in Brussels. The project board discussed and agreed upon u.o.

- the overall approach of MODULUSHCA,
- the progress and results,
- further proceeding of the project.

A third meeting had been held on December 2015 in Brussels, discussing the results and exploitation approaches with the

Board of Directors. The commitment was very good, the discussion lively.

List of Websites:

http://www.modulushca.eu/

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Related information

Result In Brief

Documents and Publications

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PTV PLANUNG TRANSPORT VERKEHR AG. Germany

Subjects

Scientific Research

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Vision of a globally interconnected logistics system by 2050 final1-modulushca-finalreport-sectiona.pdf

Permalink: https://cordis.europa.eu/result/rcn/187164_en.html