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# A view along the railroad in the organized port of Santos: a case study of sustainable logistics with multimodal operations

## Uma visão ao longo da ferrovia no porto organizado de Santos: um estudo de caso de logística sustentável com operações multimodais

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**Abstract**

This analysis has started with a third-party logistics provider to supply the production plant by a container in Brazil. The methodology of this study case is exploratory research-based on environmental saving emissions identified in method of greenhouse gases inventory about data collected in costumers which moving freight by Santos Port Authority. It can be seen in the results that a better eco-efficiency for a significant reduction in environmental impacts along the chain.

**Keywords:** Management, Railway, Modal Shift, Intermodal Transportation, Sustainability and Multimodal.

**Resumo**

Esta análise foi iniciada em um provedor de logística terceirizado para abastecer a planta de produção por contêiner no Brasil. A metodologia deste estudo de caso é uma pesquisa exploratória baseada na economia de emissões ambientais identificadas no método de inventário de gases de efeito estufa sobre dados coletados em clientes que movimentam cargas pela Autoridade Portuária de Santos. Pode-se constatar nos resultados, uma melhor ecoeficiência, por uma redução significativa dos impactos ambientais ao longo da cadeia.

**Palavras-chave:** Gestão, Ferrovia, Deslocamento Modal, Transporte Intermodal, Sustentabilidade e Multimodal.

## 1. INTRODUCTION

The transportation system in Brazil received significant shares of investments due to the privatization of railroad lines (in the '80s, through the deregulation of the Federal Railroad Network. Brazilian Govern (RFFSA, and of the ports (Lei de Modernização dos Portos [Port Modernization Act], Act No. 8.630/93), which was replaced by 12.815/2013 called Port Law. Both laws thus yield greater participation of the private enterprise inside public port areas, essentially the private companies which are providers of logistics services.

The concession by public services in port areas has resulted in the productive cargo transition allowing the thru port concept by investment for automation in utilizing more than one resource. Resources: RTG, Transtainers, and Mobile Harbor Cranes installed in ports with railways that use containers in cargo handling, chiefly for offering the best multimodal transport system in eco-efficiency results. Eco-efficiency means producing goods and services at competitive prices and gradually reducing environmental impact and consumption of natural resources throughout the product or service life cycle to a level at least equivalent to the capacity of the estimated subsistence of the planet (Almeida, 2007).

The interdependency of eco-innovative strategies in cargo handling can be obtained with an excellent combination of modes in a sustainable way and by enabling multimodal transportation. However, such procedures demand a new and complementary analysis or perception of energy resources concerning the development of the modal strategy to create a more sustainable and productive market with transportation services and fight global warming.

In the broad and metaphorical sense employed in business practices, transportation management uses the Modal expression Shift. They refer to an immediate and widespread idea of modal interface, intermodal, multimodal, which involves cargo handling through a succession of modes, or to the representation of each mode inset in the sustainable chain of logistics services.

Adopting patterns of sustainability process by the intermodal system can increase the participation of new logistics operators and shall establish paradigms in their corporate strategies, aiming at international competition and contribution to society and the environment.

Maybe, It will be the right way to help sustainable logistics, to reduce $CO^2$ emissions by adopting eco-efficient modes (Soares, 2009).

The transportation sector established in Agenda (Such a cross-sectoral analysis is a directive that does carried out by all industrial and service sectors whose operations may lead to fossil fuel burning from mobile sources or the acquisition of goods and services for passenger and cargo trips (Source: GHG Protocol – Mobile Guide (03/21/2005) v1.3). The definition of Environmentally-Sustainable Transportation as follows:

[...] transport that does not jeopardize the public health or ecosystems and that meets the mobility needs consistently with (a) the use of renewable resources at levels lower than its regeneration rates and (b) the use of non-renewable resources at levels lower than the development of renewable substitutes (OCDE, 2010).

Overall, the concept of Modal Shift suggested by several politicians and researchers seeks ways to evolve toward an environmentally sustainable transportation system, enabling the employment of cargo shifts between faster modes to slower modes. In the search for organizational models against the negative aspects of greenhouse gas emissions generated in transporting activities, which have become evident from the rise in hauling transportation use. Opportunely, the study on the environmental impact of a modal transfer can be demonstrated to influence the decision on cross-sectoral analysis in services to public or private management for Modal Shift.

This research proposes establishing an economic value, even if symbolically, on the environmental impacts, which might be avoided by transferring cargo from the road transportation mode to the rail mode or a more eco-efficient mode. From such a definition, one might consider Modal Shift as the transition of modal transfer from transportation by trucks to rail transportation, ship, barges, or other modes. To better preserve the environment by producing less environmentally loading gas emissions and other pollutants cast into the atmosphere (Konami, 2010).

The SHIFT SYSTEM is a multimodal logistics operator collaborating in this investigation. Besides that, the inventory was demonstrated to find out part of mitigation after the manager's decision for a modal shift which was a bold decision with results about reducing $CO^2$ emission for earth surface logistics.

## 2. THEORETICAL REFERENCES

### 2.1. Concept of *Modal Shift*

According to Okano et al. (2006), Modal Shift is defined as the means or ways to consider modal changes from transportation by trucks to rail or maritime transportation, which are usually more efficient concerning costs and $CO^2$ emissions. They state that combining transportation by truck with other transportation modes makes it possible to increase transportation efficiency, resulting in a reduction of logistics costs and, simultaneously, $CO^2$ emissions.

As stated by Takahashi (2006), as to the meaning of Modal Shift, in the broad sense of organizational practices, such a concept is observed by choosing the mode (style and form/modal characteristics) or type of cargo displacement (handling and equipment replacement) to another mode, see figure 1.

Figure 1. Modal Shift Concept

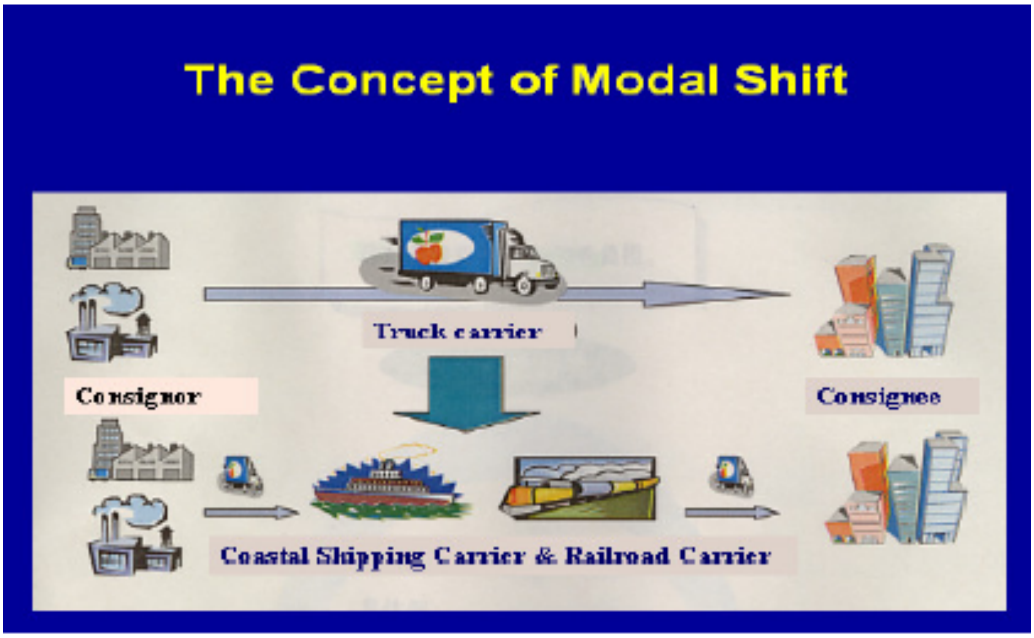


Figure 1. Modal Shift Concept
Source: SHIFT SYSTEM - Adapted from Takahashi (2006).

Frequently, the European Commission (2003) states that intermodal transportation may be a reliable solution with a combination of road and rail modes. Rodrigue et al. (2008) consider that the increase in the demand for a transportation mode to the detriment of another may entail an increase that is not at all restricted to one single modality but to all those directly involved in modal shifting. Thus, the conditions for an eco-efficient market of cargo transportation may become feasible since there is a strategy for an efficient cargo transfer, counting on the participation of maritime, rail, and fluvial transportation through the implementation of new services with technological innovations or improvements to the existing services (European Commission, 2003).

According to Rodrigue et al. (2006), the comparative advantages are confirmed, in terms of economy of scale, from one mode to another or in the functional integration of the supply chain, where, in terms of logistics costs, the advantages may be noticed in the physical distribution through other factors, such as convenience, swiftness, reliability.

In the analysis of an integrated transport-oriented perspective, a modal transfer may become feasible in the context of organizational changes to develop innovations in the corporate environment, from the macro-perspective, with a local and regional environmental policy, or from the micro-perspective, where the changes in transport offer must orient strategic decisions based upon the behavior of consumption (of people) or companies (production). For instance, in intermodal transportation of perishable goods, other specific characteristics, such as shorter distances (transit time) and transshipment time lengths, are required (Bontekoning et al., 2002).

Therefore, organizational models for transportation management, in processes of business logistics, demand to over to models of innovations reflecting needs following the modal characteristics, such as speed in long-distance, reliability for high value-added cargo, and as for short distances, higher frequency of services, which are essential innovations, mainly with the inclusion of rail mode.

For Jolic, Strk, and Lesic (2007), distance is the most significant influence for decision-making processes to adopt intermodally in port operations, considering that, in the strategic planning of a supply chain, one must include options for transportation modes with a geographic position near the Hinterland. It is the cargo-generating potential of the port due to its area of terrestrial influence. The Hinterland depends on the region's development potential where the port is located and on terrestrial transportation costs.

In that respect, contextualizing Modal Shift in cargo-transporting business management implies concerns that may first conflict with the production system and the location of the consumption market. Rodrigue, Comtois, and Slack (1999) understand that the analysis factors for Modal Shift suggest a systemic analysis in the decision-making process, which means analyzing the distance and the logistics cost of the operation when the options for examining transportation modes. The authors consider that the elements that most affect the transportation costs are:

a. Geography: distance and accessibility imply impacts and attrition of the mode, especially for long distances, energy expenditures related to the itinerary, time, and economic costs.
b. Type of product: analysis of packing (container), insurance, and other factors;
c. Economies of scale: the higher the transported quantities, the lower the costs per unity;
d. Energy: options of energy sources (types of fuels) intensity for efficiency of transporting modalities;
e. Unbalance in foreign trade: economic impacts between imports and exports;
f. Infrastructure: conditions of roads and highways (traction and attrition/friction) have a direct impact on transportation costs, as to efficiency and capacity;

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g. Modality: modal shifting that can result in transportation costs reduction;
h. Competition and regulation: in sectors with economic power, in environments with competition (e.g., rail concessionaires) regulated by a competent body. (Rodrigue, Comtois and Slack, 1999).

On the other hand, Amano, M.; Yoshizumi, T.; Okano,H. (2003) analyze the Modal-Shift Transportation Planning Problem (MSTPP), in which the answers must offer alternatives to helping find a feasible schedule for companies, with a minimum total cost, when the time of delivery orders is deemed as the responsibility of either of the network of cargo-handling facilities or the transporting companies.

The mentioned researchers have presented the movements of carriers, considering practical constraints, such as the time of their windows or diagrams and their capacities. The number of operators available regarded that, from an algorithm, the total costs to the transporting companies utilized in the process were always minimized.

Amano, M.; Yoshizumi, T.; Okano,H (2003) has proposed a descent algorithm to solve such a planning problem rapidly. The given solution was to generate a set of routes for each delivery proposal to proactively manage the distribution process in a geo-referenced way.

For instance, the analysis of the geographical location: the two facilities between starting and destination points may not be consecutive, which means that a transporting company may not be directly available, or between them. In that case, arbitrarily, the problem suggests finding out a type of transporting company that can eco-efficiently serve most of the routes or places involved in the logistics.

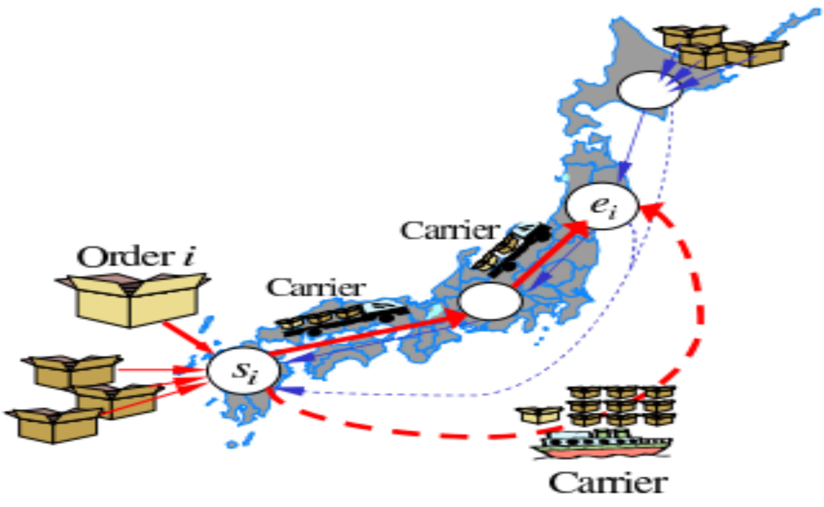


Figure 2: Schematic Figure – Transportation Planning for Modal Shift
Source: Amano, Yoshizumi, Okano (2003)

Therefore, the MSTPP bears decisions on modal transfers and inter-stops (Figure 2). In the analysis of the Okano and Koda method (2003) by means of algorithms, the solutions of the Modal Shift can be mapped for a space of abstract solution, where all configurations of the transporting company's movements are applied to the choice of the lowest total logistics cost.

**2.2. Sustainability in rail logistics**

The OCDE defines sustainability in transportation as a reference to a harmonized sector's performance by integrating public policies for transportation with other sectors and with the planning and ordering of the territory based upon the sustainable development paradigm.

However, sustainability characterizes the rising of expectations concerning economic, environmental, and social performances as the main focus and, as a secondary focus, cultural, technological, geographical, spatial, and political dimensions, among others (SACHS, 2008).

To the OCDE (2010), such dimensions are explained as:

a. Environmental sustainability: maintenance of the capability of sustainability of ecosystems and capability of absorption and recomposition of ecosystems in the face of anthropic interferences;
b. Ecological sustainability: physical base of growth to maintain stocks of natural capital incorporated into productive activities;
c. Social sustainability: seeks development and improvement of the population's life quality, which means adopting distributive and redistributive policies and universalizing services in social areas, such as health, education, housing, and social security;
d. Political sustainability: the process of constructing citizenship to ensure the incorporation of individuals into the development process;
e. Economic sustainability: efficient management of resources in general and regularity of flows of public and private investments;
f. Demographic sustainability: capability of supporting a given territory and its base of resources, scenarios, or tendencies of economic growth with demographic rates, age composition, and economically active population;
g. Cultural sustainability: capability of maintaining a diversity of cultures, values, and practices on the planet, in the country, and a region that, through time, compose the identity of the peoples;
h. Institutional sustainability: creation and strengthening of institutional engineering or sustainability-based engineering;
i. Spatial sustainability: more significant equity in the inter-region relations.

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Therefore, sustainability is consolidated into several breakdowns that can be worked up in public policies, as in the case of cargo transportation, by a set of policies that includes contributions from technological development associated to alterations in transporting activities, focusing not only on environmental aspects but also on infrastructure and production in transportation services.

Sustainability is a global and complex concept to be fully apprehended because it refers to a multidimensional practice that cannot be applied by one single activity or company (Orsato, 2009). It focuses on business opportunities and allows companies to become more responsible towards environmental, economic, and social aspects, from innovation resulting in growth and competitiveness.

This way, sustainable logistics is a concept that contributes to format a strategy to create sustainable value, since it makes necessary to examine a broad range of scenarios, such as reduction of raw material consumption and emissions, transparency levels and social-environmental responsibility, new-technology development, and fulfillment of the needs of market and society it serves. Such dynamics demand a set of activities in production and value chains.

According to Hitchcock and Willard (2008), sustainability is a business tendency that several organizations are intensely pursuing – some more successfully than others. They report that implementing a sustainability program in many aspects means programming an eco-efficiency-oriented organizational change.

Tom Sachs (2008), sustainability characterizes the elevation of expectations concerning economic, environmental, and social performances as the main focus, and cultural, technological, geographical, spatial, and political dimensions, among others, as secondary ones. The institutional dimension tackles disclosing information related to sustainability activities that the company develops in its strategy. Such dimensions refer to productive chain, investment in sustainable technologies and processes, costs, feedback of such investments in the short, medium, and long run, social impact of the market's perception, and return to shareholders of the sustainable companies.

On the other hand, the information is directly or indirectly captured from the product or service in the perspective of transportation services for sustainable logistics. For example, suppose consumers consider the price of the product. In that case, they must also be aware of transaction costs associated with logistics when acquiring the product and environmental emissions generated in such transactions.

Consequently, producers make decisions from the process perspective (production and transaction), whereas consumers make decisions based on product or service perspectives. Bartholomeu (2006) states that all the effects caused by vehicle circulation result from society's present demand, more and more dependent on goods trade – cargo transportation – and the option for individual cargo displacement, considering the flawed public mass transportation system.

To Bartholomeu (2006), the alternative for such a cultural distortion is not to assign responsibilities only to road motor vehicles but to adopt solutions or initiatives towards public policies that may put the course of atmospheric pollution increase on the right track.

In this analysis, at first, the advantages offered by rail modes in transportation activities can be compared with road operations because the effects on the rail system of goods physical distribution occur with a minimum impact on the environment. From such a perspective, the change of the Modal Shift strategy for public policies should mean, in transporting activities, modal shifting of merchandise and cargo with transfer between modes, simultaneously, during the transporting activity, where the goal is sustainable cargo mobility. The principal ground is to seek alternatives to shift from trucks, and motor vehicles to eco-efficient modes, heading cargo, mainly for long distances, for rail transportation, barges, or ships.

The Ministry of Infrastructure and Transportation supports modal shifting in long-distance cargo transportation in Japan, where carriers and logistics companies cooperate. Japan's Ministry of Infrastructure and Transportation (2008) has promoted the development of the Transportation System to modal transfer, aiming at collaborating with any pilot project from the private sector to create a distribution system with a minimum impact on the environment.

**2.3. The programs for subsidies of Modal Shift in business models**

To manage Modal Shift, there are specific programs, such as the Marco Polo Programme (Program set up according to the Regulation (CE) n.° 1382/2003 of the European Parliament and of the Council, of 22nd of July of 2003), that consists of three types of actions: firstly, actions for modal transfer that aim at transferring a maximum of cargo from road mode to short-distance maritime transportation, rail lines and inland navigation in the present conditions of the market; secondly, catalyzing actions that must change the manner non-road transportation of goods is performed in society; and thirdly, actions for everyday learning that must reinforce

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knowledge in goods transporting logistics sectors and promote advance methods and procedures for cooperation in the market of goods transportation.

In this way, the transportation policy defined by the Marco Polo Programme relies on the representative power of the European Commission (2003, p.2), in which one major topic is that Europe must stimulate a fundamental change in the standard policy for transportation.

However, some goals to achieve this target must be adjusted, such as restoring the existent unbalance between modalities of intermodal transportation, minimizing bottlenecks, improve service security and quality. The focus of the Marco Polo Programme is the common-interest-oriented efforts, from the public to the private sphere, trying to keep the correct cargo mobility in the transportation corridors of the European Union.

Regarding specific methodologies, the Environmental Protect Agency (EPA), in the United States of America, points out that there is a broad diversity of methods for the technical analysis that, in cargo transportation, can be used to make a better fuel choice in the Modal Shift process, especially considering the types of fuels utilized where there are adequate technologies for flexible-fuel engines and low-energy consumption engines.

According to the Marco Polo Programme, financial resources for such a technological initiative are still dependent on public incentives to induce intermodality or multimodality. We can then conclude that picking transportation modes without adequate technologies influences eco-efficiency obtained by adopting multimodality in the transportation sector.

In this respect, the European Council held in Gothenburg on June 15th and 16th, 2001, through the European Parliament, has stated that rebalancing relations between transportation modes is the center of the European Community's sustainable development strategy.

## 2.4. A concept of the Modal Shift to reach the multimodality

The practice of transportation via more than one mode in Brazil demands further technical studies that might enable the practice of cargo modal displacement sustainably according to the type of technology per product.

To Bortolim et al. (2008), containerized cargo transportation is the common denominator between rail, road, and water transportation; besides, it speeds up and facilitates transshipment with cargo unitization aggregating several smaller packages or packing into a more oversized unitary cargo. Consolidation of several individual items into one transport unity to ease their handling.

Conversion of several unities that fractioned cargo into only one to store and handle with intermodal containers and pallets. Was demonstrates that, in containerized transport, cargo handling is standardized, and it offers higher safety to the product by preventing damage and discrepancies in customs checks. Another aspect is that such equipment enables logistics costs reduction for the operations and eases the integration of the transportation modes, according to figure 3.

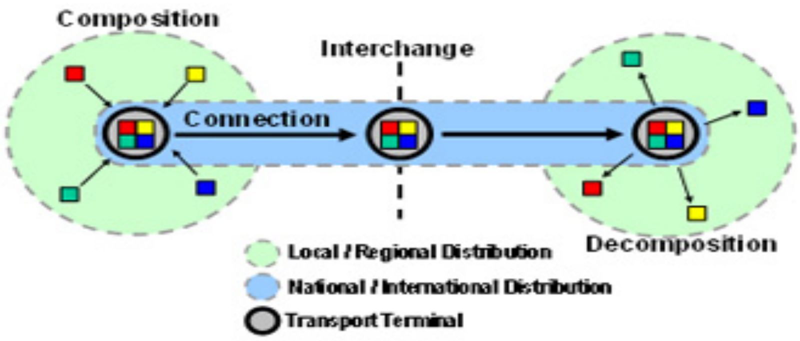


Figure 3: Multimodal Transport Chain
Source: Adapted by Rodrigue et al (2004)

Rodrigue et al (2004) quoted that The Delft University of Technology, Netherlands, and Vrije Universiteit Brussel, Belgium, showed that the choice of transport mode and pricing strategies are important decisions. The determining factors have the sensitivity to assess the cost and quality of intermodal transport. However, the results are not widely applied but are specific to a particular set of data, the research population, and geographic region.

Modal Shift was introduced as a modal shifting practice by several agents, and it has increased to improve global efficiency in goods circulation systems – mainly of containerized cargo. Such a concept may be a practical solution to bottlenecks, which yield conflicts in urban logistics, to the physical distribution of goods (Soares, CBC, 2009). Port costs are complementary to distribution logistics and cargo transshipment costs in ports. Transshipment operations depend on specific equipment and the available infrastructure for the modes, from logistics to the terminal's modal shifting.

According to Segundo Jolic, Strk, and Lesic (2007), distance is the decisive factor of significant influence on the decision to adopt intermodality, considering that strategic planning can only be defined from the geographic position of the port to its Hinterland.

The scenario with high port costs results from additional costs to transport, which is caused by the difference between the maximum and minimum distances of the transport. When

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such complementary costs are high, the strategic positioning of cargo transshipment and costs can be adopted as a tool for analyzing port competitiveness, the available infrastructure to define modes, and modal shifting.

In the sphere of organizational innovations utilizing Modal Shift, some possible sustainable solutions in logistics can be identified, emphasizing the integrated approach for cargo mobility between transportation modes and the attenuation of social-environmental impacts, which will be the subject of further detailing.

From Act No. 9.611/98, such activities became one of the functions of the Multimodal Transportation Operator to reduce logistics costs and total costs in the following stages:

1. Operationalization of the activity, adding value throughout the process, and making loading, unloading, and transshipment operations more efficient.
2. Improvement of the information flow and the reduction of documentation with more straightforward legislation, ensuring some warranty to operation control.

Once Act No. 9611/98 has been enforced, the MTO is held responsible for the execution of the multimodal agreement, including eventual losses resulting from loss, damage, or harm to cargo under their custody, as well as for those resulting from delivery delay (when there is an appointed delivery time).

The difference between the MTO's function, when compared to the logistics operator's function, is that the responsibility for the transport operational stages is integrated in the CTMC, which can only be issued by an MTO, who, before the customer, assumes the custody of the cargo until its delivery at the final destination ensuring the actions or omissions of their collaborators, agents, institutors or third-parts, hired or sub-hired to execute the services of Multimodal Transport.

## 3. METHODOLOGY

The present research is characterized as an exploratory case study. It searches to analyze mainly some variables related to the modal shift theory. For Yin (1994), the case study is applied to approach one description of reality definitively. The main characteristic in use is to question how and the reason of the facts, not being necessary as a premise the control about the behavior of the event.

According to Gil (1999), the case study shows appropriately that this type of empirical investigation is characterized by the deep and exhaustive study of an object, allowing one detailed knowledge.

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The case study is considered a type of qualitative analysis. What, second Laville and Dione (1999), is an investigation that allows supplying explanations in what concerns the respected case straightly and to the elements that mark the context. The advantage of this strategy is the possibility of deepening its offers because the resources are concentrated in the case endorsed.

The quantitative method of this case study is often placed as more used and appropriated in exploratory research to explain how calculating the eco-efficiency can happen in transport companies or logistics servers. The case study was carried out through action research in a road-rail transporting company, where the modal Shift is adopted as an alternative to decreasing the environmental impact of transportation.

Data were collected from the analyzed company's directors within such a perspective. The employed documentary research gives priority to the analysis of all material or knowledge that is susceptible to being used for consultation, study, or test. Data were interpreted by content analysis providing subsidies to reach the proposed goals.

The collected data were analyzed to consider the elements of the decision and to propose social costs resulting from decisions on cargo transportation. Some evidence of the advantages that can be obtained by adopting modal shifting was revealed by the report analysis, in which the calculation of emissions per transport route is periodically performed.

**3.1. Hypothesis for analysis of data from Marco Polo Programme**

From the example of organizational practices applied in the European market, according to information disclosed in the Marco Polo Programme (2009), we have investigated the method for the calculation of provision, per an estimate of the reduction in "tons per kilometer" and of "carbon dioxide emissions," in the "covered distance per mode," to analyze the Modal Shift systems.

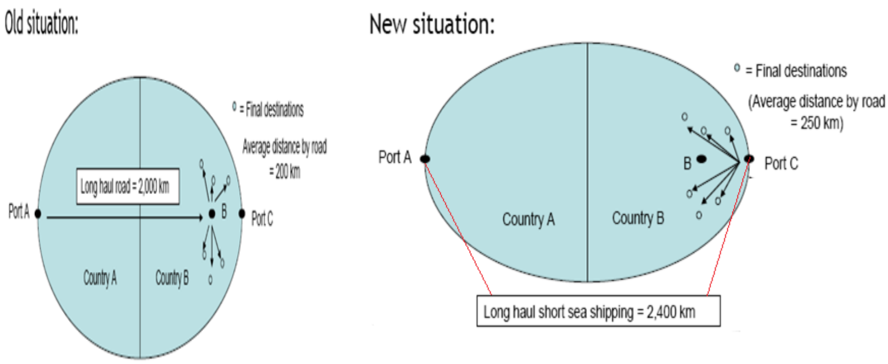


Figure 4: Hypothesis Diagram of physical distribution of cargo for Modal Shift
Source: by Marco Polo Programme (2009) – Adapted by the authors

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Regarding the environmental aspect, the calculation of $CO^2$ emissions proposed by the IPCC (2010) was carried out. In the calculation of emissions, data collection and parameters for the methodology of emissions are defined as follows:

a. The logistical product (type of cargo): Container
b. Parameters of the calculation of $CO^2$ emissions per mode, are as follows:
    1. Transport distance: Route in [km]
    2. Fuel consumption (in liters): per mode (consumption total)
    3. Fuel Efficiency: Relation Distance/Weight/Consumption
    4. Cargo weight: Amount of cargo (in tons).
    5. User's participation: in tonnage per vehicle
    6. Participation of the cargo: (%) in the total capacity of the transportation system
    7. Consumption participation (%): availability of cargo per vehicle
    8. TKU = tonnage of the cargo in the covered distance in (Km)
    9. Calculation of emissions per mode: Fuel Consumption (per cargo) multiplied by the coefficient available per mode.
c. Definition of the transportation route: Analysis of the areas or places of cargo transfer.
d. Transportation Modes: Road and Rail (analyzed hypothesis).

The table 1 below, shows the data for calculating $CO^2$ emissions according to spreadsheet with the calculation of emissions IPCC.

| Distance | Fuel Consumption | Fuel Efficiency | Transported Cargo | | User's Participation | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Total weight | USER's Participation | Fuel Consumption | | Tonnage Distance | $CO^2$ Emission |
| (km) | (L) | (km/L) | (ton) | (ton) | (%) | (L) | (ton-km) | ($CO^2$ ton) |
| (1) | (2) | (3) = (1)/(2) | (4) | (5) | (6) = (5)/(4) | (7) = (2)x(6) | (8) = (5)x(1) | (9) = (7)xCoeff |

Table 1. Spreadsheet with the calculation of emissions of the IPCC (2010)
Source: IPCC (2010) –Adapted by the author

The results were presented by comparing the calculation of emissions resulting from diesel consumption per different modes in the same route. The observation focused on comparing the parameters in the unimodal system: between road and rail modes, and afterward to complete the analysis integrated to the view of a multimodal system.

It starts from the premise that rail transportation must be used for most of the distance and road mode for the shorter part of the distance, for cargo distribution centralized in a combined way in multimodal practices.

## 4. ANALYSES E RESULTS

### 4.1. Case study: sustainable logistics by Mshift System (MTO)

As this study tries to determine by aiming for sustainability in transportation, the proper operational analysis depends on the operational characteristics of the type of mode available per geographic space and political environment to put into effect the concept of Modal Shift, which can be broadly propagated in the macroeconomic setting of business logistics.

In the case study of Mshift System – the principal methods to assess CO² emissions in this research were taken from the GHG Protocol and Marco Polo Programme, which ground the management of the Modal Shift.

For this case study, the model examined in the functional diagram of Modal Shift of the Mshift System shows rail transportation for most of the itinerary (distance), that is, from the Port of Santos to cargo transfer from the EADI (Suzano) to later delivery to the provider located in (Sao Bernardo).

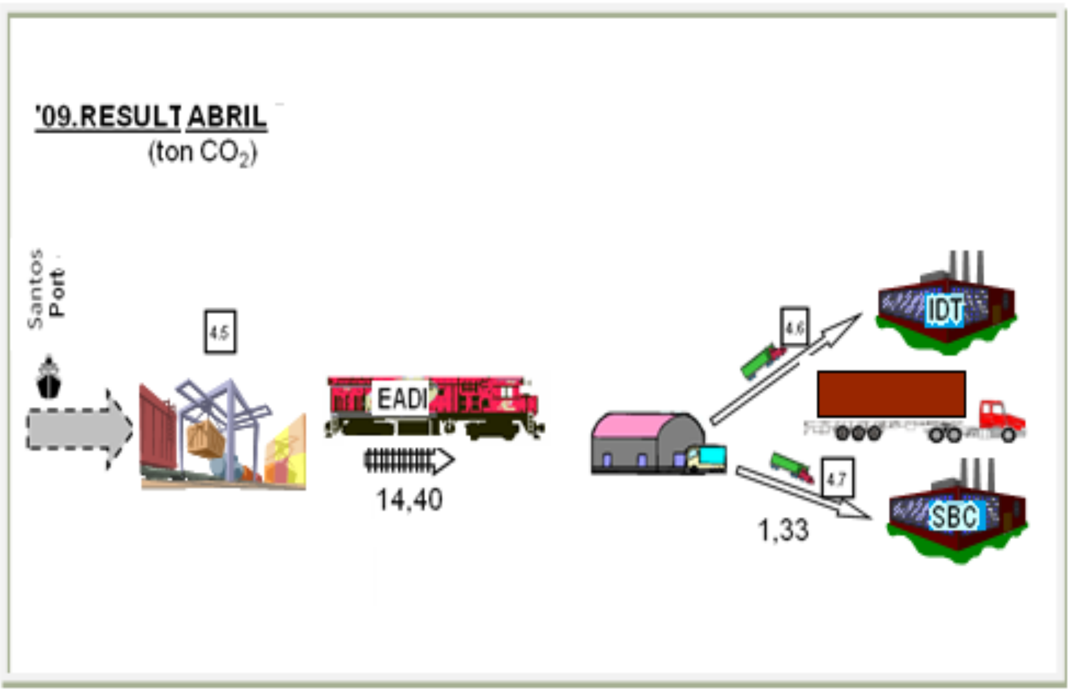


Figure 4. Diagram of routes of Carbon Dioxide emissions (CO²)
Source: MSHIFT SYSTEM (2010)

Customer applications for controlling environmental emissions and implementing improvements. In table 1, They can see the control of CO² emissions and their comparison. The

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directive aims at simplifying the corporative level for reports and assessment of greenhouse gases (GHG) of transportation per mode and other mobile sources. A section discusses direct emissions from mobile-owned or controlled sources and indirect emissions from sources of transportation that are owned or controlled by other entities. The following categories of covered mobile sources are Road, rail, air, and water transportation. Source: GHG Protocol – Mobile Guide (03/21/05) v.1.n.3.

| | | | | | SUPPLIER | Measure | Unit | ANO 07 | FY08 | FY09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1) PARTS IMPORT | RAIL | SANTOS | BONDED | | ITRI | Distance | km | 30.294 | 107.904 | 127.684 |
| | | | | | MSP/JSP | Cargo Weight | ton | 34.517 | 39.757 | 22.319 |
| | | | | | | Cargo x Distance | ton.km | 1.760.391 | 2.656.704 | 2.024.936 |
| | | | | | | CO2 Emission | ton CO2 | 38 | 99 | 115 |
| | | | | | | | ACC. | | | |
| | | | | | | KPI | | | | |
| | | | | | | | g CO2 / ton.km | 21,7 | 37,3 | 56,8 |
| | TRUCK | BONDED WAREHOUSE | IDT | SUZAN-IDT | SUZAN MSP/JSP | Distance | km | 493.860 | 517.650 | 284.200 |
| | | | | | | Cargo Weight | ton | 25.735 | 19.396 | 10.804 |
| | | | | | | Cargo x Distance | ton.km | 8.949.982 | 6.788.611 | 3.781.554 |
| | | | | | | CO2 Emission | ton CO2 | 567 | 583 | 315 |
| | | | | | | | ACC. | | | |
| | | | | | | KPI | | | | |
| | | | | | | | g CO2 / ton.km | 63,3 | 85,8 | 83,4 |
| | | BONDED WAREHOUSE | SBC | SUZAN-SBC | SUZAN MSP/JSP | Distance | km | 13.400 | 10.900 | 13.300 |
| | | | | | | Cargo Weight | ton | 2.074 | 1.713 | 3.090 |
| | | | | | | Cargo x Distance | ton.km | 207.431 | 171.348 | 150.414 |
| | | | | | | CO2 Emission | ton CO2 | 15 | 12 | 15 |
| | | | | | | | ACC. | | | |
| | | | | | | KPI | | | | |
| | | | | | | | g CO2 / ton.km | 72,5 | 71,4 | 98,6 |
| | TOTAL | IMPORT | | | TOTAL | Distance | km | 790.781 | 926.576 | 569.735 |
| | | | | | | Cargo Weight | ton | 63.484 | 62.755 | 36.920 |
| | | | | | | CO2 Emission | ton CO2 | 742 | 819 | 514 |
| | | | | | | | ACC. | | | |
| | | | | | | KPI | | | | |

Table. 1. Control per KPIs of emissions for each mode of transport
Source: Mshift System (2010).

Thus, to attend to the physical distribution of goods, the shortest part of the itinerary is carried out by road transportation for fewer emissions in the customer's logistics. For Modal Shift, fuel efficiency in cargo transportation can be noted from road mode to rail mode. However, the blended fuel technology has been changing the results of gas emissions and the economic effects in transport to handle the same tonnage by cargo or the same product although in distinct modes, according to table 2.

| HYPHOTISIS BY RAILWAY PARAMETERS DIAGRAM | | | | | |
|---|---|---|---|---|---|
| Distance | Diesel consumption | Fuel efficiency | Cargo Weight | Cargo x Distance | Fuel $CO^2$ emission |
| KM | Total in liters | Liters / Km | Ton / Km | Ton x Km | $CO^2$ emission |
| 100 | 350 | 0,7 | 0,1 | 50.000 | 1,085 |

| | | | | | |
|---|---|---|---|---|---|
| 200 | 700 | 1,4 | 0,05 | 100.000 | 2,17 |
| 400 | 1400 | 2,8 | 0.0025 | 200.00 | 4,34 |
| 800 | 2800 | 5,6 | 0,0013 | 400.000 | 8,68 |

Table 2. Standard of fuel emission factor per tons
Source: IPCC / BEN adapted by the author (2007)

In rail transportation, the capacity per moved ton is multiplied by the distance covered in kilometers (TKU) to determine the environmental efficiency in TKU. Such an indicator is important as a differential to the conversion of the emission factor, per differentiated technology, per mode

In this analysis, the displacement of the train is performed with traction from a locomotive HP 1300. The practice of the Modal Shift is finally observed with the multimodality in the comparison of the data from combined transportation, in which the same amount of cargo is assigned, that is, 500 tons. In this analysis, the transport capacity related to fuel consumption is highly relevant to improving productivity. With one single locomotive, we can reach the transporting potential of 3,000 tons per traction, according to table 3.

| Comparison by Multimodal Transport System | | | | |
|---|---|---|---|---|
| Modal | Quant. | Cargo Weigh | Efficiency/liter | Sistem Distribution |
| Trucks | 50 | 500 ton | 3,5 L/ km | for short distances |
| Cars | 25 | 500 ton | 0,5 L/ Km | for long distances |
| Observations: | | Diesel Fuel | Factor Emissions $CO_2$/Ton | |
| Capacity by Truck: | | 10 ton | 0,00264 | |
| Cpacity by Locomotive: | | 3,000 ton | 0,00027 | |

Table 3. Parameters in comparison by Multimodal Transport System
Source: MSHIFT SYSTEM (2010)

In that example (table 3), the multimodal route covers part of the itinerary by Road (for short distances) and the other part of the itinerary by rail (for long distances) to attend the transport of containers carried from the Port of Santos to its Hinterland, specifically to the ABC region.

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MODELO COMPARATIVO - MULTIMODAL - ITRI 2010

| Parâmetros - Curta Distância | RODOVIÁRIO | | Coeficiente | | RODOVIA |
|---|---|---|---|---|---|
| Distância | Total | Litros | Eficiência do | Produção | $CO_2$ Emission |
| (Km) | de Litros | p/tonelada | Combustível | TKU | (ton $CO_2$) |
| 10 | 250 | 0,50 | 0,050 | 5000 | 13,1217 |
| 20 | 500 | 1,00 | 0,050 | 10000 | 26,2434 |
| 40 | 1000 | 2,00 | 0,050 | 20000 | 52,4868 |
| 80 | 2000 | 4,00 | 0,050 | 40000 | 104,9736 |
| 150 | 3750 | 7,50 | 0,050 | 75000 | 196,8255 |
| 300 | 7500 | 15,00 | 0,050 | 150000 | 393,651 |
| 400 | 10000 | 20,00 | 0,050 | 200000 | 524,868 |

| Parâmetros - Longa Distância | Dif. de Externalidade ao Modal Shift | | MULTIMODAL | FERROVIA | MULTIMODAL |
|---|---|---|---|---|---|
| Distância | Total | Litros | Produção | $CO_2$ Emission | $CO_2$ Emission |
| (Km) | de Litros | p/tonelada | TKU | (ton $CO_2$) | (ton $CO_2$) |
| 100 | 2150 | 4,3 | 50000 | 1,085 | 14,21 |
| 200 | 4300 | 8,6 | 100000 | 2,17 | 28,41 |
| 400 | 8600 | 17,2 | 200000 | 4,34 | 56,83 |
| 800 | 17200 | 34,4 | 400000 | 8,68 | 113,65 |
| 1500 | 32250 | 64,5 | 750000 | 16,275 | 213,10 |
| 3000 | 69500 | 129,0 | 1500000 | 32,55 | 426,20 |
| 4000 | 86000 | 272,0 | 2000000 | 43,4 | 568,27 |

Fator de emissões de CO2 no processo de combustão de diesel

| Parâmetros do Modelo | Frota | Total da Carga (ton.) | | Eficiência/L |
|---|---|---|---|---|
| Frota Rodoviária | 50 caminhões | 500 | | 3,5 Km |
| | | | | |
| Locomotiva - 1300 HP | 25 vagões | 500 | | 0,5 Km |
| | | | | |
| | | | | |
| Observação: | | | | |
| (*) Capac. 10 Ton./veículo (Rodovia) - Normalmente utilizado para distribuição física de bens | | | | |
| Locomotiva - 1300 HP | Tração | | | |

Table 4. Control of emissions KPIs for combined transportation per systems ROAD- RAIL
Source: Parameters investigated by Mshift System (2010)

The environmental benefit of multimodality can be noticed from the minimization of the high level of $CO^2$ emissions from road mode for short distances. The environmental savings occurs in the mitigation of emissions by rail mode, which presents low levels of CO2 emissions, what, in this example, can be confirmed for medium and long distances.

## 5. CONCLUSION

In the case study of Mshift System, from qualitative and quantitative approaches, we have concluded that multimodal transportation (road-rail), if compared to a unimodal transportation system (Road), can promote eco-efficiency in logistics and, consequently, sustainability in cargo transportation management towards multimodality.

The quantitative result of $CO^2$ emission was calculated through the handling of five hundred (500) tons, carried in containers, in both modalities demonstrated herein. Multimodality in the case study of Mshift System has obtained an astonishing result, when compared to a unimodal system (Road), in such a way that, for cargo transportation through a distance of 140 km, we considered the use of rail lines through most of the journey (100 km) and the road mode for 40 km to the physical distribution – to minimize the emission level, which reached the amount of 53.4 tons of $CO^2$.

For instance, the analysis of eco-efficiency of the two modes in the handling of five hundred (500) tons, in the covered distance of 140 km in the unimodal combined system (Route A [100 km] by rail) adding to (Route B [40 km] by rail), the number of accumulated emissions would be of 2.04 tons of $CO^2$.

By the way, the same cargo, in the same distance of 140 km, in the unimodal combined system (Route A (100 km] by Road) adding to (Route B [40 km] by Road), the number of accumulated emissions would be 183.6 tons of $CO^2$.

We can conclude that the existing organizational models can be more eco-efficient in multimodal transportation as long as, regarding the choice of modes, energy consumption is minimized, and higher productivity is achieved in cargo transportation.

Multimodality, by the study of Modal Shift, can make cargo mobility more susceptible to the decreasing of greenhouse effect gases, mainly with the model of the transfer of containerized cargo from a unimodal system (Road) to a multimodal solution (road-rail).

The scope of sustainability via multimodality in transportation must start with the environmental dimension aiming at reaching a holistic view for other dimensions, such as cultural, social, economic, special, and geographic dimensions; and, finally, it shall reach the expected corporate social responsibility by defining a nationwide matrix of more eco-efficient and sustainable cargo transportation.

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