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An Analysis of Factors: Transport Mode Selection & Sustainable Development

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Abstract: This study will look at several ways to distribute finished items as part of supply chain management's outbound logistics. Nonetheless, a large number of writers have written about supply chains, and some of them have also attempted to shed light on supply chains in other nations. In addition to the aforementioned, this study will provide insight into sustainability, the pillars of sustainability, and the factors of modes of transportation.

Studies have been written about supply chains, sustainability, and sustainable transportation in India and other nations. Additionally, this study will shed light on the various aspects that influence the choice of transportation mode, as well as the elements that affect outbound logistics, distribution, and the pillars of sustainability. Environmental, social, and economic factors are examples of pillars of sustainability. Factors pertaining to the mode of transportation, such as expenses, duration of travel, dependability of arrival times, itinerary, distance travelled, frequency, volume, weight/size, damage sustained during transit, environmental concerns, retrieval and deposit, tracking and tracing, requirements specific to the cargo, frequency of losses/damages, coordination with the carrier/shipper, etc.

1. Introduction

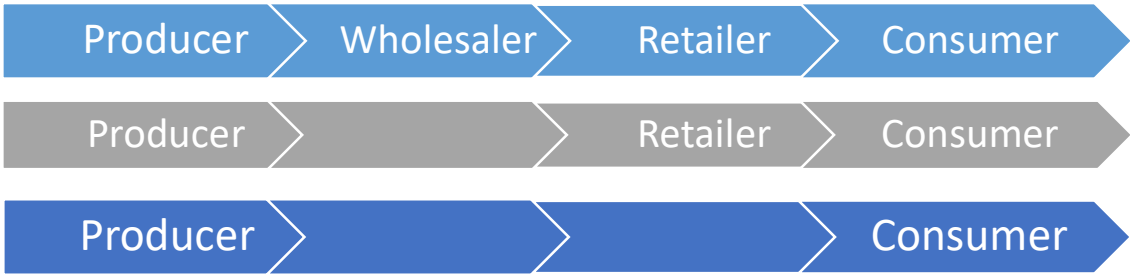
1.1 Supply Chain/ Logistics: -

- **In 1982, Keith Oliver**, a consultant at Booz Allen Hamilton introduced the term "supply chain management" to the public domain in an interview for the Financial Times.
- **In 1983 Wirtschafts Woche** in Germany published for the first time the results of an implemented and so called "Supply Chain Management project", led by Wolfgang Partsch.
- In the mid-**1990s**, more than a decade later, the term "supply chain management" gained currency when a flurry of articles and books came out on the subject.
- Originally defined as encompassing all activities associated with the flow and transformation of goods from raw materials through to the end user, as well as the associated information flows.
- Supply-chain management was then further defined as the integration of supply chain activities through improved supply-chain relationships to achieve a competitive advantage.
- Logistics management refers to the acquisition, storage and transportation of inventory from its origin to its destination. It involves maintaining the inventory, resources and related information, and getting the goods to the right location at the right time and to the right customer.

1.2 Outbound Logistics/Last Mile Transport: -

- As part of the Supply chain/ Logistics, Outbound logistics focuses on the Demand side of the supply chain equation i.e. Execution of the demand or Order cycle fulfilment. Storing & moving goods to the customer or end user like Order Fulfilment, Packaging, Shipping, Delivery & Customer Service related to delivery.

- Last mile transport is the last leg of the journey (Physical) comprising the movement of the goods from transportation hub/plant/warehouse to the final destination.



1.3 **Mode of Transports: -**

- Transportation refers to the movement of people, goods, or information from one place to another. It plays a crucial role in modern society, enabling economic activities, social interactions, and access to essential services.
- Term used for provide differentiation between different ways of transporting people or goods.
  - **Road Freight:** Trucks and lorries transport goods over highways and roads. This mode is flexible and widely used for short to medium distances.
  - **Rail Freight:** Trains carry bulk cargo and containers over dedicated rail networks. It's efficient for long distances and heavy loads.
  - **Maritime Freight:** Ships transport goods across oceans and seas. Container ships, bulk carriers, and tankers are common.
  - **Air Freight:** Cargo planes swiftly move high-value or time-sensitive goods internationally.
  - **Inland Waterway Freight:** Barges and vessels operate on rivers, canals, and lakes.
- Each mode of transport talks about policies, Procedures, compliance & infrastructure requirement and capabilities.

1.4 **Sustainability/Sustainable Development: -**

- Sustainability refers to the ability to maintain or support a process continuously over time.

  It encompasses three core concepts:
  - **Economic Sustainability:** This focuses on conserving natural resources—both renewable and exhaustible—used in economic production. It aims to ensure that these resources remain available for the long term.
  - **Environmental Sustainability:** Here, the emphasis is on maintaining life support systems such as the atmosphere and soil. These systems are essential for economic production and human existence.
  - **Social Sustainability:** This aspect considers the human effects of economic systems. It includes efforts to eradicate poverty, combat inequality, and promote overall well-being.
- In **1987, the United Nations World Commission on Environment and Development** defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Essentially, sustainability seeks to balance economic progress, environmental health, and social equity for the benefit of current and future generations.
- In essence, **sustainability** aims to ensure a harmonious balance between economic progress, environmental health, and social equity. It's about safeguarding our planet and its resources for generations to come.

1.5 **Sustainable Transport Mode: -**

- Sustainable transportation aims to reduce negative impacts through electric vehicles and Alternative-fuel vehicles.
- Sustainable mode of transportation refers to mode of transport which having
  - low- and zero-emission, (Environmental indicator)
  - energy-efficient, and (Environmental & Economic indicator)

- affordable, (Economic Indicator)

2. Problem Statement

- What are different factors of Sustainability and Sustainable Mode of Transport?
- What are various factors influencing Sustainable Transport Mode selection in ceramic industry as part of outbound logistics/physical distribution?

3. Research Framework

1.6 Need for Research

- Basis on the Literature Review, it is observed that there are research studies done by various researchers/authors on the Sustainable Transport, Modes of Transport and Factors of Transport Mode as individually or two of the said subjects together but still there is a gap to further work/focus on Factor Analysis for Sustainable Transport Mode.

1.7 Aim

- The aim of the study is to identify the different factors and modes of transport available for transportation and also to identify the various factors affecting Sustainable Transport Mode for transportation of the finished goods.

1.8 Research Objectives

- To identify different Indicators/factors of sustainability and Sustainable Mode of Transport
- To study various factors that affect the Sustainable transportation mode selection for Distribution of Finished Goods.

1.9 Research Framework

- Descriptive Research

1.10 Data Collection

- *Secondary Data* collected from
  - Research Papers
  - Reports
  - Magazines & Newspapers,
  - Textbooks,
  - Published Material

4. Literature Review and Analysis

1.11 Sustainability & Sustainable Development

Over time, the definition and understanding of sustainability have evolved significantly thanks to the contributions of many academics and organisations.

Sustainability was first defined in **1987 by the World Commission on Environment and Development (WCED)**, who defined it as the capacity to meet present demands without compromising the capacity of future generations to meet their own requirements. Intergenerational equity and the necessity to strike a balance between the use of resources today and their availability in the future were highlighted in this concept.

The idea of sustainable development, which goes beyond only maximising profits, was first presented by **Elkington in 1998**. He emphasised the significance of tackling social and environmental challenges in addition to economic objectives. The triple bottom line strategy, which takes into account profit, the environment, and people, is the cornerstone of contemporary sustainability practices.

By emphasising the requirements of present stakeholders without sacrificing those of future stakeholders, **Dyllick and Kramer (2002)** improved the idea even further. In order to ensure that sustainability initiatives are inclusive and equitable, their point of view stressed the significance of taking into account the interests of all parties concerned.

The coexistence of environmental preservation and socioeconomic development was highlighted by **Kielczewski in 2010**. He maintained that in addition to emphasising economic growth, sustainable development should make sure that this progress is accomplished in a way that conserves and maintains the environment.

Gore elaborated on this concept in 2022, emphasising the need to strike a balance between economic expansion and sustainability. He emphasised that sustainable practices should not impede economic success

but rather integrate with it to produce a balanced approach, suggesting that attaining sustainability may necessitate trade-offs with economic growth.

The three essential components of sustainable development—economic, environmental, and social development—were recognised by **Varma et al. in 2022**. They maintained that in order to truly achieve sustainability, all three aspects must be addressed at the same time, making sure that economic activity does not negatively impact society or the environment.

In 2023, **Misztal** emphasised that concurrent advancement in the domains of economics, society, and environment is critical to the sustainable growth of present and future generations. He underlined that in order to build a robust and balanced system, sustainable development necessitates a comprehensive strategy that integrates efforts from all sectors.

When taken as a whole, these contributions offer a thorough grasp of sustainability's complexity. They emphasise the significance of combining economic, environmental, and social goals, striking a balance between present demands and future supply, and making sure that sustainability initiatives are fair and inclusive. This changing knowledge emphasises how difficult it is to achieve sustainability and how important it is for all sectors to continue innovating and working together.

1.12 Pillars of Sustainability/Sustainable Development

Author	Factors
(Vijayalakshmi, Raj, 2019)	Economic Environmental Social
(Chakroborty, 2017)	
(Pyddoke, 2023)	
(Rodríguez-Rad, et al., 2023)	
(Charnavalau, Szymańska, Czapski, 2022)	
(Srinet, Short, Doss, 2023)	
(Reis, et al., 2024)	
(Kadłubek, 2022)	
(Jiang, 2021)	
(Varma, et al., 2022)	
(Misztal, 2023)	

1.13 Traditional Dimensions of Sustainable Development

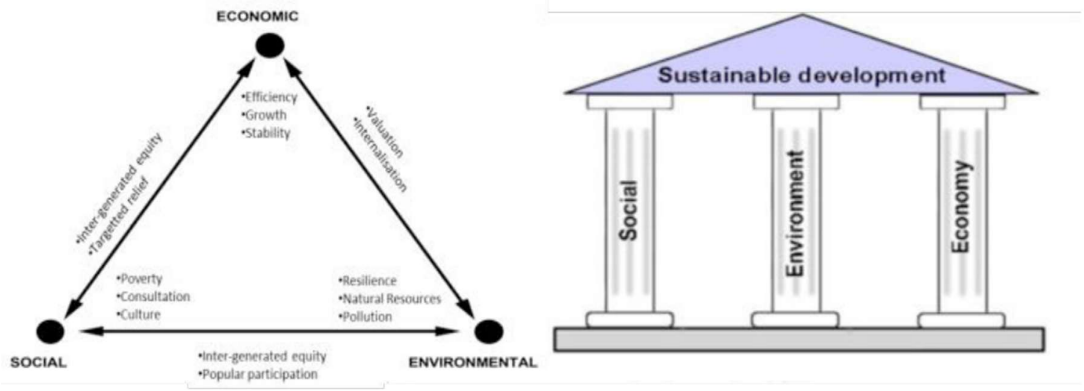


Figure 2. The traditional dimensions of sustainable development (Heijungs et al., 2010; Munasinghe, 1993)

1.14 Logistics & Supply Chain

The field of logistics and supply chain management has been extensively studied, with various authors contributing to its understanding and development.

According to **Rius et al. (2006)**, logistics is a method used in close coordination with supply chain participants to meet customer requirements while ensuring the highest level of safety and an ideal mix of costs, resources, and stocks.

The significance of supply chain design, planning, and operation decisions for a company's performance is emphasised by **Chopra and Meindl (2013)**, who also emphasise the need for supply chains to be well-managed in order to adjust to evolving customer demands and technological advancements.

According to **Rushton, Croucher, and Baker (2014)**, supply chain refers to the fusion of suppliers, logistics, and customers, while logistics is the management of supplies and distribution. They place a strong emphasis on the effective and economical movement of goods from the point of origin to the site of consumption while upholding acceptable service standards.

An example of logistics in the ceramics industry is given by **Zou A. (2018)**, who describes the steps involved in the process from acquiring raw materials to distributing products to customers.

Supply chain management (SCM), as defined by **Khan and Yu (2019)**, is the coordination and collaboration of all supply chain participants in the manufacturing, distribution, and selling of goods. This definition broadens the meaning of the term.

According to **Purnowidodo, Anam, and Wahyudi's (2022)** analysis, logistics expenses make up 11% of a business's overall costs. Important components of these costs include transportation, inventory, storage, handling, and customer-related services.

Last but not least, **Bruzzone et al. (2023)** propose that operational improvements, including merging passenger and freight flows, can support freight and logistics management (FLM) transport that is both energy-efficient and sustainable. Together, these contributions deepen our knowledge of supply chain management and logistics and emphasise the value of cooperation, efficiency, and creativity.

1.15 Last Mile Transport/ Outbound Logistics

The study of supply chain and logistics encompasses various aspects, as highlighted by different authors.

According to **Hokey Min (2002)**, there are two primary business activities in the supply chain: physical distribution (outbound logistics) and material management (inbound logistics). The significance of controlling both the entry of raw materials and the outflow of completed goods is highlighted by this contrast.

Key elements of distribution and outbound logistics, such as the mode of transportation, kind of delivery operation, load planning, and route scheduling, are outlined by **Rushton, Croucher, and Baker (2014)**. Together, these contributions offer a thorough grasp of the intricacies and important variables in supply chain and logistics management.

Maan (March 2023) talks about how efficient various transportation methods are in preventing product damage or breakage. The article claims that rail transit is more efficient than road or sea transport, with only

10% breakage or damage as opposed to 75% for each.

According to **Bruzzone et al. (2023)**, first-last mile (FLM) transportation has a major impact on overall transportation costs, pollution, and energy consumption. This underscores the necessity of effective FLM policies.

1.16 Sustainable Transport

The concept of sustainable transportation has been explored by various authors, each contributing unique perspectives and insights.

Among the crucial elements of sustainable transportation that **Monto (2010)** highlights are:

1. **Effective Long-Term Transportation System:** Long-term sustainability and efficiency in transportation are required. This entails making plans and investments in technologies and infrastructure that will continue to be useful and efficient in the long run.
2. **Satisfying Basic Transportation Needs:** The system must provide for the population's basic needs in terms of transportation without compromising the availability of natural resources or the economy. This suggests striking a balance between saving resources for later use and offering essential services.
3. **Innovation:** To increase sustainability and efficiency, transportation requires constant innovation. Creating innovative methods, procedures, and regulations that improve the sustainability of transport networks is part of this.
4. **Clean Fuels and technology:** Using clean fuels and technology is essential to lessening the impact of transportation on the environment. This entails utilising renewable energy sources, switching to electric cars, and putting in place technology that lowers emissions and boosts fuel economy.

Chakroborty (2017) provides a comprehensive definition of a sustainable transportation system, emphasizing three key aspects:

1. **Accessibility and Development:** The system must make it possible for people, organisations, and society to safely satisfy their fundamental needs in terms of access and development. It should guarantee equity within and between generations and advance the health of people and the environment. This means that transport need to be accessible to all societal groups, suit their requirements, and not jeopardise the capacity of future generations to do the same.
2. **Affordability and Efficiency:** The transit network must to be reasonably priced and run well. It ought to provide a variety of transit options, fostering both balanced regional growth and a competitive economy. This suggests that the system should be affordable, give people a variety of options, support regional balance and economic progress.
3. **Environmental Impact:** Waste and emissions should be limited to what the world can sustain. It should consume non-renewable resources at or below the rates at which renewable substitutes are developed, and renewable resources at or below the rates at which they are generated. It should also lessen the effects on noise production and land utilisation. This emphasises how crucial environmental sustainability is to preventing transportation-related activities from going beyond the planet's natural bounds.

Varma et al. (2022) suggest that sustainable transport can be achieved through several measures:

1. **Transportation System Management:** This entails maximising the efficiency and minimising the environmental effect of the current transportation services and infrastructure. It covers tactics including promoting non-motorized transportation, enhancing public transportation, and managing traffic.
2. **Energy Management:** This aims to encourage the use of renewable energy sources in transport while lowering energy usage. It entails actions like using alternative fuels, implementing electric and hybrid car models, and increasing vehicle fuel efficiency.
3. **Capacity Management:** This refers to controlling the ability of transport networks to accommodate demand without putting undue strain on the system. It covers tactics like charging for congestion, managing demand, and building more infrastructure as needed.
4. **Environmental Management:** This aims to reduce the negative effects that transportation-related activities have on the environment. It consists of actions like lowering emissions, limiting noise pollution, and safeguarding natural areas.

These detailed contributions provide a robust framework for understanding and achieving sustainable transportation, highlighting the importance of accessibility, affordability, efficiency, and environmental sustainability.

1.17 Mode of Transports & Factors affecting Mode of Transport

The selection of transport modes and the factors influencing these choices have been extensively studied by various authors, each highlighting different aspects of logistics and transportation.

Rushton, Croucher, & Baker (2014) discuss multiple modes of transport including truck, rail, ship, and air. They identify several factors influencing the choice of transport mode:

a) **Cost**: The expense associated with using a particular mode of transport.
b) **Transit Time**: The time taken for goods to travel from the origin to the destination.
c) **In Transit Damage**: The potential for goods to be damaged during transportation.
d) **Pick up & Drop Off**: The ease and efficiency of loading and unloading goods.
e) **Distance**: The length of the journey.
f) **Weight/Size**: The dimensions and mass of the cargo.
g) **Reliability of Transit Time**: The consistency and predictability of delivery times.
h) **Cargo Specific Requirement**: Special needs based on the type of cargo.
i) **Volume**: The quantity of goods being transported.
j) **Coordination with Carrier**: The level of collaboration required with the transport provider.
k) **Coordination with Shipper**: The level of collaboration required with the sender of the goods.
l) **Route**: The path taken by the transport.
m) **Frequency**: How often the transport service is available.
n) **Environmental Concerns**: The environmental impact of the transport mode.

Stinga & Olteanu (2019) focus on truck and rail transport, emphasizing factors such as:

a) **Cost**: The financial implications of using a particular mode.
b) **Structure of the Loading Units**: The design and configuration of the cargo units.
c) **Cargo Specific Requirement**: Special needs based on the type of cargo.
d) **Frequency**: How often the transport service is available.
e) **Volume of Cargo**: The amount of goods being transported.
f) **Distance**: The length of the journey.
g) **Quantity**: The number of items being transported.
h) **Frequency of Transport**: How often goods are transported.
i) **Transit Time**: The time taken for goods to travel from the origin to the destination.
j) **Route**: The path taken by the transport.
k) **Reliability of Transit Time**: The consistency and predictability of delivery times.
l) **Collection/Delivery (Pick & Drop)**: The ease and efficiency of loading and unloading goods.
m) **In-transit Damage**: The potential for goods to be damaged during transportation.
n) **Frequency of Losses/Damages**: How often goods are lost or damaged.
o) **Track & Trace**: The ability to monitor the location and status of goods during transit.

Wilson, Bisson, & Kobia consider truck, rail, parcel/mail, air, and ship transport, focusing on:

a) **Transit Time**: The time taken for goods to travel from the origin to the destination.
b) **Reliability of Transit Time**: The consistency and predictability of delivery times.
c) **Frequency of Shipment**: How often goods are shipped.
d) **Pick up & Drop Off**: The ease and efficiency of loading and unloading goods.
e) **Track & Trace**: The ability to monitor the location and status of goods during transit.
f) **Coordination with Carrier**: The level of collaboration required with the transport provider.
g) **Coordination with Shipper**: The level of collaboration required with the sender of the goods.

ITF (2022) examines truck, rail, inland waterway, ship, air, and pipeline transport, highlighting:

a) **Cost**: The expense associated with using a particular mode of transport.
b) **Transit Time**: The time taken for goods to travel from the origin to the destination.
c) **Reliability of Transit Time**: The consistency and predictability of delivery times.

Purnowidodo, Anam, & Wahyudi (2022) focus on:

a) **Cost**: The financial implications of using a particular mode.
b) **In Transit Damage**: The potential for goods to be damaged during transportation.

Arnold, Peeters, & Thomas (2004) discuss truck and rail transport, emphasizing:

a) **Cost**: The financial implications of using a particular mode.
b) **Environmental Concerns**: The environmental impact of the transport mode.

Hanaok & Regmi (2011) focus on truck and rail transport, highlighting:

a) **Environmental Concern**: The environmental impact of the transport mode.

Marek (2021) and **Lydia, Gerard, & Anthony (2024)** discuss various modes including rail, road, sea, and air, but do not specify particular factors.

These contributions collectively provide a detailed understanding of the factors influencing the choice of transport modes, emphasizing the importance of cost, transit time, reliability, environmental concerns, and specific requirements based on the type of cargo and transport mode.

5. Findings

The selection of a transport mode and sustainable development are the topics of this study. According to the article, a variety of factors influence the choice of mode of transportation, and these elements can be further divided into the three categories of sustainable development: economic, environmental, and social.

Factors of affecting Sustainable Transport mode selections can be categorized under:
Economic Parameters consist of Cost, Transit Time, Reliability of Transit time, Route, Distance, Frequency, Volume, Weight/Size, Frequency of loss/damage, and Intransit Damage.
Environmental Parameters consist of Pollution, Fuel Consumption, Energy Saving, Alternate Energy/Fuel
Social Parameters consist of Accident, Safety and Health

Cost is a measure of economic parameter that makes it extremely evident which factor will have the biggest impact on the choice of transport mode. It depends on the movement's **size, frequency, volume, weight, and distance.**

E.g. **Distance** will make it clear that the greater the distance, the higher the cost. In order to lower the cost, it is suggested that the longer distances be travelled by rail or ship, depending on infrastructure availability and feasibility, and that the shorter distances be travelled by road, taking cost into consideration. The **reliability of transit time** and its **distance** will also be determined by the various modes of transportation.

E.g. **Volume** specifies how much needs to be transported at any given moment; the best modes of transportation are rail and ship for higher cargo volume. Also, roads should be employed as a mode of transportation for low-volume cargo while taking cost into account. The movement's **frequency** will influence the choice of **transport mode** and **cost** in the same way as **volume**. Road transportation should be employed if movement is irregular and volumetric, or else rail and ship transportation should be utilized.

E.g. **Weight & Size**, depending on the weight and size, in other terms cargo specific requirements were having direct impact on cost, since the requirement of the cargo defines the Mode of transport selection, **Cost** having no role to play in this case. This to be considered as the basic necessities for the movement to take place.

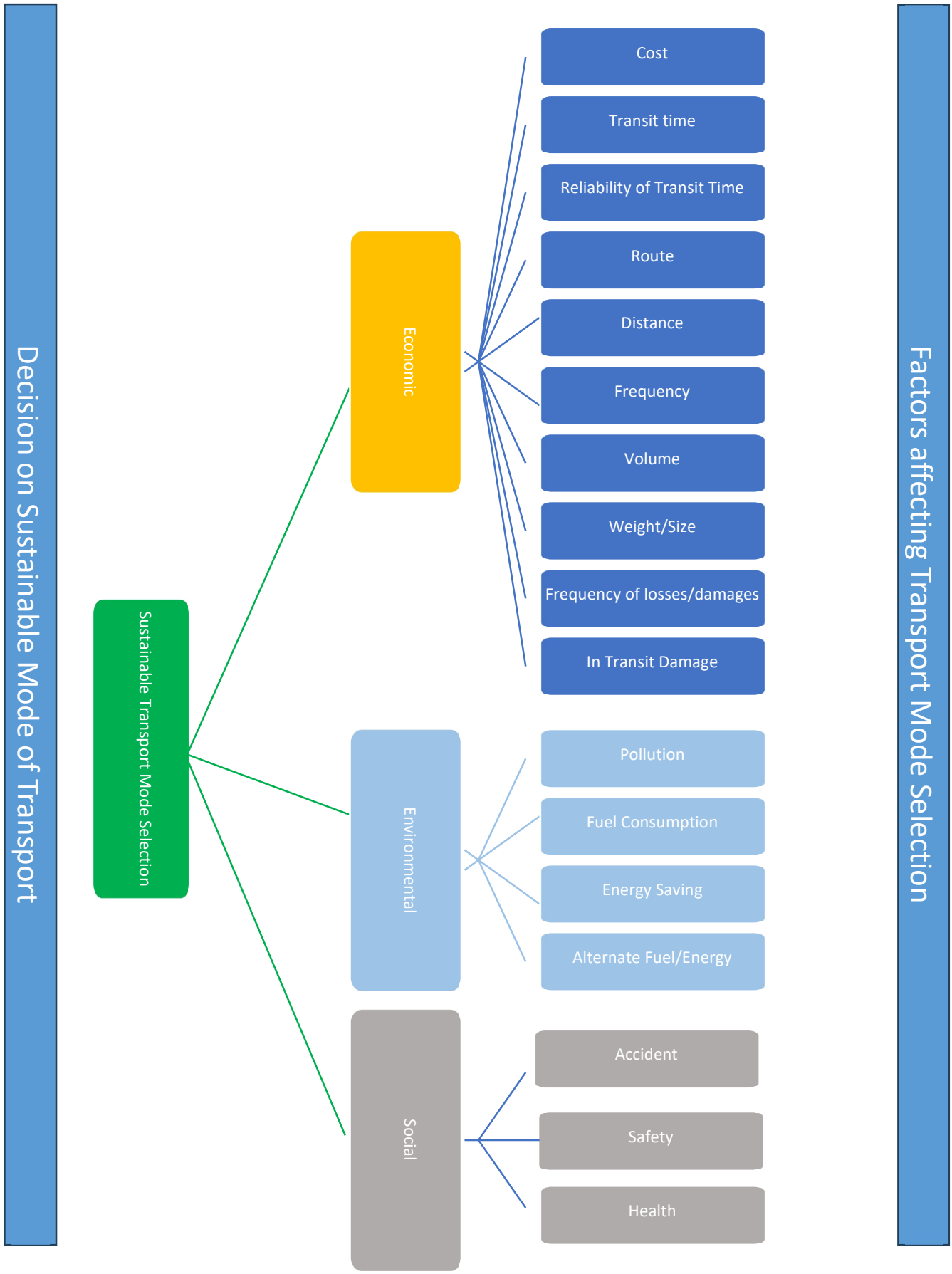
Transit time, or reliability of transit time, is the amount of time it takes to move goods from one location to another, or from the point of origin to the point of destination. Since transit time directly affects the cost component, it is also taken into account under the economic parameter. **Cost** compared to other modes of transportation and opportunity lost on transit days. Dependability on the mode of transportation is indicated by the transit time's reliability. A more dependable form of transportation will influence the decision to choose it over another.

Route: The dependability of travel time, distance, and transit time reliability are all dependent on the route.

Ideally, the route has a significant impact on defining other factors like cost, transit time, and distance. The availability of infrastructure along a particular route influences the choice of mode of transportation.
When it comes to **transit damage** and **the frequency of loss or damage**, these two factors are crucial and have an effect on the cost of the transport since they directly affect the cost factor and the transport's economic viability. Materials that are easily damaged or lost should be transported using a mode of transportation that minimizes damage during transit. For example, road transportation of tiles and marbles is more likely to cause damage than rail transportation.

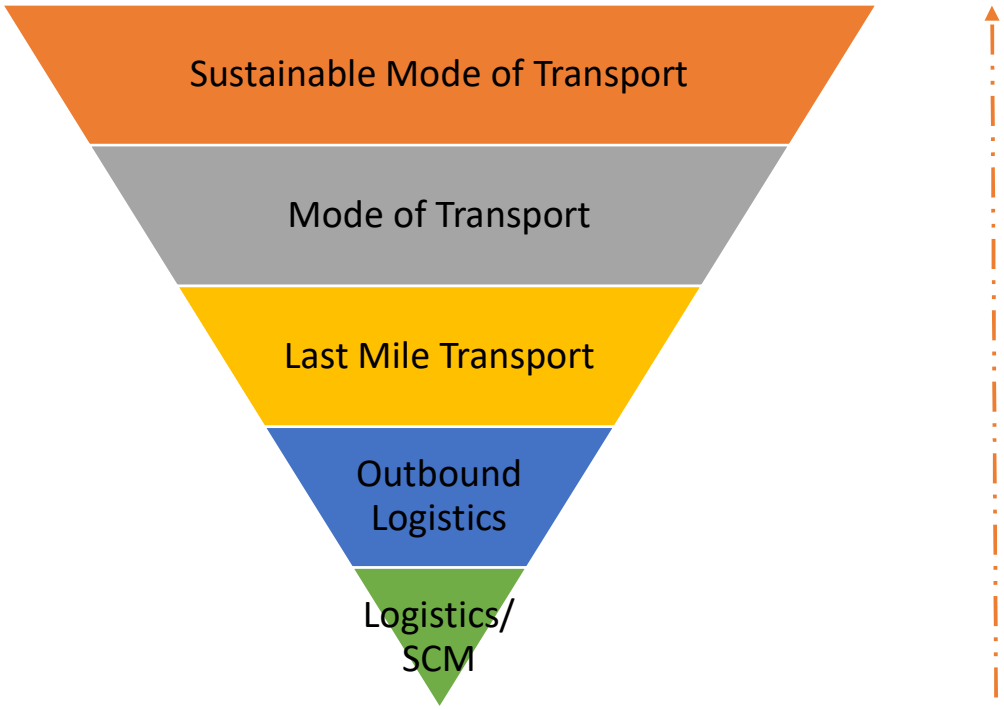
These days, it's thought that two factors are essential when choosing a form of transportation: **pollution and fuel consumption**. In light of CO2 emissions, rail and ship transit are more fuel-efficient than Road. When choosing a transport mode, these are also taken into account as compliance parameters and are examined above cost.
Energy-saving, alternative energy and fuel: On the other hand, in light of sustainability, alternative energy and fuel choices must also be created for each mode of transportation, such as electric vehicles, electrification of the rail network, biodiesel, etc.

Accident: Even in the short Run movement, such as switching from road to rail mobility to prevent road accidents and their effects on society. alternate modes of transport are being developed while taking into account the accident criteria and the effects the incident has on drivers, emergency personnel and other affected parties.
These days, **safety and health** are regarded important compliance criteria that directly influence the choice of transportation mode, even more so than cost.


Decision on Sustainable Mode of Transport
Sustainable Transport Mode Selection
Economic
Cost
Transit time
Reliability of Transit Time
Route
Distance
Frequency
Volume
Weight/Size
Frequency of losses/damages
In Transit Damage
Environmental
Pollution
Fuel Consumption
Energy Saving
Alternate Fuel/Energy
Social
Accident
Safety
Health
Factors affecting Transport Mode Selection

6. Conclusion

- Categorization of factors of Transport Mode under the Sustainability Pillars
- Definitions of the Factors and general terms of the factors on the transport mode



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7. Future Scope of the Study

The study having limitation as considering the secondary data only. Future scope of this document is, it may further be analyzed that these factors having impact on the decision of the transport mode selection considering the Sustainability factors into account.

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