# POLITECNICO DI TORINO

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# Plant Location Strategies in the Tyre Industry: A Comprehensive Analysis


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**ABSTRACT**

The following thesis unravels the dynamics of the global tyre industry, tracing its historical trajectory, analyzing the current competitive landscape and prospective trends. As its core, the study explores the complex realm of international expansion through Foreign Direct Investment (FDI) and the Ownership, Location, and Internationalization (OLI) framework strategies. The objective lies on navigating the strategic factors that determine tyre plant locations, where Efficiency Seekers, Strategic Asset Seekers, Market Seekers, and Resource Seekers, each play a distinct and significant role. The firm decides what it seeks and then pursues a strategy based on the priority of their business, such as economies of scale, transportation costs, trade barrier mitigation, internationalization through M&A, market access, proximity to raw materials and supply chain resilience. The study concludes with a proposal of an economic model, rooted in the OLI framework, and integrated with previous determinants, offering tyre companies a comprehensive tool for assessing and analyzing plant location decisions.

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# 1. TYRE INDUSTRY OVERVIEW

## 1.1. The history of the Tyre

In order to gain a comprehensive understanding of the history of the tyre, one must begin by examining one of humanity's most significant invention, the wheel. The wheel was first invented around 3500 BC as a curved piece of wood which was primarily used for transportation, particularly in the form of carts of wagons. The wheel revolutionized the movement of goods and people, making it much easier to transport heavy loads over long distances. It significantly improved agriculture, trade, and overall efficiency of many activities. One of the major issues of wheels was wear and tear, which lead to require the creation of a layer over the wheel that would protect it from damage and could be easily replaced, instead of replacing the whole wheel.

This is where the concept if tyre arises, firstly as a leather band wrapped around the wheel, and later as metal bands. The transition from using wooden and metal wheels to rubber tyres occurred much later, in the 19th century, when vulcanization was discovered by Charles Goodyear. Vulcanization is essentially the process of heating rubber with sulfur, transforming it from a sticky soft substance into a firm material. The first rubber tyre created was not pneumatic (inflatable), but solid rubber. These tyres provided a smoother and quieter ride compared to wooden or metal wheels, but they were still very heavy and uncomfortable. The actual breakthrough in the evolution of rubber tyres came with the introduction of the pneumatic tyre, featured by the inflatable inner tube enclosed by a rubber outer layer. In 1888, an Irish veterinary, John Boyd Dunlop, created the pneumatic tyre for bicycles after watching his son struggle with its solid rubber tyres. The product was successful, over the following years, the veterinary worked hard to develop these tyres for all vehicles. In the early 20th century, companies like Michelin, Goodyear and Firestone played significant roles

in popularizing them. These tyres offered superior performance and comfort, making them a standard feature on automobiles by the 1920s.

In 1931, DuPont successfully develops synthetic rubber and revolutionizes tyre manufacturing processes. These processes used to be merely dependent on natural rubber, therefore, this new reliable and consistent source of rubber allowed the increase in stability and production capacity of tyre manufacturers. “Bias Ply” were the tyres in this moment, made out of an inflated inner tube and the outside tyre.

Tubeless tyres were introduced in 1947 in an attempt to relieve the high cost of oil prices, since these tyres contributed to the diminish of the vehicle’s weight, reducing fuel costs. Then, in 1948, Michelin developed the first radial tyres in Europe, with the piles at a 90-degree angle from the wheel rim and a layer of steel belts at the circumference beneath the thread. Radials quickly proved their advantages such as extended tread longevity, improved handling, and reduced rolling resistance. Their production cost was notably higher compared to other tyre types, however, they have become the standard since they gain their most popularity around the 1970’s.

Replacement tyres were introduced when Bias Ply tyres were prevalent, offering a cost-effective method for reusing high-quality tyre casings. Marion Oliver, in 1912, was the one who devised and patented pre-cured treads. This becomes popular during critical periods like The Great Depression and WWII, where people saw themselves in need to prolong their useful life to their tyres by retreading them.

Nowadays, a tyre consists of a rim and is filled with compressed air. It is produced from various natural and synthetic substances such as rubber, wire, cotton, glass, silica, carbon black and steel. Tyres are commonly found in both tubed and tubeless forms, and include several important components like the bead, bead

filler, belts, body ply, inner liner, sidewall, and tread. These components together bear the weight of the vehicle, absorb shocks, and manage the physical forces acting upon the vehicle while it is in motion. Tyres are extensively used in various types of vehicles including passenger cars, motorcycles, three wheelers, off – road vehicles (OTR), as well as light, medium, and heavy-duty commercial vehicles all around the world. They can also be classified by tyre tread high performance, summer tyres, winter tyres, all season, and all terrain.

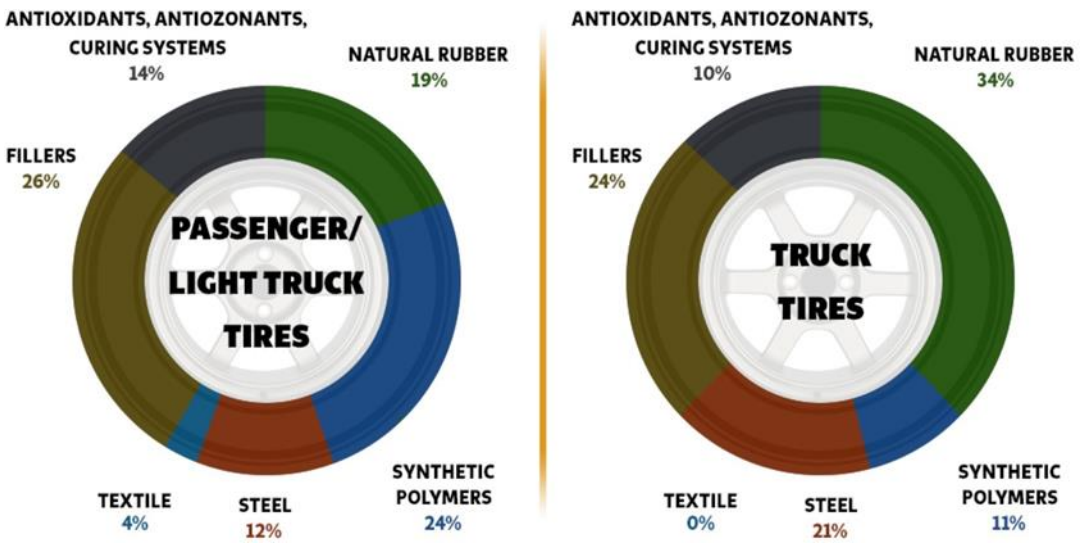


*Figure 1. Passenger* and Truck Tyres Composition

## 1.2. Distribution Channels

The distribution for car tyres is divided into three channels: OE (Original Equipment), Replacement and Exports. The replacement channel has a high reach with distributor as key stations as below. The options for the channels are divided into direct and indirect sales. Direct sales are the tyres that are directly sold to the large users such as transport, bus and taxi companies, or government entities' users. Meanwhile, indirect sales are those where tyre dealers supply the tyres to the end user. Additionally, the component ratio (quantity) of sales for each

channel in 2021 is 24.6% for original equipment, 46.5% for replacement and 28.9% for exports.

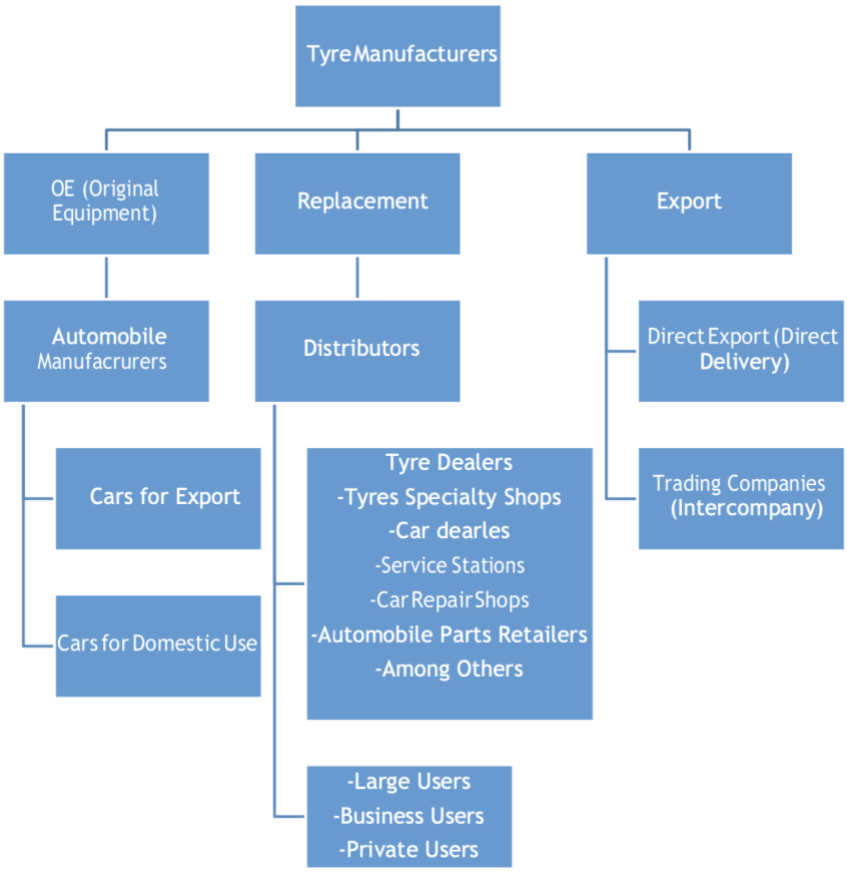


*Figure 2. Distribution Channels for Tyre Manufacturers*

### 1.2.1. Distribution Network: Warehouses

For a better comprehension of how tyres are sold and distributed all throughout the world, it is essential to understand the prior figure involving warehousing distribution. A physical warehouse represents a supply chain point where the tyres are stored while they await to be delivered.

Main types of warehouses for tyre manufacturers:

**Factory Warehouse:** Factory that receives the product directly from production and it primarily serves export market.

**Regional Warehouse:** Second network level which receives the tyre from the Factory Warehouse, and it primarily serves the local market.

**Service Warehouse/Distributor:** Third network level which receives the tyre from the Regional Warehouse, and it serves a specific domestic market.

As well, well it is important to state the existence of transit points, which are physical locations without inventory establishment but only Cross Docking activities. Cross Docking is when the product will be directly delivered to the final customer without passing through storage, meaning the product is unloaded from one truck and loaded into another outbound truck or rail in that moment. The benefits are that with the removal of storage there are reduced inventory costs, improvement in delivery times, better responsiveness, reduces number of shipments and increases the accuracy by decreasing the manual handling of the tyre.

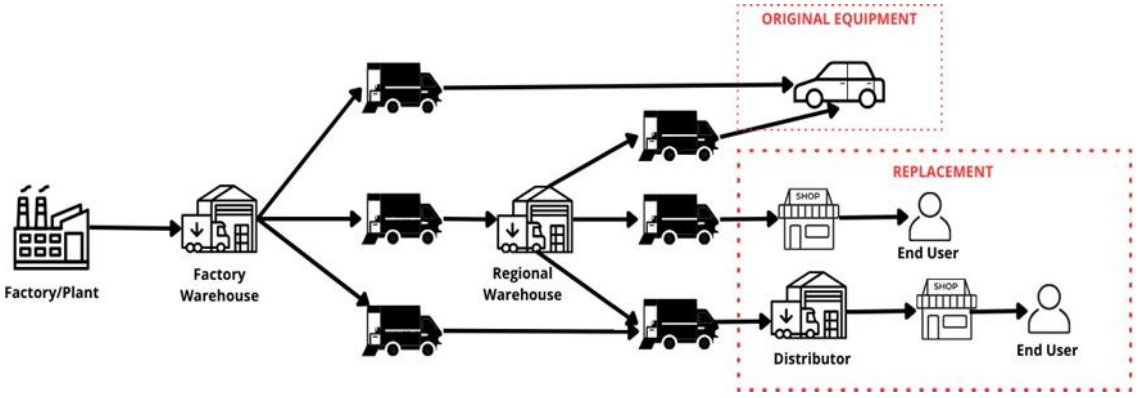


*Figure 3. Distribution Network Breakdown*

OE tyres can be directly delivered from the plant, it can pass through transit points where cross docking activities can be pursued, but with no storage points in between. Or, the tyres can be delivered from a second network level, a regional warehouse, if these have gone through a process of homologation, which refers to gaining authorization or certification from regulatory authorities or specific organizations. This will ensure that the tyre meets specific standards, regulations, and safety requirements for the car manufacturer, as well as perfect integration with the vehicle.

On the other hand, replacement demand can be supplied by tyres stored in regional warehouses and service warehouses. Service warehouses speed up the delivery process, since they serve specific domestic market so there are tyres which are previously forecasted by the specific demand in the area and stored there. Therefore, from the regional to the service warehouse there should be a constant flow, and from the distributor to the retailer, it should be a fast delivery.

### 1.3. Current Market and Future Expectations

The global tyre market size reached 2,321 million units in 2022. The International Market Analysis Reseach and Consulting Group (IMARC Group) forecasts that the market will be able to reach 2,741 million units by 2028, representing a growth rate of 2.88% from 2023.

The tyre industry operates within a very volatile market framework, forcing major industry players to frequently reconsider their business models. Additionally, it remains highly susceptible to factors such as the fluctuations in raw materials' prices and availability, as well as the challenges on production and transportation costs. Despite the oligopolistic nature of the market with few international players operating and gaining a major part of the market share; there is modest product differentiation and low switching costs, thus presenting an appealing scenario for potential entrants. The prior opened the door for a new strong wave of competitors from Asia, specifically from China, which are now leading the market.

On a global scale, there is a notable increase in the production and sales of both passenger and commercial vehicles, which is poised to drive tyre consumption in the upcoming years. According to the International Organization of Motor Vehicle Association (OICA), the year 2022 witnessed the production of over 97 million new passenger and commercial vehicles, reflecting a cumulative increase of more than 2.36% compared to previous years. Notably, the Asia-Pacific region, with China as a prominent contributor, stands as the largest market for two-wheelers. Two-wheelers have gained widespread popularity in the region due to their maneuverability and cost- effectiveness.

The consistently expanding demand for passenger automobiles and commercial vehicles in the Asia- Pacific region underscores a substantial untapped sales potential. This anticipated growth in vehicle sales across the region is expected to have a positive impact on the global tire market in the foreseeable future. The

demand for tyres is primarily induced by several key factors, including the expansion of automotive industry, the increase in vehicle production, the growth in transportation and logistics sectors, and consumers' preference for fuel-efficient tyres. Furthermore, government regulations related to tyre labeling, safety standards, and fuel efficiency exert a considerable influence on market demand.

Asia-Pacific region has maintained its position as the largest regional tyre market, with significant contributions from major tire manufacturers located in countries such as China, Japan, South Korea, and India. Meanwhile, North America and Europe also represent substantial markets, driven by the demand for replacement tyres and advancements in tyre technology.

### 1.3.1. Technological Advancements

Global tyre manufacturers are actively prioritizing the development of sustainable tyre technologies to extend their existing capabilities. One such technological advancement is the Contact Area Information Sensing (CAIS). This innovation is about the installation of sensors on the inner tyre wall to monitor its interaction with the road surface. The system analyzes the road conditions in real- time, to identify whether it is dry, wet, snowy or slippery, and this data is displayed to the driver through a digital screen.

CAIS will also be able to progress further by enabling data sharing among other networked vehicles on the road. This way, this could potentially anticipate the actions of the one in front of it. Also, CAIS may integrate air pressure data from air pressure sensors to provide information about tyre tread wear.

Furthermore, companies like BKT are using automated equipment and monitoring systems to promote better performance and efficiency while reducing

risks to the drivers. The SPOTech (Satellite Performance Optimization Technology) monitoring system collects various data, including average/maximum speed, cycle times, lateral, vertical, and longitudinal forces, percent grade, and other relevant variables. This data helps address tyre-related issues such as uneven wear, belt contour separations, and heat buildup.

These tire manufacturers are also developing premium smart tires tailored to specific market segments. For instance, Goodyear's Assurance Weather Ready tires incorporate features like outboard tread ribs and 3D Tredlock Technology Blades, enhancing braking performance in slippery conditions. Additionally, season-specific tires are expected to generate global demand.

However, the tyre industry faces challenges related to fluctuating raw material prices, elevated input costs due to a shortage of natural rubber, and the substantial influence of oil prices. The primary tire production materials, synthetic and natural rubber, constitute a significant portion of manufacturing expenses. Recent surges in global crude oil prices are anticipated to lead to increased costs for synthetic rubber and other essential raw materials used in tire manufacturing in the coming years.

### 1.3.2. Opportunities and Market Trends

Currently, the global market of tyres is experiencing growth driven by several factors such as increasing sales of automobiles (both passenger and commercial vehicles), growing demand for Replacement tires, and rising penetration of electric vehicles are generating new demand for tyres. The increased demand for tires is an opportunity for companies to grow and acquire market share.

These players have the possibility to innovate and produce new products that increase performance, safety, and fuel efficiency. Tyre firms, for example, can concentrate on manufacturing more environmentally friendly tires that lessen the environmental effect of transportation. One example is that there is a concerning

rise in road accidents attributed to damaged and poor-quality tyres across the world. This, coupled with the demand for high-quality tyres aimed at reducing accidents, ensuring the driver's and passenger's safety, and enhancing fuel efficiency is further promoting the market expansion.

Furthermore, the market is witnessing a growing demand also because of the increase in the adoption of Electrical Vehicles (EV) and fuel-efficient alternatives, offering lucrative growth prospects for industry investors. The escalating need for tyres is also linked to the growing volume of logistics and transportation activities aimed at timely package delivery. As well, IoT sensors provide real-time input on a variety of tire properties. The increased popularity of electric and hybrid cars has prompted tyre producers to create tyres that are more energy-efficient and have a longer range. To diminish environmental effects, tyre manufacturers are investing considerably in sustainable materials such as natural rubber and recyclable materials.

The market is additionally benefited by the various advantages offered by modern tires, such as improved stopping power, enhanced overall safety, and superior handling capabilities. Moreover, the wide availability of tires through both offline and online distribution channels is contributing to market growth. The growing use of modern technology in the car industry is enhancing demand for smart automotive tyres for automobiles. The tyre-pressure monitoring system, temperature management, and feedback on the status of the road and the tires are all safety features. This kind of predictive analysis can reduce maintenance costs, ensure more safety, and leverage by increasing tyre useful life. Lastly, major industry players are introducing innovative airless or non-pneumatic tires capable of carrying heavy loads while maintaining a smooth ride with minimal turf disruption, therefore stimulating more the market expansion.

### 1.4. Competitive Landscape

Tyres can be considered a commodity in the sense that they are standardize goods for which there is a constant and universal demand, driven by the existence of automobiles. They are a complementary product of the vehicle; therefore, their demand is dependent to the widespread use of vehicles. Currently, there is no substitute for the tyre, it cannot be replaced by another product. However, while the tyre can be an homogeneous product since the specifications and functionalities are very similar no matter the manufacturer, firms decide to compete providing product differentiation based on quality, branding, performance features and technological innovations. Firms also compete by offering a range of products that cater to various segment of the market, moreover, each company has its own approach, reach, and strategy; which demonstrate characteristics of an oligopoly.

The Global Tyre Industry has changed a lot throughout the years. Before the 1980s, the competition was mostly local and fragmented, with numerous small manufacturers producing a variety of tyre types. However, finalizing the 80's, the market started being populated by few large multinational firms like Michelin, Goodyear and Firestone. This industry's consolidation mainly happened because of the new radial tyre technology offered and widely spread by Michelin by the 1970's since other firms were not able to keep up with the technological advance. These new radial tyres revolutionized the market, they provided more security, sensitive road handling, and lasted double compared to the rest. This shift to radial from 1970 until 1980 reduced the demand for replacements, which resulted in excess capacity, price wars, and plant closures that led to a major international consolidation. (Scherer, 1992)

The late 80's and late 90's for Tyre Industry was the time for M&A's (Mergers and Acquisitions). Firestone was acquired by Bridgestone in 1988, forming one of the world's largest tyre manufacturers. Michelin has also consistently expanded its global presence through acquisitions, like the notable purchase of Uniroyal-Goodrich in 1990, and BFGoodrich in 1988. Also, Continental acquired General Tire in 1987, and Pirelli acquired Armstrong Tire. Pirelli tried to acquire

Continental in the early 1990s but was unsuccessful. Goodyear acquired several smaller tyre manufacturers and expanded its operations globally, also forming strategic alliance with Sumitomo Rubber, which had acquired Dunlop Tyre back in 1987. By the end of these mergers, the five major companies in the world were Michelin, Continental, Pirelli, Bridgestone, and Goodyear, holding together a market share of over 75% by the early 1990's. Even if the market was highly concentrated, there was no real cooperation among companies. Price competition was vivid, pricing was being pressed, and profits were lower than industries with similar structures. Companies are continually investing in R&D in order to create safer, more fuel-efficient, and longer lasting tyres, which makes the margin shorter.

In the late 20th century and into the 21st, emerging market players, particularly from Asia like Hankook and Toyo, have gained prominence, challenging the established leaders. In many developing economies like Russia, the number of tyre plants has increased over the last years. According to "Russia Tyre Market Forecast & Opportunities" (TechSchi Research, 2017), the most important factor for tyre producers is the availability of raw materials at low prices. As well, labour costs are less in countries like Russia or Romania due to a huge labor-intensive market that has emerged. Also, cost of energy in Russia is less than the rest of Europe, disregarding Romania. Demand for premium tyres has increased in the country, which pushed producers to manufacture tyres in the host country for domestic supply, saving also around 20% of the cost, since customs expenses are not being paid. Adding all these factors, production capacity can be way higher in Russia than in other countries. Companies like Continental, Michelin, Pirelli, Yokohama, etc., have entered Russian ground, because with the benefits generated from Economies of Scale, these companies are going to be improving their profits by manufacturing there and exporting all over the world. As companies increase their production volume, they can maintain their fixed costs over a larger quantity of tyres, reducing this way the cost per unit and positively impacting on their profit margins.

It is important to note, that economies of scales has its limits, because at a certain production volume, further expansion may not lead to cost reductions anymore and returns can decrease. Either way, it is not the main reason for investing in abroad manufacturing. Michelin per instance, adopted a specialized/focused factories strategy to fulfill various customer needs and achieve local customization on demand. They achieve product differentiation by capturing the new customer in the emerging market, as well as their local presence to adapt to the specific features of the world markets. Anyway, their global footprint (France, U.S., China, etc.) allows them to also optimize production volumes, lower production costs and respond to regional market demands effectively.

### 1.4.1. Oligopolistic Market

In this context of oligopolistic competition, firms recognize their mutual interdependence. Unless there is a prearranged division of the global market, foreign investments inevitably lead to interactions among international oligopolists across multiple markets. Existing literature suggests that this intensified head-to-head does not necessarily leads to reduced profits. Bernheim and Whinston (1990) conducted a study on the relationship between multimarket interactions and a firm's capacity to maintain noncompetitive or collusive behaviors. They proposed that international oligopolists can impose strong penalties as reduced profits on single market competitors, promoting collusive outcomes. Additionally, Klemperer's model (1992) demonstrated that in cases where consumers exhibit brand loyalty or faces significant switching costs, directly replicating rivals' product offerings can result in reduced competition and higher prices when compared to segmenting the products.

### 1.4.2. Current Players

- **Bridgestone**: Founded in Kurume – Fukuoka (Japan), Bridgestone is known globally for its premium tyres. As a top industry leader, it commands a significant market share. Presently, it is operating approximately 180 manufacturing plants and R&D facilities. Their tyres are distinguished by their long durability and exceptional traction on various surfaces. The company is actively expanding internationally in response to rising tyre demand.

*Image 1. Bridgestone Logo*

- **Michelin**: A prominent French tire manufacturer, Michelin was established on May 28, 1889, in Clermont-Ferrand, France. It boasts a strong global presence with numerous tire distributors. With nine R&D facilities, 117 production plants in 26 countries, and commercial operations in over 170 countries, Michelin is at the forefront of tire technology and quality.

*Image 2. Michelin Logo*

- **Goodyear**: American corporation, founded on August 29, 1898, in Akron, Ohio, Goodyear has been a tire industry pioneer for over a century. It is celebrated for innovations such as the creation of the first tubeless tire in 1903. Goodyear's reputation for performance excellence earned it recognition as the world's largest tire manufacturer in 1916. The company

continues to be a preferred choice for high-performance vehicles and has collaborated with NASA on airless spring tire technology.


*Image 3. Goodyear Logo*

- **Continental**: Founded on October 8, 1871, in Hanover, Germany, Continental is recognized for producing durable and resilient tires. Its brand enjoys significant demand worldwide, particularly in Middle Eastern countries where consumers prefer Continental tires. Continental's focus on market-driven tire technology has made it a cost- effective option with cutting-edge features.


*Image 4. Continental Logo*

- **Pirelli:** Italian tyre manufacturer founded on January 28, 1872, in Milan, Italy, Pirelli is a pioneer of innovation in the tyre industry. Renowned for premium quality, Pirelli tyres are frequently seen in Formula 1 races and are favored in European countries. Pirelli focuses solely on the Consumer tyre market for cars, motorcycles, and bicycles. 71% of their revenues come from high-value tyres, 29% from standard tyres. The firm competes with “Tier 1” manufacturers, being the leader in Prestige tyres with a market share of over 50% in the OE channel.


*Image 5. Pirelli Logo*

- Hankook Tyre: Founded in South Korea in 1941 as "The Chosun Tire Company" and later renamed Hankook in 1968, the company has been expanding its global presence to meet high demand. Known for its top- tier quality, Hankook excels in the Middle Eastern and African premium tire markets, offering a strong reputation and performance ratings.


*Image 6. Hankook Tyre Logo*

- Yokohama Rubber Company: Established on October 13, 1917, in Yokohama, Kanagawa, Japan, Yokohama tires are recognized for their exceptional grip due to their wide shoulder design. Over a century in operation, Yokohama utilizes advanced technologies to create high-quality rubber products, ensuring a noise-free and comfortable driving experience.


*Image 7. Yokohama Rubber Company Logo*

- Sumitomo Rubber Industriees: Established in Japan in 1909, Sumitomo Rubber Industries operates through numerous subsidiary companies, employing over 39,000 individuals and achieving sales exceeding 108 million units. Falken, one of Sumitomo's prominent brands, is known for its sporty aesthetics.


*Image 8. Sumitomo Rubber Industriees Logo*

- Zhonace Rubber Group: Founded in 1958 in China, Zhongce Rubber Group boasts five key brands: "Westlake," "Chaoyang," "Arisun," "Goodride," and "Trazano." As China's largest tyre manufacturer, it produces high-quality tires meeting international standards. Westlake is a popular choice in the Chinese truck tire category.


*Image 9. Zhonace Rubber Group Logo*

- Maxxis Tyres: Originating in Taiwan in 1967, Maxxis Tires has achieved a global revenue exceeding 4 billion US Dollars and distributes products to over 170 countries. Initially focusing on bicycle tires, the company expanded across various categories. Maxxis is widely recognized and has garnered numerous global awards for its exceptional service and build quality, primarily through international exports.


*Image 10. Maxxis Tyres Logo*

| No. | Company | Country of origin | Presence in the world (no of coutries) | No. of factories |
|---|---|---|---|---|
| 1. | Bridgestone | Japan | >150 | >180 |
| 2. | Michelin | France | 170 | 69 |
| 3. | Goodyear | USA | 54 | 49 |
| 4. | Pirelli | Italy | 160 | 19 |
| 5. | Continental | Germany | 56 | 13 |
| 6. | Hankook | South Koreea | >180 | 5 |

*Table 1. Presence in the World of top Car Tyres Manufacturers (Studia Universitatis Economics – Vasile Goldis, 2020)*

tyres and accessories

Updated: 21.06.2023

| Rank (2021 | Manufacturer | | 2022 Euro | 2022 Share tyres | | 2022 Local currency | 2021 Euro | 2021 Share tyres | | 2021 Local currency |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. (1.) | MICHELIN | | 28,590.0 | 28,018.2 | 98.0% | | 23,795.0 | 23,319.1 | 98.0% | |
| 2. (2.) | BRIDGESTONE Solutions for your journey | 1) | 29,220.1 | 27,028.6 | 92.5% | 4,110.1 | 24,897.2 | 23,029.9 | 92.5% | 3,246.1 |
| 3. (3.) | GOODYEAR | 2, 14) | 19,505.9 | 19,505.9 | 100.0% | 20,805.0 | 15,431.8 | 15,431.8 | 100.0% | 17,478.0 |
| 4. (4.) | Continental The Future in Motion | | 39,408.9 | 14,005.2 | 35.5% | | 33,765.2 | 11,807.6 | 35.0% | |
| 5. (5.) | SUMITOMO RUBBER INDUSTRIES | 1) | 7,811.0 | 6,682.1 | 85.5% | 1,098.7 | 7,179.0 | 6,173.9 | 86.0% | 936.0 |
| 6. (6.) | PIRELLI | | 6,615.7 | 6,615.7 | 100.0% | | 5,331.0 | 5,331.0 | 100.0% | |
| 7. (7.) | HANKOOK driving emotion | 3) | 6,245.3 | 6,245.3 | 100.0% | 8,394.2 | 5,304.8 | 5,304.8 | 100.0% | 7,142.3 |
| 8. (8.) | YOKOHAMA | 1) | 6,117.6 | 5,371.3 | 87.8% | 860.5 | 5,145.0 | 4,496.7 | 87.4% | 670.8 |
| 9. (9.) | 中策橡胶 zc rubber | 4, 13) | 4,348.9 | | n/a | 32,000.0 | 4,209.4 | | n/a | 30,285.7 |
| 10. (11.) | TOYO TIRES | 1) | 3,534.8 | 3,241.4 | 91.7% | 497.2 | 3,018.1 | 2,804.4 | 90.1% | 393.5 |
| 11. (10.) | MAXXIS | 5) | 3,000.5 | 3,000.5 | 100.0% | 98,622.9 | 3,229.4 | 3,229.4 | 100.0% | 101,537.0 |
| 12. (15.) | SAILUN | 4) | 2,976.6 | 2,976.6 | 100.0% | 21,902.2 | 2,501.6 | 2,501.6 | 100.0% | 17,998.4 |
| 13. (14.) | apollo TYRES | 6, 9) | 2,748.1 | | n/a | 245,681.3 | 2,501.7 | | n/a | 210,711.0 |
| 14. (13.) | Giti | 13) | 2,696.0 | | n/a | | 2,506.0 | | n/a | |
| 15. (18.) | KUMHO TIRE All-ways, Go With you | 3) | 2,648.0 | 2,648.0 | 98.5% | 3,559.2 | 1,932.0 | 1,903.0 | 98.5% | 2,601.2 |
| 16. (17.) | MRF TYRES | 6, 9, 10) | 2,553.3 | | n/a | 228,264.4 | 2,291.9 | | n/a | 193,044.3 |
| 17. (12.) | LINGLONG TIRE | 4) | 2,311.2 | | n/a | 17,005.9 | 2,582.4 | | n/a | 18,579.2 |
| 18. (16.) | COOPER TIRES | 2, 14) | n/a | | | n/a | n/a | | | n/a |
| 19. (20.) | TITAN | 2) | 2,033.9 | 2,039.9 | 100.0% | 2,169.4 | 1,571.8 | 1,571.8 | 100.0% | 1,780.2 |
| 20. (---) | NEXEN TIRE | 3) | 1,932.5 | | n/a | 2,597.4 | 1,544.4 | | n/a | 2,079.4 |

*Table 2. Tyres Manufacturers Ranking by Tyres and Accesories based on sales (2023)*

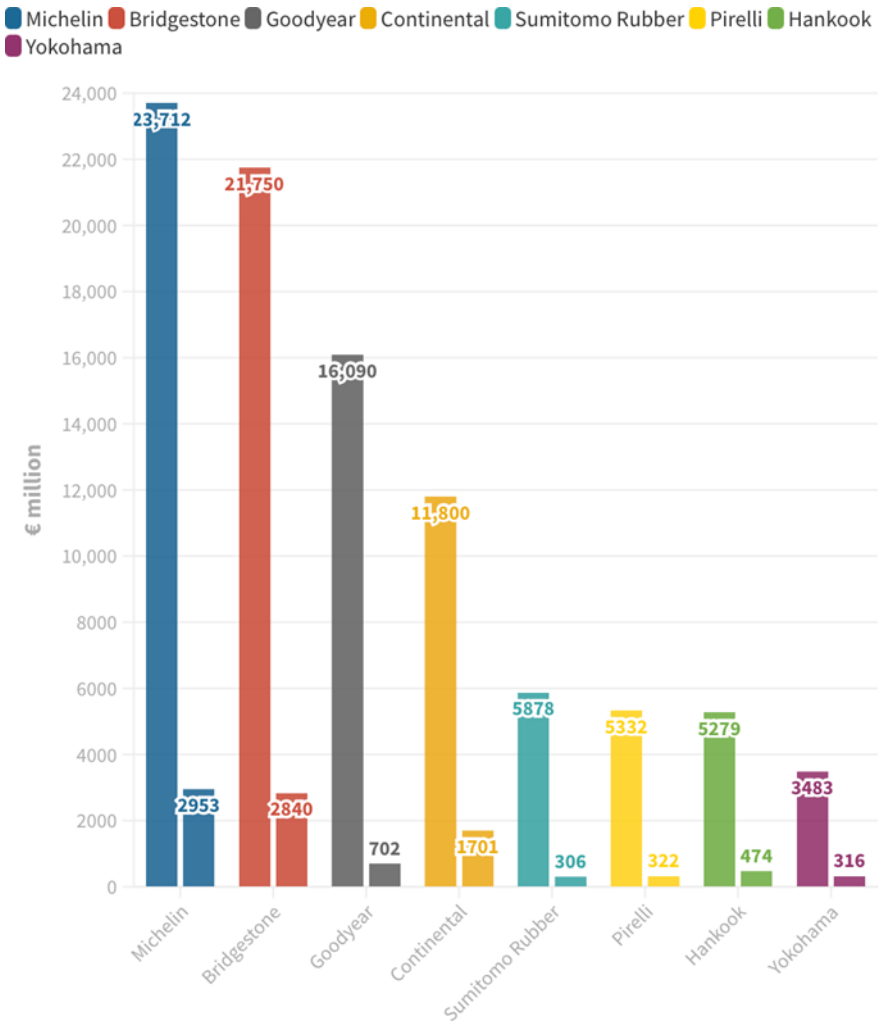


*Figure 4. Top 8 Tyre Global Manufacturers Ranked on their Revenues and Profits (2021 Financial Reports)*

### 1.4.3. Benchmarking Highlights

- Nowadays, the top 3 companies -Michelin, Bridgestone and Goodyear- combined, come close to 50% of the entire tyre industry revenue.

- The leading top 8 tyre companies have an average profit margin of 9.2%.

- The highest profit margin in 2022 goes to Continental with a ratio of 14.4$. This because Continental enjoys of lower production costs and better customer mix than top 3 competitors by having the strongest network of manufacturing plants in low-cost countries, which gives it a cost base that competitors can't match.

Also, by expanding its scope selectively to offer more automotive components, Continental can bundle products and create strong relationships with their customers.

- Bridgestone is the largest manufacturer in North America, with a strong revenue of €9,282 millions

- Pirelli invests the most on R&D

| COMPANY | REVENUE (in thousands of EUR) | PROFIT (in thousands of EUR) | PROFIT MARGIN | R&D COST/REVENUE | NUMBER OF EMPLOYEES |
|---|---|---|---|---|---|
| **MICHELIN** | € 23,712 | € 2,953 | 12.45% | 2.88% | 124760 |
| **BRIDGESTONE** | € 21,750 | € 2,840 | 13.06% | 2.94% | 138036 |
| **GOODYEAR** | € 16,090 | € 702,000 | 4.36% | 2.84% | 72000 |
| **CONTINENTAL** | € 11,800 | € 1,701 | 14.41% | 2.5% | 57217 |
| **SUMITOMO RUBBER** | € 5,878 | € 306,000 | 5.21% | 3.1% | 39298 |
| **PIRELLI** | € 5,332 | € 322,000 | 6.03% | 4.5% | 30690 |
| **HANKOOK** | € 5,279 | € 474,000 | 8.98% | | 20000 |
| **YOKOHAMA** | € 3,483 | € 316,000 | 9.07% | | 27222 |

*Table 3. Top 8 Tyre Manufacturers Financial Stats*

## 2. INTERNATIONAL EXPANSION: FOREIGN DIRECT INVESTMENT (FDI)

Initially, for a company to pursue international expansion, it must become a Multinational Enterprise (commonly known as MNE), meaning that the company is required to have operations in another country other than their home-country and generate around 25% of their revenues outside of it. Companies enter a decision-making process where they must choose whether to service the targeted foreign markets by setting up production plants in strategic locations or instead by just exporting the product fabricated in the home-country.

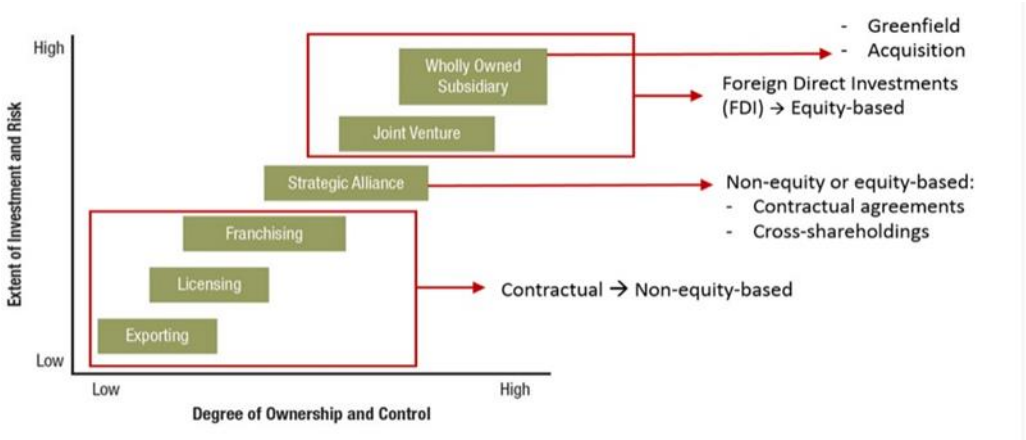


*Figure 5. Entry Strategies for International Markets (Root, 1994)*

FDI refers to the investment made by individuals, businesses, or entities from one country into tangible assets or ownership interests in another country. It is crucial for facilitating this cross-border economic integration, enabling capital to flow between nations, fostering economic growth and promoting global business expansion and collaboration. According to the OECD (2010), direct investments involve the initial transaction between two entities as well as all subsequent capital transactions between them. This investment must be translated into a long-term relationship between the direct investor and the entity, where the

investor acquires a significant degree of influence into the management of the company.

## 2.1. OLI Paradigm

The eclectic paradigm, also known as the OLI (Ownership, Location and Internalization) framework, is a general and practical model that firms can follow when they are trying to decide on whether to pursue FDI or not. This is based on the internalization theory and was first introduced by academic John H. Dunning inn 1979), under the assumption that companies will avoid transactions in the open market if the cost of executing the same actions in the home-country can be carried by a lower price.

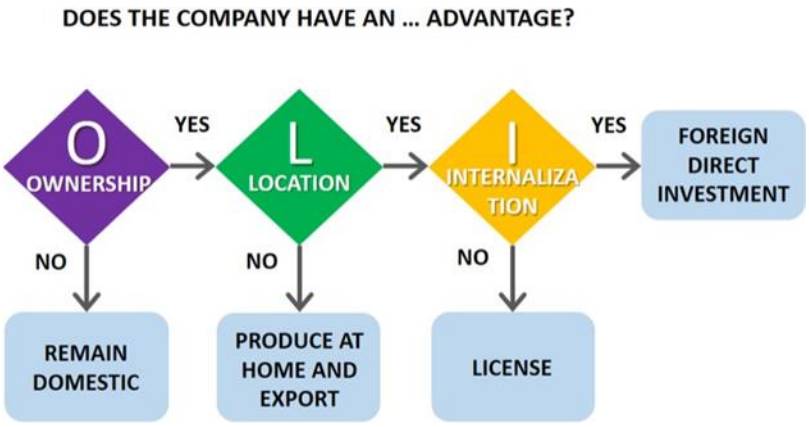


*Figure 6. OLI Framework*

The Ownership advantage evaluates if the company can offer a certain valuable, rare, hard—to-imitate resource compared to foreign competitors. If the company can transfer something valuable (could be reputation, economies of scale, etc.) into a host-country that could offset any negative difficulty of foreignness, then it is justifiable not to remain domestic. For the location advantage, the company should consider if the host country can benefit by geographical advantage or factors such as lower prices on raw material and/or labor, skilled labor force, special taxes, overall, by better tariffs. Porter's Diamond Model is a great way to

evaluate this. If there are no location advantages, it could be better to keep production at home-country and export the product instead. Lastly, for internalization advantage, the company must evaluate if the value chain activity would be better performed internally or by an external party. Outsourcing can be a wise choice if the company does not want to specialize on the activity in question, or just if companies abroad are better at it, or can do it cheaper, etc. If this is the case, the company can license its product design to another foreign company or just outsource production to an OEM (Original Equipment Manufacturer). Otherwise, if the firm wants control over all activities, they can engage in FDI, either through joint ventures, acquisitions or from starting from scratch through a greenfield investment.

### 2.1.1. OLI Taxonomy

- Resource Seekers: Companies who tend to invest abroad in the search of cheaper production inputs such as raw materials, labor, fuels, agricultural products, etc. Typically, these are firms of the manufacturing sector investing in developing countries.

- Market seekers: Companies who invest on a particular market to cover its demand through their own subsidiaries instead of through international trade. Dunning and Lundan (2008) state that market seeking FDI originate from firms that were initially exporters to the host market but choose to strengthen their position through FDI, either to cover themselves from the international competition, to reduce transportation costs, or even to adapt better to local demands and preferences.

- Efficiency seekers: Companies who want to reduce production costs and gain from economies of scale or scope, rationalizing their production processes through value chains among operations in different countries. These companies are usually big and diversified Multinationals, that typically belong to the manufacturing sector. (Dunning and Lunndan, 2008)

- Strategic asset seekers: Companies who look to engage into FDI activities by establishing a new or acquiring and merging an already established foreign company, this way to integrate and exploit strategic assets from them, such as technology, brand reputation and/or distribution networks. Usually, if the investor is in a developed country they acquire the foreign company to establish themselves and exploit Ownership advantages into the host-country. If it's the other way around, emerging countries might acquire a foreign firm in order to incorporate these advantages into their existing value chain. (Cross and Voss, 2008)

## 3. TYRE MANUFACTURING PLANT LOCATIONS

**The European Tyre and Rubber Manufacturing Association (ETRMA)** stands as the advocate for tyre and rubber goods manufacturers. Since its inception in 1959, the Association has been committed to representing the interests of the industry to European Union institutions and various international organizations. ETRMA plays a pivotal role in promoting the development, competitiveness, and expansion of the tyre and rubber industry. This commitment extends to supporting initiatives related to health, safety, environmental protection, transportation, road safety, and access to international markets, all in close coordination with European public authorities.

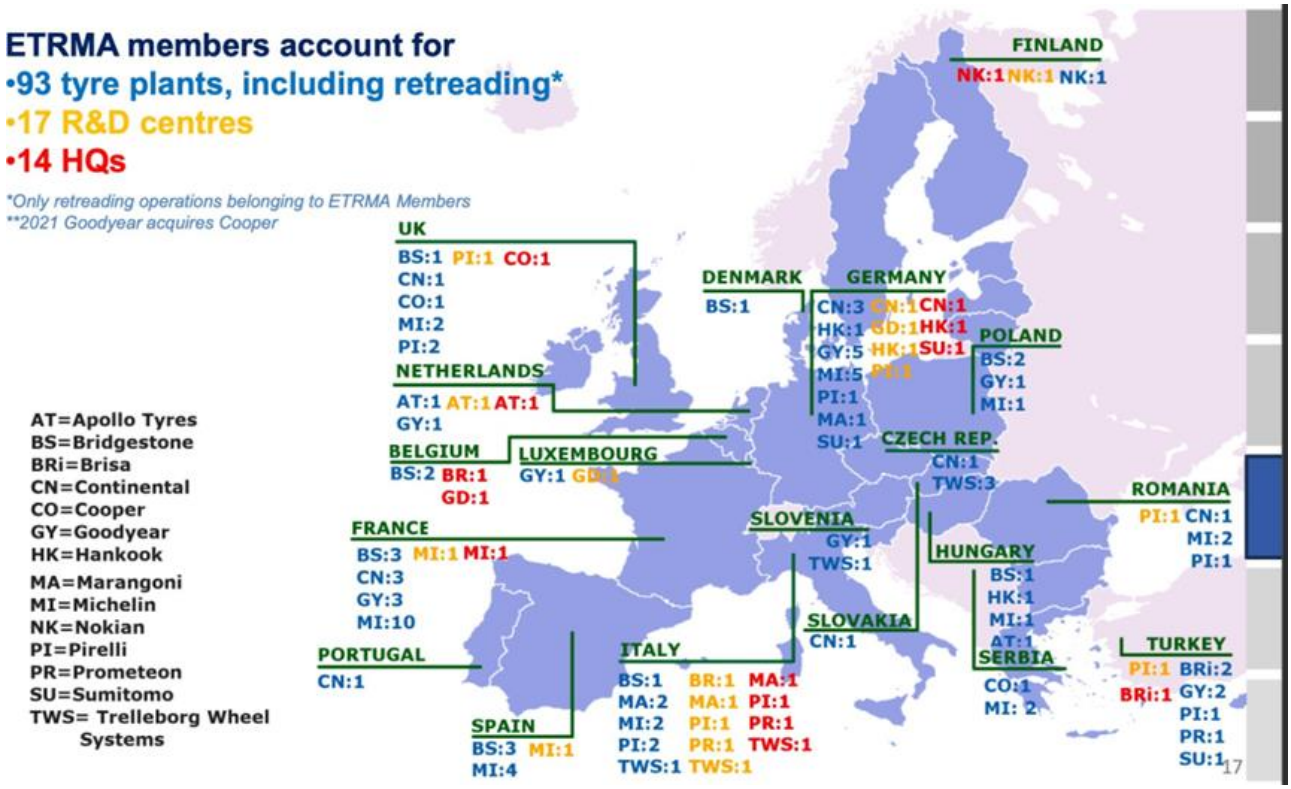


*Figure 7. ETRMA Tyre Manufacturers Plants (ETRMA Statistics, 2021)*

## 3.1. Factors for Tyre Manufacturing Facility Location

### 3.1.1. Economies of scale (Efficiency Seekers)

Establishing large manufacturing plants allow tyre companies to achieve economies of scale by increasing the volume that is produced and therefore, decreasing the cost per tyre. These large-scale production facilities can provide a significant volume of tyres and optimize their operations, leading to cost efficiency. This includes minimizing labor and energy costs per tyre produced, reducing waste, and streamlining production processes. Also, higher production volumes allow these companies to purchase raw materials such as rubber and steel in bulk, and bulk purchasing often leads to discounted prices, again lowering the cost of tyre production. Economies of Scale are often associated with standardized manufacturing processes, which means these companies can standardize production methods and equipment across different plants, reducing the need for customizations and associated costs.

Bridgestone has a network of large-scale manufacturing plants across the globe (U.S., Japan and Europe). These plants are strategically located to maximize production efficiency and achieve economies of scales with a production volume that benefits from its internationalization. As well, one of Pirelli's biggest manufacturing facility is located in Romania, where production and labor costs are low and capacity of the plant is very high. The company benefits by producing a high volume at a lower cost, which not only serves for the local market but for sales all throughout Europe, and even oversees, by shipping a higher volume and bearing transportation costs by still benefiting because of the low production costs. This helps Pirelli remain competitive in terms of pricing and production efficiency.

### 3.1.2. Transportation costs (Effiiciency Seekers)

- Proximity to markets: Tyre companies establish manufacturing plants in or near their target markets in order to minimize transportation distances. Proximity to customers and distribution centers reduces shipping costs and transit times. A company operating in the North America, for example, could have on going facilities in the U.S. and Mexico to supply tyres to both domestic and international markets, reducing the need for long-haul transportation.

- Fuel costs: Shipping tyres over long distances can be costly due to weight and bulk of the products, reducing transportation distances can lead to significant fuel cost savings, costs which can be very high especially when considering large-scale production. Shipping tyres from a central facility location in the U.S. to various regions within the country can result in substantial fuel savings compared to importing tyres from overseas.

- Import and export costs: Custom duties, taxes, and administrative expenses. A tyre manufacturer with a plant in China can produce tyres for the Asian market without incurring in these import/export duties, therefore resulting in costs savings.

- Lower shipping and handling expenses: Transportation of tyres often requires specialized equipment and handling at origin and destinatiioon to ensure product quality, sometimes through a freight forwarder or else. Locally producing the tyres require less specialized handling and reduced shipping expenses. There are also specific handling charges when loading the tyres, known as LTHC and also for unloading the cargo at the port of destination, known as DTHC.

- Logistics efficiency effects: local production streamlines the supply chain and reduces the complexity of logistics. It simplifies inventory management, warehousing, and distribution, which in turn leads to cost savings. Having a plant in Europe, for example, enables a tyre company to distribute tyres more efficiently within the European market, minimizing storage and handling costs.

- Surcharges: When there is congestion between ports, local charges (Equipment Imbalance, Equipment handling, War Risk Charges, etc.) that are not previously negotiated may be imposed. The party who bears these charges depend on the Incoterm agreed between them, however, the charges are not negotiable, and they could be triple the cost of the shipment. Avoiding these costs is in fact a great saving for vendors.

Per instance, Continental has manufacturing plants in regions where they have a substantial customer base. For example, they have facilities in the U.S. and Europe to cater these markets, this way, reducing shipping costs and enhancing supply chain efficiency. Hankook has also expanded its global presence with facilities in the U.S., China, and Hungary, also to improve its competitiveness. Nokian Tyres, on the other hand, based in Finland, operates in the U.S. to serve the North American market.

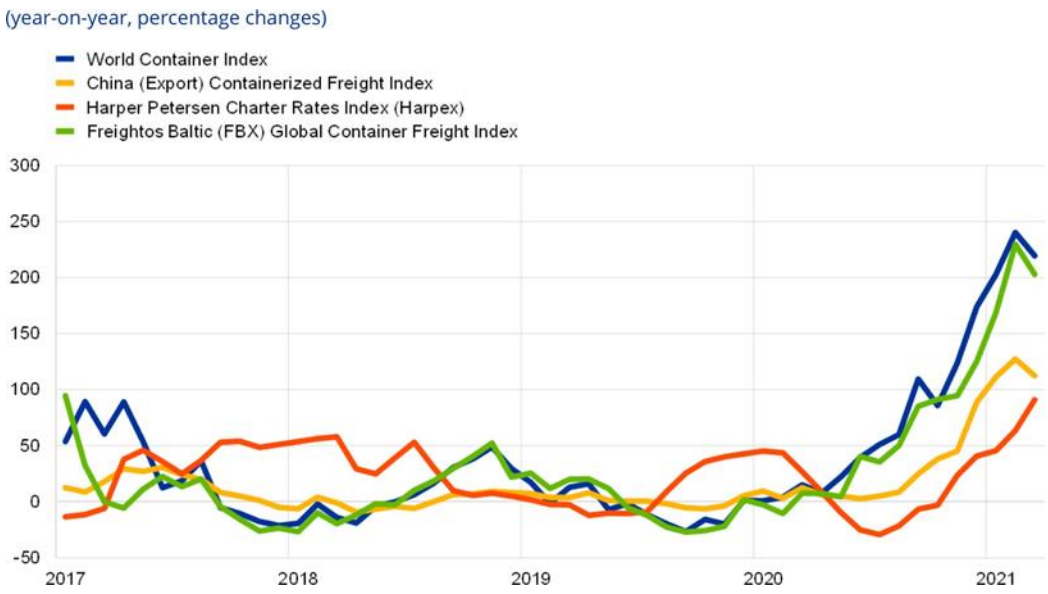


*Figure 8. Global Shipping Costs Indexes (European Central Bank, 2021)*

The World Container Index (WCI) is an indicator of container freight rates for eight major trade lanes between Asia, Europe and North America. The China (Export) Containerized Freight Index (CCFI) is an indicator of container freight rates from all major ports in China (Qingdao, Shanghai, etc.). The Harpex is an indicator of weekly container shipping rate changes in the time charter market for eight different classes of container ships. The Freightos Baltic Global Container Freight Index (FBX) is a composite indicator of container freight spot rates (unfrequent port pairs) across twelve major global trade lanes. Shipping costs are in fact very sensible to market fluctuations.

In a hypothetical case that Pirelli has a customer in Colombia and wants to ship moto tyres from the Indonesian factory that fabricates them directly with the Indonesian natural rubber plantations; the ocean freight for that lane, according to current prices with shipping line Maersk, the costs would be around 4000/5000USD for a 40FT container, which holds around 600 car tyres. Now, fortunately, Pirelli also has a high-capacity manufacturing plant which takes advantage of natural rubber planted in South America, located in Brazil. From Santos- Brazil to Cartagena-Colombia, the ocean freight with the same company can be worth around 1000USD, and if there is land possibility of transportation, it

would be worth even less. Local production very much helps in reducing transportation costs and provides a much quicker access to customers in the region.

### 3.1.3. Mitigation of Trade Barriers and Tariffs (Efficiency Seekers)

- Local production to avoid tariffs: By manufacturing tyres in a specific region, tyre companies can avoid or mitigate these tariffs and import duties imposed on foreign-made tyres. This can result in significant costs savings and competitive pricing.

- Compliance with regional regulations: Different regions often have varying regulations and quality standards for tyres. Local production ensures that these standards are met and that these tyres comply, avoiding potential costs related to product modifications or compliance issues.

- Reduced administrative costs: Importing tyres oversea can involve administrative expenses as customs paperwork and compliance checks. Local production simplifies these processes and reduces administrative costs.

- Minimizing currency risks: Operating local plants can mitigate currency exchange risks, as international transactions often involve currency fluctuations. Local production could reduce exposure to exchange rate volatility and associated costs.

- Maintaining competitive pricing: Avoiding tariffs and compliance issues allows tyre companies to keep competitive pricing in foreign markets, which is essential for market penetration and gaining market share.

Goodyear has plants in multiple regions like the U.S. and Europe with the specific objective to avoid potential tariffs and trade barriers in these markets. Producing tyres in the EU allows them to meet EU standards and regulations like the labeling, to avoiding compliance issues and potential fees. Tyres need to meet specific criteria to be eligible for sale in the European market, as stipulated in Regulation (EC) No 661/2009, concerning the overall safety of motor vehicles. This legislation mandates consistent testing methods for identical parameters on the tyre label and established minimum standards for efficiency, safety and health protection.

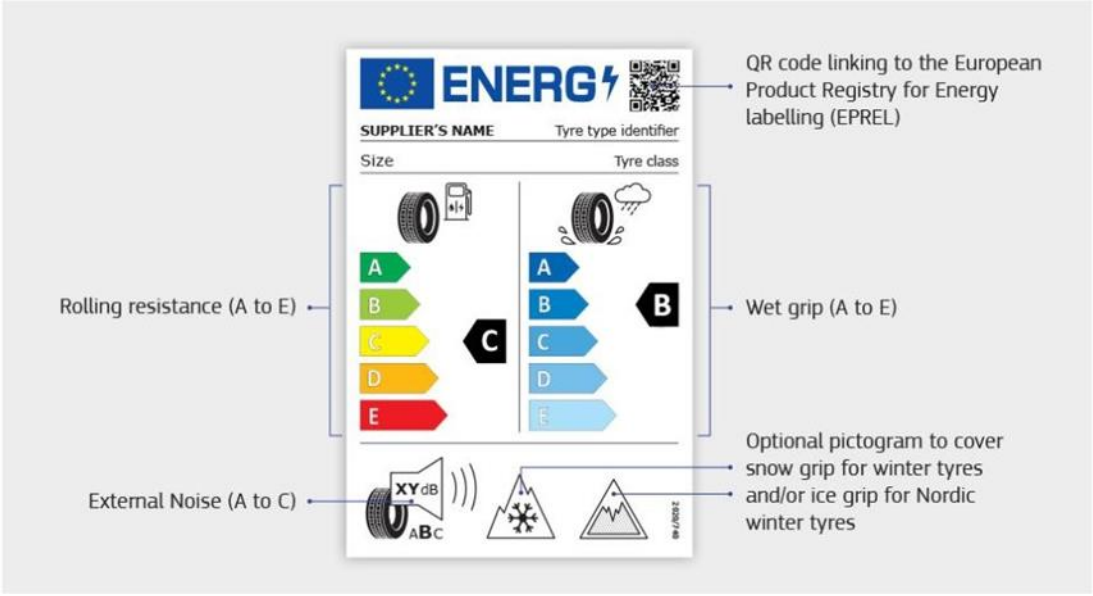


*Figure 9. Tyre Labelling (European Comission, 2021)*

As tyre performance has consistently advanced, the prerequisites for the minimum acceptable performance level allowed in the EU single market have become more stringent. Consequently, tyres with lowest performance level have been prohibited progressively. This entails the exclusion of tyres with an energy class below E, a wet grip class below E, or a noise class worse than B from being available in the European market.

### 3.1.4. Effect of Internationalization by Mergers and Acquisitions (Strategic Asset Seekers)

- Market Entry and Expansion: M&As provide tyre companies with opportunities to enter new markets and regions by acquiring existing facilities that allows them to quickly establish a physical presence in the areas where they may not have had operations before.

- Access to Established Manufacturing Facilities: This Brownfield approach gives companies the access to well-established manufacturing plants. These facilities are already equipped with the necessary infrastructure, equipment, and even workforce, which results in no need for new capital investments on these points.

- Operational Synergy and Efficiency: M&As can lead to operational synergies in the tyre Industry. The acquiring company may introduce best practices, advanced technologies and effective management methods to the acquired plants. This can lead to improved production efficiency, reduced manufacturing costs, and increased competitiveness in the tyre market.

- Diversification and Risk Mitigation: Expanding through M&As allows to tyre companies to diversify their manufacturing network. Having plants in different regions helps mitigate risks linked to geopolitical instability, natural disasters, economic fluctuations, etc. This diversification enhances the resilience of tyre production.

- Leveraging Local Expertise: Acquiring company gains access to the local expertise and knowledge of the acquired workforce. This is particularly valuable for understanding regional market dynamics, consumer preferences and any specific requirements related to tyres.

Bridgestone and Firestone merger in 1988, as previously mentioned, was a pivotal move in the tyre industry. This merger allowed Bridgestone to expand its presence in North America and access Firestone's well-established manufacturing facilities, enhancing its tyre production capabilities in the region. Michelin and Tigar Tyres in 2005 is also a fair mention, since it provided Michelin with an immediate entry into the Eastern European tyre market, with all access to Tigar Tyers' manufacturing plants and local market insights. On another hand, Sumitomo Rubber acquired Goodyear's Dunlop tyre facility in South Africa in 2013 as a strategic move to expand its presence in the African market. This allowed Sumitomo Rubber to cater to local demand and leverage the acquired manufacturer plant's production capacity.

### 3.1.5. Market Access and Proximity (Market Seekers)

- Market access: Tyre companies strategically establish manufacturing plants in proximity to their target markets in order to gain better access to these markets, respond quickly to market demand, reduce lead times, and enhance customer service.

- Regional market demands: different regions often have unique tyre preferences and requirements due to varying road conditions, climate, and overall customer preferences. In a cold weather country, for example, winter tyres would be the top demand, or let's say they require off-road use or high- performance vehicles. By having local facilities, tyre companies can manufacture their product offerings to meet these specific regional demands more effectively.

- Faster market response: Proximity allows tyre companies to respond rapidly to changes in market demand. They can quickly adjust production volumes and product offerings more quickly, ensuring that they meet consumer needs effectively.

- Competitive advantage: Being close to the market can give tyre companies a competitive advantage. It allows them to offer just-in-time deliveries, reduce inventory carrying costs and improve customer satisfaction through faster response times.

Italian tyre manufacturer, Pirelli, approaches a market proximity strategy which they call Local for Local operations, to locate factories for car and Motosport tyre production as figure below shows.

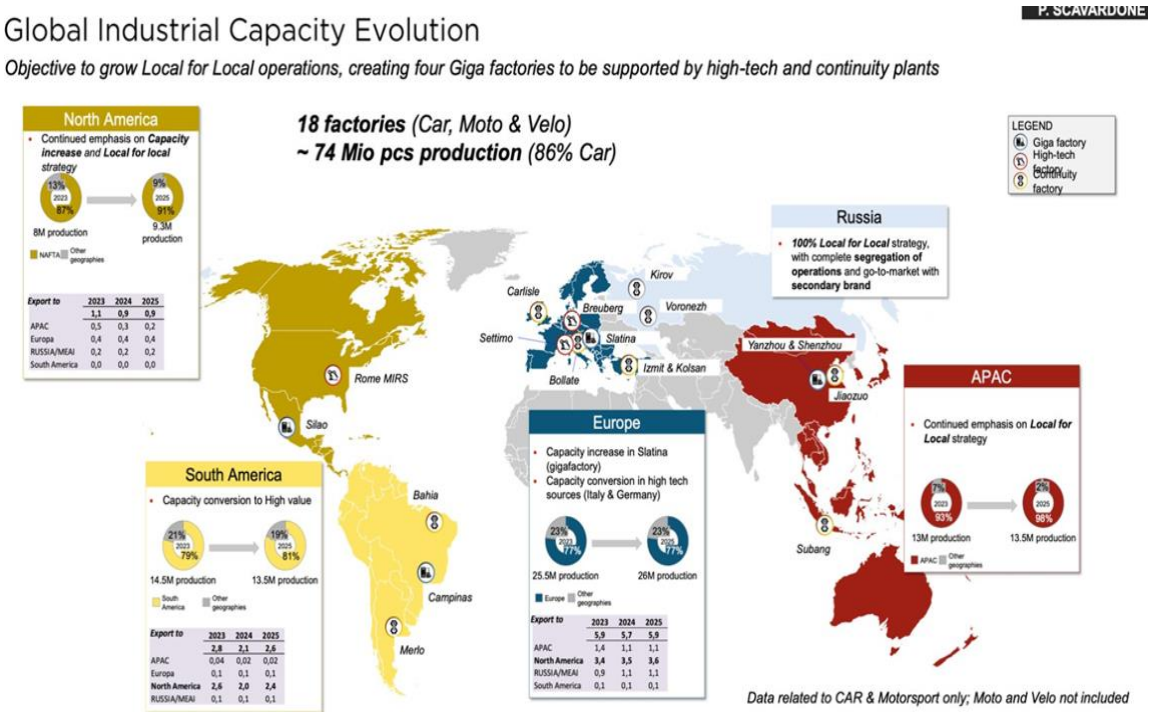


*Figure 10. Pirelli's Footprint for Car and Motosport (Pirelli Academy, 2023)*

For the market in North America, Pirelli counts with two manufacturing facilities, one Giga factory (high-Capacity plant producing medium/long lots for premium tyres) in Silao, Mexico; and a High-tech factory (medium capacity plant producing medium lots for prestige/high performance tyres) in Rome, Georgia, U.S. These plants currently cover 87% of NAFTA with the objective to increase their coverage up to 91% by 2023. Russia, per instance, has a strong emphasis in local operation and market adaption, they have 100% local for local strategy, meaning these tyres

are specifically produced and tailored for the Russian market, according to their consumer's preferences, cultural nuances, and market conditions. Their operations differ and separate from operations in other regions, and they have a go-to-market strategy with a second brand spefically used for the Russian market. with complete segregation of operations and go- to-market with secondary brand. Also, for APAC, the main factories are located in China and in Indonesia, with the objective to go from the current coverage of APAC market of 93% to 98% in 2025. South America and Europe operations follow more an "allocation" approach, taking advantage of high volume of production, overall, in Brazil and Romania, and evaluate best possible trade allocation without decreasing the local coverage.

### 3.1.6. Access to Raw Materials (Resource Seekers)

- Rubber Plantations and Availability: Tyre production heavily relies on natural rubber as a key raw material. Tyre companies may locate manufacturing facilities strategically in proximity to rubber plantations to ensure a stable and timely supply of raw rubber. For example, companies may have manufacturing plants in regions with abundant rubber plantations, such as Southeast Asia (Indonesia, Thailand, Malaysia), Africa and some parts of South Africa.

- Supply Chain efficiency and cost reduction: proximity to raw material sources enhances supply chain efficiency as it reduces transportation distances and lead times, important for these perishable raw materials like natural rubber. Also, by manufacturing close to raw material sources, tyre companies can reduce costs in handling, transporting and inventory management.

- Steel and chemical components: In addition to rubber, tyres require steel belts and various chemical components. Tyre manufacturers strategically

position plants to ensure access to these materials, proximity to steel production centers or suppliers of chemical components allow companies to streamline the supply chain, reduce costs and maintain a consistent and reliable flow of materials.

- Reducing dependency on imports: This is crucial for critical raw materials where supply chain disruptions or geopolitical factors may impact availability. For instance, having manufacturing facilities near rubber-producing regions reduces the vulnerability of tyre companies to fluctuations in global rubber markets.

- Environmental considerations: Access to raw materials in close proximity aligns with environmental sustainability goals. Shorter transportation distances lead to less carbon emissions, contributing this way to environmentally friendly practices in the tyre manufacturing process.

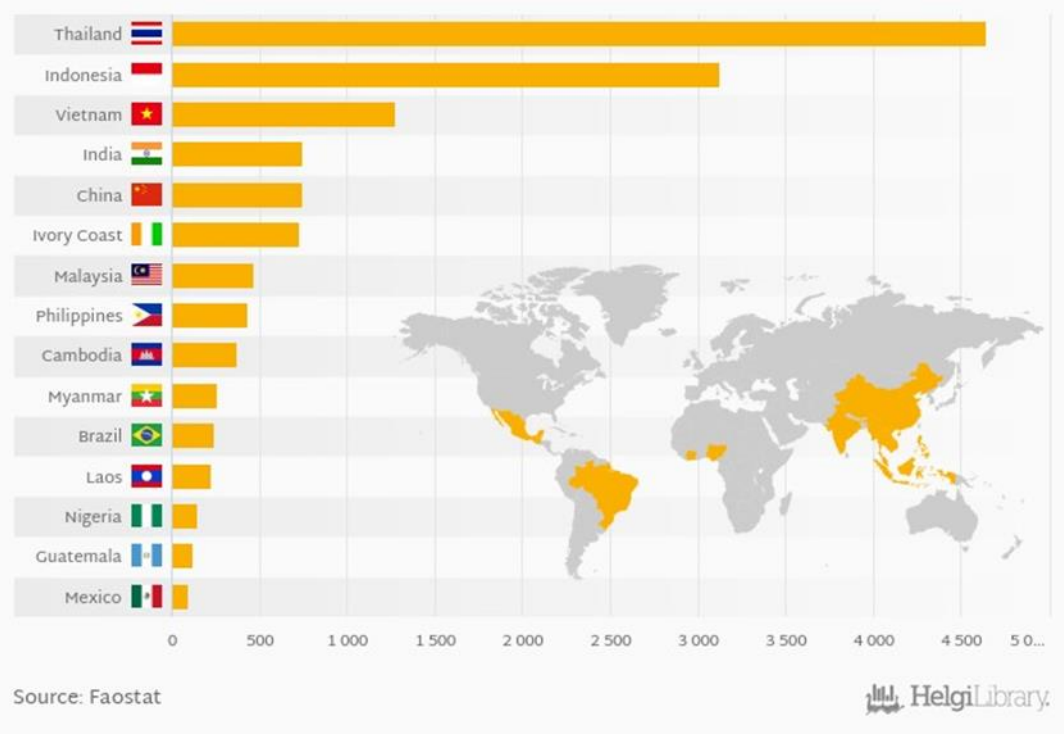


*Figure 11. Natural Rubber Production (Faostat, 2021)*

Continental and Pirelli have manufacturing plants located in Brazil to take advantage of the region being one of the strongest producers of natural rubber. By having a facility there, these tyre producers ensure direct access to locally sourced rubber, optimizing the supply chain and reducing raw material costs. As well, Apollo Tyres, whose focus is on raw material sustainability, strategically positions various manufacturing facilities in regions with a strong presence of rubber plantations. This includes locations in Far East and Africa, where natural rubber is abundant. Sumitomo Rubber and Pirelli also place manufacturing facilities in Far East, again to gain easy access to the natural rubber, and contribute to a stable supply chain for raw materials.

### 3.1.7. **Supply Chain Resilience (Efficiency Seekers/Market Seekers**)

- Strategic distribution centers: Tyre manufacturers locate their plants strategically to serve as key nodes in the supply chain, often these plants double as distribution centers, allowing for efficient storage, management, and distribution of tyres to regional markets. This strategy can ensure a more resilient and responsive supply chain.

- Reduced lead times: Location manufacturing plants closer to major markets reduces lead times for delivering products to distributors, retailers and ultimately, to end consumers. This is important when time delivery is a critical factor, such as for the automotive sector, where tyres are a crucial component.

- Optimized logistics and inventory management: minimizing transportation costs, reducing excessive inventory levels, and streamlining the flow of products through the supply chain, strategically locating plants, companies can better control inventory levels, respond to demand fluctuations and minimize storage costs.

# 4. PROPOSAL OF AN ECONOMIC MODEL: DETERMINANTS OF PLANT LOCATION (OLI FRAMEWORK + FACTORS)

The model would work as a framework to provide insights into the key factors influencing plant location decisions based on the OLI theory and the factors discussed in the previous section. By testing the hypotheses and analyzing the variables, the research would contribute to a deeper understanding of the dynamics shaping investment choices. Each firm in the tyre industry pursue different strategies, therefore, it is relevant to stand out the possibility to work this model from a tyre industry point of view, conducting with industry data, as well as analyzing firm specific datasets and performing a microanalysis. As previously mentioned, since each firm established its own footprint approach, it is suggested to make a case on a micro level as well. This model is an analysis on factors that could make a country attractive to establish a manufacturing plant in, however, what makes it attractive for the company is according to their own purpose.

As the following information to complete the whole model is out of reach for the aim of this paper (since it conducts with highly confidential information from firms), the model will be constructed as below, derived from the studies performed in previous sections.

## 4.1. Hypothesis

- **Ownership (O)**

Hypothesis 1: Countries with a more stable economic environment (higher GDP growth and lower inflation) attract tire manufacturing plants.

Hypothesis 2: Stringent regulatory environments in potential host countries negatively impact the likelihood of plan investment from tyre companies.

- **Location (L)**

Hypothesis 3: Proximity to major raw material sources positively influences the location choice for tyre manufacturing plants.

Hypothesis 4: Presence in regional economic clusters promotes the attractiveness of a location for tyre industry investment.

- **Internationalization (I)**

Hypothesis 5: Host countries with favorable FDI policies and incentives attract a higher volume of plant investment from tyre companies.

Hypothesis 6: Technology transfer and knowledge spillover positively impact the internalization decision for tyre manufacturers.

### 4.1.1. Variables

1. Ownership (O):

Dependent Variable: Probability of plant location in a country

Independent Variables: GDP growth rate, inflation rate, employment growth

Restrictions: Population size, trade openness

2. Location (L):

Dependent Variable: Proximity score to raw material sources

Independent Variables: Distance to rubber plantations, Access to transportation infrastructure

Restrictions: Geographical size of the country, trade policies

3. Internationalization (I)

Dependent Variable: FDI attractiveness index

Independent Variables: FDI policies and incentives, technology transfer index

Restrictions: Corporate tax rates, political stability

### 4.1.2. Expected Outcomes

1. Ownership (O): Countries with higher GDP growth rates, lower inflation and a more favourable regulatory environment are expected to attract a higher probability of tyre industry plants.

2. Location (L): Tyre manufacturers are anticipated to favor locations with closer proximity to rubber plantations, better transportation infrastructure, and access to regional economic clusters.

3. Internationalization (I): Host countries with more attractive FDI policies, higher technology transfer indexes, and favourable tax rates are expected to have a higher FDI attractiveness index for the tyre industry.

## 4.2. Model

This model could be validated using statistical techniques such as regression analysis to assess the significance of each variable and control for multicollinearity between plant location and the influence of ownership, location, and internationalization factors.

**Model Building in R**

**Step 1: Load Necessary Libraries**

*# Install and load required libraries*

*install.packages(c("tidyverse", "sf", "spdep", "caret"))*

*library(tidyverse)*

*library(sf)*

*library(spdep)*

*library(caret)*

**Step 2. Read Datasets**

For the evaluation of the OLI framework, the following three datasets (CSV formats) should be the better fit for the analysis:

1. Tyre Data: containing information about tyre manufacturing plants (‘tyre_data.cs´) with variables like latitude, longitude, ownership, location, .etc.

2. Rubber Plantations Data: containing details about rubber plantations (´rubber_plantations.csv´), specifically data of latitude and longitude.

3. FDI Data: should contain information on FDI attractiveness (´fdi_data.csv´) for each country in evaluation, should be information as country code and FDI scores

*# Read datasets*

*tyre_data<-read.csv("tyre_data.csv")*

*rubber_plantations<-read.csv("rubber_plantations.csv")*

*fdi_data <- read.csv("fdi_data.csv")*

**Step 3. Data Preprocessing and Integration**

*# Convert datasets to spatial objects*

*rubber_sf <- st_as_sf(rubber_plantations, coords = c("longitude", "latitude"), crs = 4326)*

*tyre_sf <- st_as_sf(tyre_data, coords = c("longitude", "latitude"), crs = 4326)*

*# Calculate distance between tyre manufacturing plants and rubber plantations*
*tyre_data$proximity_to_rubber <- st_distance(tyre_sf, rubber_sf)*

*# Merge datasets to include FDI information*

*tyre_data <- left_join(tyre_data, fdi_data, by = "country_code")*

*# Assuming 'fdi_attractiveness' and 'other_fdi_variable' are variables included in the FDI dataset (should be replaced with the actual variable names in the dataset)*

**Step 4: Linear Regression Model**

*# Linear regression model*

*lm_model <- lm(plant_location ~ proximity_to_rubber + ownership + location + fdi_attractiveness + other_variables, data = tyre_data)*

*# Summary of the model summary*

*(lm_model)*

Each coefficient in the summary output corresponds to the impact of the respective variable on the dependent variable ('plant_location'), allowing to access the evidence for each hypothesis.

**Step 5: Hypothesis Testing**

- Hypothesis 1: Countries with a more stable economic environment (higher GDP growth and lower inflation) attract tire manufacturing plants.

  Supporting evidence: A significant positive coefficient for the 'ownership' variable in the summary output would support this hypothesis.

- Hypothesis 2: Stringent regulatory environments in potential host countries negatively impact the likelihood of plan investment from tyre companies.

  Supporting evidence: A significant positive coefficient for the 'location' variable (representing regional economic clusters) in the summary output would support this hypothesis.

- Hypothesis 3: Proximity to major raw material sources positively influences the location choice for tyre manufacturing plants.

  Supporting evidence: if there is a significant positive coefficient for ‘proximity_to_rubber’ in the summary output, it would support this hypothesis.

- Hypothesis 4: Presence in regional economic cluster promotes the attractiveness of a location for tyre industry investment.

  Supporting evidence: If there is a variable related to regional economic clusters (‘regional_clusters’), should be included in the model, and a significant positive coefficient would support this hypothesis.

- Hypothesis 5: Host countries with favourable FDI policies and incentives attract a higher volume of plant investment from tyre companies.

  Supporting evidence: A significant positive coefficient for ‘fdi_attractiveness’ in the summary output would support this hypothesis.

- Hypothesis 6: Technology transfer and knowledge spillover positively impact the internalization decision for tyre manufacturers.

  Supporting evidence: A combination of significant coefficients for ‘proximity_to_rubber’, ‘ownership’, and ‘location’ variables in the summary output would support this hypothesis.

**Model's validation**

The following steps provide a comprehensive evaluation of the model's performance, to understand the impact of the variables, and assess generalization through cross-validation.

**Step 6: Model Evaluation**

```
# Assess multicollinearity using variance inflation factor (VIF)
vif(lm_model)
# Visualize actual vs. predicted values

plot(lm_model$fitted.values, tire_data$plant_location, main = "Actual vs. Predicted Values")

abline(0, 1, col = "red")
```

VIF (Variance Inflationn Factor) analysis: Check for high VIF values, indicating potential multicollinearity among independent variables. Values above 5 or 10 may be a cause for concern, it could indicate that the predictor variable may be too highly correlated with the other variables in the model. If this happens, removing one of the correlated predictors, or combining them into a single variable, could be the solution.

Actual vs. Predicted Values Plot: Evaluates how well the model could predict the actual values.

**Step 7: Model Interpretation**

*# Interpret the coefficients*

*coefficients(lm_model)*

*# Assess the significance of each variable*

*anova(lm_model)*

*# Check the residuals*

*plot(lm_model, which = c(1, 2, 3, 5))*

Coefficient Interpretation: Examines the coefficients to understand the direction and significance of each variable's impact on the dependent variable ('plant_location')

ANNOVA Analysis: Assess the overall significance of the model and individual variable contributions.

Residual Analysis: Evaluates the residuals for homoscedasticity, normality, and independence assumptions.

**Step 8: Cross-Validation**

*# Using 10-fold cross-validation*

*set.seed(123)*

*cv_results <- train(*

*plant_location ~ proximity_to_rubber+ ownership + location + fdi_attractiveness + other_variables,*

*data = tyre_data,*

*method = "lm",*

*trControl = trainControl(method = "cv", number = 10)*

# View cross-validation results

*cv_results*

Cross-Validation: Evaluates the model's performance using 10-fold cross-validation. The output includes metrics such as RMSE (Root Mean Squared Error) and R Squared for each fold.

### 4.3. Relevant Data

To make an example of relevant information to consider when analyzing, below table shows a list of countries with the highest number of tyre manufacturing facilities located. For each country, there is relevant data to understand the size of the market such as population and GDP Per Capita. (WorldoMeter, 2021) As well, there are three FDI columns with OECD information on Outflows in 2022, which are the value of outwards direct investment made by residents of the country in question to external economies, Inflows in 2022, which are the value of inward direct investment made by foreign individuals into the country, and lastly, the Regulatory Restrictiveness Indexes in 2019, which evaluates the restrictiveness of a country's FDI rules by looking at foreign equity limitations, closeness and hard approval mechanisms, restrictions to hire foreign workers, and more operational restrictions. Lastly, there are two columns showing the quantity of tyres in USD billions exported and the production of natural rubber in that same country.

| Country | Market Size | | Labour Market | FDI | | | Tyre Industry | |
|---|---|---|---|---|---|---|---|---|
| | Population (Millions) 2021 | GDP per Capita (USD) 2021 | Labour costs in manufacturing USD per hour 2021 | FDI Outflows (USD Millions) 2022 | FDI Inflows (USD Millions) 2022 | Regulatory Restrictiveness Indexes 2019 | Exports (USD Billions) 2022 | Natural Rubber Production (1K metric tons) |
| China | 1410 | $ 11.486 | $ 4 | $ 149.692 | $ 180.167 | 24,4% | $ 18,9 | 0,84 |
| Thailand | 69 | $ 5.975 | $ 2 | | $ 10.196 | 26,8% | $ 6,6 | 4,8 |
| Germany | 83 | $ 52.776 | $ 50 | $ 142.788 | $ 11.039 | 2,3% | $ 5,9 | NR |
| Japan | 126 | $ 47.619 | $ 9 | $ 161.556 | $ 32.526 | 5,2% | $ 5,5 | NR |
| United States | 332 | $ 68.373 | $ 39 | $ 402.641 | $ 318.370 | 8,9% | $ 4,9 | NR |
| South Korea | 52 | $ 30.769 | $ 7 | $ 66.408 | $ 17.996 | 13,5% | $ 3,2 | NR |
| India | 1408 | $ 2.158 | $ 2 | $ 14.461 | $ 49.915 | 20,7% | $ 3,0 | 1 |
| Poland | 38 | $ 16.763 | $ 9 | $ 1.988 | $ 29.203 | 7,2% | $ 2,9 | NR |
| Spain | 47 | $ 29.787 | $ 28 | $ 39.463 | $ 33.973 | 2,1% | $ 2,8 | NR |
| France | 67 | $ 41.791 | $ 47 | $ 31.686 | $ 42.225 | 4,5% | $ 2,6 | NR |
| Vietnam | 97 | $ 2.779 | $ 3 | | $ 17.900 | 13,0% | $ 2,5 | 1,19 |
| Slovakia | 5,5 | $ 18.364 | $ 17 | $ 432 | $ 2.902 | 4,9% | $ 2,2 | NR |
| Mexico | 129 | $ 10.077 | $ 5 | $ 12.849 | $ 35.292 | 18,8% | $ 1,8 | 0,08 |
| Indonesia | 273 | $ 4.035 | $ 2 | $ 6.848 | $ 21.968 | 34,7% | $ 1,8 | 3,4 |
| Turkey | 84 | $ 11.310 | $ 5 | $ 4.713 | $ 12.806 | 5,9% | $ 1,8 | NR |
| Brazil | 214,1 | $ 6.542 | $ 8 | $ 25.242 | $ 85.121 | 8,2% | $ 1,6 | 0,22 |

*Table 4. Geographical Behaviour: elevant Characteristics by Country*

Above information can glance a simple outlook and an analysis can be made. Countries that produce natural rubber and have low labour costs in manufacturing are the ones with more tyre exportations, like China and Indonesia, exporting in 2022 18,9 USD Billions and 6,6 USD billions respectively. Also, the country with the highest FDI restriction index of 34,7% is Indonesia, which could explain the reason why even if there is a significant amount of natural rubber production (3.4K metric tons), and labour costs are of the lowest (around 2USD per hour), the exportation of tyres were 1,8 USD billions, making them one of the lowest among countries listed. Spain for instance, even if they have the lowest FDI restriction index, the labor cost is not very cheap in comparison to the countries and there is no natural rubber plantations in the territory. In this case, companies like Pirelli opt for a different way to participate and take advantage in that market of the natural rubber, disregarding full ownership on a subsidiary and instead approaching a joint venture with Astra Otoparts. (Pirelli, 2023)

Of course, a margin of error should be considered for this statements since there are more factors that should be considered, as the ones considered such as transportation costs, which would depend on the allocation of the sales of each company and is stated as confidential information.

# 5. FURTHER CONSIDERATIONS: DISTRIBUTION NETWORK AND WAREHOUSING

The last section proposes a model which would provide the insights of the main factors that affect the plant location decision. However, at the end, the network design depends entirely on each firm's objective, and one important aspect left out at the model is warehousing network. On a microlevel, there are way more factors to consider when designing a footprint because firms must really understand the focus of their sales. Which is the product, who is the customer, and what is going to be the strategy? The network design is not static, it changes as the market and demand changes, as the customers' preferences diverge, as new customers appear, as new strategies arise, etc., in this way, the decision comes first allocating product to order and then structuring the firms' footprint, which can also be dynamic.

Going back to Section 1, point 1.4.1 Distribution Network Breakdown. Creating a hypothesis, if a company wants to supply customer Porsche (Germany Car Manufacturer), with Original Equipment. The firm needs to balance if the homologation process for the tyre would be feasible, or if it is easier to just deliver the tyres directly from a plant located in Germany. Homologation process can be very stagnant and costly, therefore, this has to be evaluated when allocating OE orders, because if it is not justifiable, it is better to ship.

Another aspect to consider is that when a firm decides to manufacture in a country by a resource seeking reason, meaning cheaper costs of productions, materials and/or labor, the firm takes advantage of economies of scale, produces high volumes, and sell at lower prices. This kind of production will not only serve well for the local demand, but it's purpose is also for export demand. Transportation costs will be bearable since production is so cheap. Also, if the customer is a retail or distributor, they need to buy the tyres at the minimum possible price so they can make a good profit by reselling them, therefore, firms

usually focus on these customers by allocating production from cheap production plants in Romania, China, Turkey, etc. The key element here is the dealer and its requirements or preferences, and the objective of firms is to increase the dealer's loyalty through services.

The lead time the customer requires for the order is also a very important factor at the moment of allocating the tyres. If the firm has a recurring dealer in Milan that requires tyres to arrive within the same day they make the order, the fair solution is to have a hub, to have a sevice-third level warehouse anticipating the order, therefore, with inventory of the tyres the customer asks for. It is also recommended to embrace a Safety Stock for these cases. In this way, delivery can be made within hours.

### 5.1. Network Reengineering

Project Steps: the goal is to identify the number and the localization of plants and warehouses that can serve one market in order to minimize distribution costs (transportation costs, warehousing and handling costs, distribution) and maintaining the expected service level in terms of lead time in deliveries.

The objective function for all firms will be to minimize the primary distribution costs, which are the exportation costs from a plant in one country to a warehouse or customer in another country. As well, to minimize the secondary costs, which are from the warehouse until the customer, and lastly the warehousing costs which would involve handling and housing.

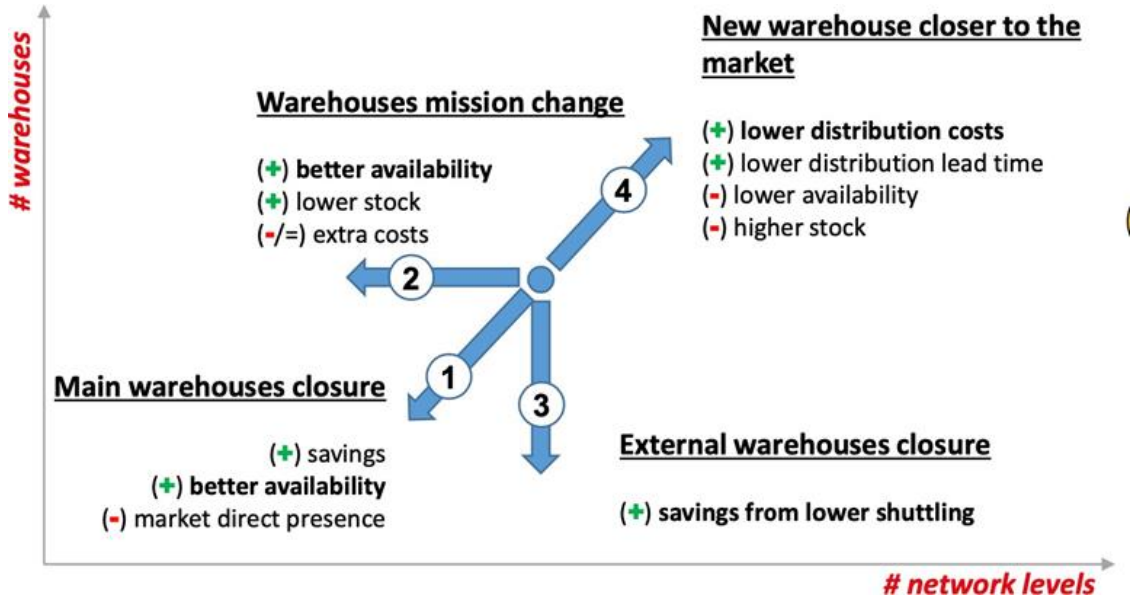


*Figure 12. Warehouses vs. Network Levels*

Increasing warehouses or plant numbers is not always the best solution. As figure 12 illustrates, the decision with its results can be approach by moving in the graph between number of warehouses versus network levels. When the firm decides to close a main warehouse, and therefore reduce the network level, the firm will incur in more savings, a better availability since products must be at hand, and market direct presence, meaning less local distribution. When, for instance, warehouses mission change, which could mean the network level for the warehouse changes, but the number of warehouses remain the same, then results could be again better availability, lower stock, and less or same costs. On the other hand, if external or services warehouses are closed, the level of network remains the same, and the result is savings from lower shuttling. Lastly, if the firm decides to create a new warehouse closer to the market, the firm would lower distribution costs in general, lower distribution lead time, it would increase availability and provide a higher stock.

For example, Pirelli has one big factory in Dieburg, Germany, which serves two customers, one in Germany and another one in Poland. Initially, they had two

second level warehouses, in Germany, and another one in Poland, which served for both big and small orders, also urgent and non-urgent orders. Then, noticing that the demands for the customer could be divided into big-non urgent orders and small-urgent orders, the second warehouse in Poland changed its function and became a Service Warehouse replenished from the Main Warehouse back in Germany which would serve for urgent and small orders. This is a strategy which increased product availability and reduced stock level, therefore, inventory costs. It is identifiable in Figure 12 as strategy 2 since the warehouse in Poland was not eliminated but instead converted to a Service Warehouse. (Pirelli Academy, 2023)

The design of a distribution network is dynamic. Some companies work with digital tools that can calculate the real time KPIs as the Barycenter, which is the center of gravity, according to the demand.

Below, some examples of how these new tools can provide an alternative solution to existing warehousing and plant location. In France, for example, for this X company, the platform Qlik provides all the necessary data for an analysis and reevaluation of the warehouse and/or plant location.

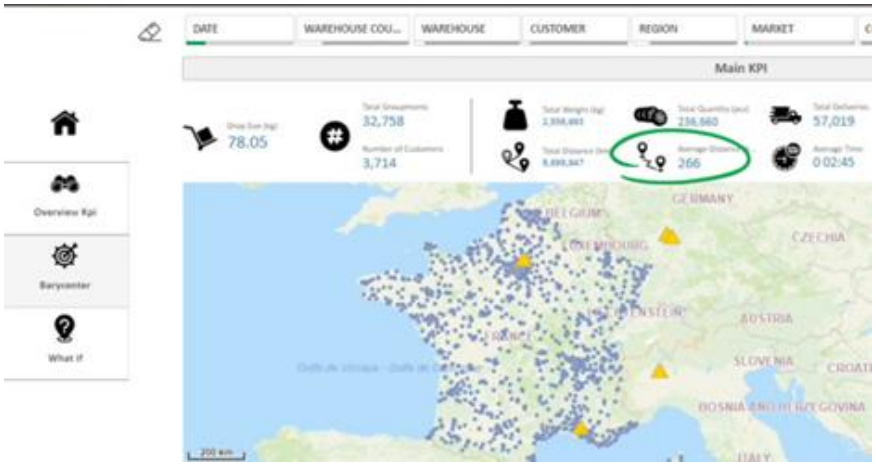


*Figure 13. Screen Print Digital Tool Qlik Company X – France*


*Figure 14. Screen Print Warehouse Suggested by Qlik for Company X - France*

## 6. FINAL CONSIDERATIONS

This comprehensive exploration of plant location strategies in the tyre industry illuminates the multifaceted dynamics of its present and future. From tracing historical data trajectory to analyzing the current competitive landscape, the study offers deep insights. However, to determine a general behavior or pattern on plant location decisions can be a challenging task as it was understood throughout this study, because the final said on plant location and network distribution lays on several critical factors.

Economies of scale emerge as a driving force for Efficiency Seekers, exemplified by major players such as Bridgestone and Pirelli. Large-scale manufacturing plants strategically positioned not only optimize production volumes by reducing production costs but also increase competitiveness on both local and global scales. Transportation costs as well play a pivotal role, as Efficiency Seekers like Continental and Hankook strategically position plants for proximity to markets, thereby minimizing fuel costs, and avoiding import/export duties, and ensuring overall cost-effectiveness. Mitigation of trade barriers takes center stage for the Efficiency Seekers, exemplified by Goodyear. Local production becomes the approach to comply with regional regulations, minimize administrative costs and maintain competitive pricing in foreign markets.

Per instance, Strategic Asset Seekers like Bridgestone and Michelin, leverage M&A's to strengthen their market presence, introducing operational synergies and diversifying their manufacturing network, which not only facilitates market entry but also enhances resilience in the supply chain in the face of uncertainties. On the other hand, Market Seekers like Pirelli, strategically position manufacturing facilities to access their target market, going for their "local for local" strategy to supply regional demand, ensure faster market response and a competitive edge. Resource Seekers such as Continental and Pirelli again, position their plants strategically where they can get an easy access to natural rubber plantations,

which not only improves the supply of raw materials but also aligns with an environmental sustainability goals.

The proposed economic model, rooted in the OLI framework, synthesized these critical determinants. It offers tyre companies a comprehensive point of view through which to assess and understand their plant location decisions. The dynamic nature of distribution networks and warehousing must also be acknowledged, since the interaction between factors such as product, customer and strategy needs continuous review and adaptation of the network design to meet with the changes in market demands. The model illustrated that internationalization in tyre manufacturing is not driven by a single factor but rather by a combination of elements, including proximity to raw materials, ownership structures, and regional economic clusters. The R code serves as a robust tool for future investigations and industry applications. Decision-makers in the tyre manufacturing sector can leverage the insights gained from this model to optimize their location decisions, considering factors that contribute to efficiency, cost-effectiveness, and collaboration within the industry.

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