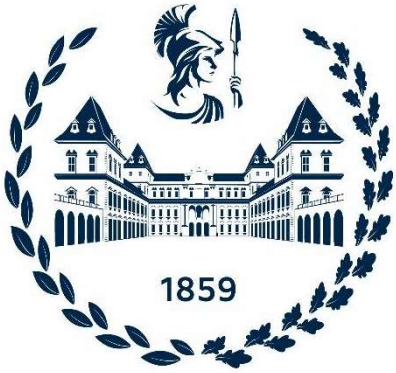
POLITECNICO DI TORINO

Master of Science in Automotive Engineering

MASTER'S DEGREE THESIS



Ciavarella Alessandro

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Master of Science in Automotive Engineering

Management of Industrial Processes

COVID-19 Impacts on the Automotive Industry: A Survey on Supply Chain Resilience

Supervisor:

Anna Corinna Cagliano

Candidate:

Alessandro Ciavarella

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INTRODUCTION

Supply chains are inherently vulnerable to disruptions that can jeopardize the normal course of operations. Some disruptions are predictable, thus companies can move beforehand in order to prevent and mitigate their effects, while some are unpredictable and enterprises can only hope diminishing the magnitude of their impact. The latter can have catastrophic consequences on the entirety of the supply chain, especially in case of one-of-a-kind events like the SARS-CoV-2 one. In these cases, the decision-making process regarding risk mitigation is harder with respect to the one adopted when dealing with foreseeable disruptive forces. As one of the most predominant industries worldwide, the automotive industry presents one of the most globally shattered example of supply chain, susceptible to a wide range of different events. The outbreak of the coronavirus pandemic at the beginning of 2019 profoundly impacted the automotive scenery, unfolding many vulnerabilities hidden in different geographic locations. In order to face the pandemic effects, the actors involved in the automotive supply chain had to renew their strategies, evaluating possible alternatives, and to build up their inherent levels of resilience. Supply chain resilience is, in fact, one of the most discussed topic the literature has to offer, thoroughly investigated as the main tool to shield against unforeseeable disruptive forces. Aim of the present study is to highlight the effects of the COVID-19 pandemic on the automotive industry, investigating enterprise-to-enterprise transparency enhancement, suppliers relocation and digitalization as the main processes through which increase a firm's level of resilience. By means of a survey, the author inquires Tier-1 and Tier-2 automotive suppliers about the virus' effects and their thought about the afore-mentioned processes. The thesis work is organized in 6 Chapters. In the first one the environment enveloping the automotive industry is described, with a major focus on its

supply chain. Followingly, in the second Chapter, the main disruptive forces affecting the afore-mentioned sector are explained, paying a particular attention to the effects due to the COVID-19 pandemic outbreak. In Chapter 3, the improvement of the automotive Supply Chain by means of an enhanced Supply Chain Resilience, achievable through Suppliers' Relocation, Enterprise-to-Enterprise Transparency and Digitalization, is investigated as the main path to undertake in order to recover from the virus doing and to regain the initial performance level. Chapters 4 and 5, focus on the purpose, the development and the characteristics of the administered survey, together with the analysis of the results retrieved and analyzed according to two different types of clustering. Lastly, in Chapter 6, conclusions will be drafted about emerged trends within the automotive supply chain regarding the modality by which boost their inner resilience. Thanks to the latter Chapter, the thesis work reveals how the actors involved along the supply chain of the automotive industry act in different fashions, on the basis of their size or the type of supplied product, and explains which are the most viable ways to increase the Supply Chain Resilience levels, highlighting the relative underlying reasons. Followingly, the study ends displaying the benefits it brings to the existing state of art, its limits and the possibilities for upcoming researches on the same matter.

1. THE GLOBAL SUPPLY CHAIN

In the present chapter, it will be introduced the scope of this master thesis, by characterizing the environment in which the automotive industry is currently working into. It has been chosen to first discuss about the features describing the Global Supply Chain (GSC), being that the automotive industry was one of the first truly global industries [1], and following to proceed by explaining, with a higher degree of detail, the automotive industry as a whole and its Supply Chain (SC), displaying for both their inherent characteristics. Such a preliminary introduction sets the boundaries of the study and allows to investigate about the effects of COVID-19 driven disruptions on the automotive supply chains, and subsequently it enables addressing, in the chapters to come, the identified methodologies of interest that can be adopted when recovering from the COVID-19 aftermath.

1.1. THE ORIGINS OF THE GLOBAL SUPPLY CHAIN

The term "global supply chains" refers to the cross-border organization of the activities required to produce goods or services and bring them to consumers through inputs and various phases of development, production and delivery [2]. This is the definition of the worldwide system that a business uses to produce products or services. The fostering of supply chains globalization was mainly due the developments in transportation

and communication technologies; such technological developments, in fact, enabled the reduction of both transportation and communication costs and the narrowing of distances between countries. As air transportation became popular, international corporations could well coordinate their worldwide operations in different regions. In short, for majority of the industries, a final product, which had been priorly produced at one production plant, was fragmented into different venues by increased specialization and standardized production stages shifted to low-wage countries, and specifically to China. Therefore, outsourcing activities of international corporations have progressed rapidly. In this process, international firms might either own their suppliers through foreign direct investment or form subcontracting relations through various nonequity modes, such as contract manufacturing and services outsourcing, licensing, franchising, and management contracts (UNCTAD, 2011: 132; Weiss, 2002: 147). Once highlighted the underlying reason pushing industries toward the globalization of their supply chains, it is then possible to characterize the Global Supply Chain also from a theoretical standpoint. As a matter of fact, a GSC can be defined as the crossroad of three different spaces: a technological-productive space, a strategic space, and a value-creation space [3].

The first one clusters together the different operations that take place along the whole chain and that are contributing in order to produce a final good or service.

The second, instead, refers to the space of the interactions between a firm, their suppliers, and their customers. Such space includes the links established between firms within their own GSC, often asymmetric, due the different bargaining power strategically exercisable by the players along the chain.

The third, and last one, is about the value-creation space created through the cooperation between firms. Large firms capture value produced by smaller ones along the chain and then reap the benefits of the value created by leveraging their relational power in contractual and non-contractual arrangements [3]. The complexity of such environment compelled companies to often become part of a collective entity, with several relationships, utilizing the available resources (Gadde et al., 2003), necessary when dealing with the global market and to harness all the most profitable conditions available [4]. Representing one of the world's largest industries by revenue, the automotive industry is surely a major example of a global network, branching worldwide and benefiting from most favorable conditions within itself.

1.2. THE AUTOMOTIVE INDUSTRY

The automotive industry represents an essential asset for the global economy and the resulting prosperity (Saberi, 2018). Its criticality is testified by the numerosity of the seemingly un-ending interconnections, running through a variety of layers shaping the global economic landscape, that characterize its complexity. The automotive industry has an important multiplier effect in the economy. It is important for upstream industries such as steel, chemicals, and textiles, as well as downstream industries such as ICT, repair, and mobility services, and all the other industries in-between the two ends of the spectrum. The automotive industry has 14,6 million people employed in Europe, accounting for 6,7%

of total employment in the European Union, 8 million in the US, and approximately 5 million in China, thus accounting for 7%, 3-3.5% and 10% of their Gross Domestic Product (GDP) respectively [5]. The European Economic Community (EEC) automotive industry accounts for around 4% of GDP, 18% of exports of goods, 14% of business R&D and employs almost 1 million people, making such industry a deeply integrated player in its Global Value Chains (GVCs). The implied wide knit of relationship, constituting the very fabric of the industry itself, develops, as previously mentioned, globally and involves a multitude of different players belonging to different countries. This characteristic feature, obviously inherent of each industry with a GSC, makes the environment vulnerable to broad spectrum of events, both positive and negative, that can impact a specific region within the overall network. It follows that a large part of the success of the participants in the automotive industry can only be ensured by structuring a profitable supply chain, able to extract value safely and at lower costs with respect to competitors, while withstanding potential disruptive forces.

1.3. THE AUTOMOTIVE SUPPLY CHAIN

Corporate's supply chains have to adapt to both business needs and external forces. The constant rise in competitive pressure in the automotive industry leads to outsourcing and a global sourcing of parts, which has created highly complex supply chain structures [6]. This has brought to a certain configuration of the automotive GSC according to

which numerous foreign Final Assembly Lines (FAL) of automotive companies are located all over the world. Multiple suppliers are shattered around the globe as well; their choice is, once again driven by opportunity cost, scale, unavailability of desired quality and quantity of raw materials and manpower skills in the domestic market and revolves around the concept of cost efficiency, pursued by finding the lowest cost of sourcing and by keeping minimum inventory. Such strategy allows to meet the demand, in terms of production capacity, to satisfy possible missing specific competencies (by tapping into foreign technological and skill capabilities), to adapt products to external markets and to harness favorable manufacturing circumstances (e.g., according to labor cost per hour benchmark analysis) [3].The current configuration of the automotive industry has begun to take shape at the beginning of 1990s, when big automotive companies began to shift not only production of particular parts and components, but also product design, stock control, and management responsibilities of diverse modular systems such as braking system, electronic components, seating system, and cooling system to their first-tier suppliers (Veloso and Kumar, 2002). In order to achieve economies of scale, the OEMs started seeking only specific products or systems from their suppliers; the condition under which the latter had to procure parts and component of that product/system became irrelevant. In this process, first-tier suppliers began to form their own production networks and decide on the quality and costs. The now referred to as mega-suppliers, namely first-tier suppliers, began to control majority of the supply chain with forward and backward linkages. To give a hint of the extensiveness of the network of relationships knitted within the automotive industry, according to supply chain specialist Michael Essig, German automobile producer Volkswagen alone has 5000 first-tier suppliers, and each supplier has nearly 250 sub suppliers, which

constitutes a total of 1,250,000 [7]. In such a production structure, it is very likely, for an international firm, to have an informal sub supplier, resident offshore; in the automotive landscape this generally translates in having one or more based in China. Global integration has advanced as firms have sought to leverage engineering effort across products sold in multiple end markets. And, as suppliers have taken on a larger role in design, they have established their own design centers close to those of their major customers to facilitate collaboration. On the production side, the dominant trend is regional integration, a pattern that has been intensifying since the mid-1980s for both political and technical reasons. In North America, South America, Europe, Southern Africa, and Asia, regional parts production tends to feed final assembly plants producing largely for regional markets. Political pressure for local production has driven automakers to set up final assembly plants in many of the major established market areas and in the largest emerging market countries, such as Brazil, India, and China. Increasingly, lead firms demand that their largest suppliers have a global presence as a precondition to be considered for a new part (Sturgeon and Florida, 2004). To sum up the complex economic geography of the automotive industry, it is possible to state that global integration has proceeded the farthest at the level of buyer-supplier relationships, especially between automakers and their largest suppliers. Production tends to be organized regionally or nationally, with bulky, heavy, and model-specific parts-production concentrated close to final assembly plants to assure timely delivery (for example, engines, transmission, seat sand other interior parts), and lighter, more generic parts produced at a distance to take advantage of scale economies and low labor costs (for example, tires, batteries, wire harnesses). Vehicle development, instead, is concentrated in a few design centers. As a result, local, national, and regional value chains in the

automotive industry are ‘nested’ within the global organizational structures and business relationships of the largest firms. Yet regional production has remained very durable in the automotive industry. Because lead firms in the automotive industry are few in number and very powerful, they have the strength to drive supplier co-location at the regional, national, and local levels for operational reasons, such as just-in-time production, design collaboration, and the support of globally produced vehicle platforms. But politics also motivates lead firms to locate production close to end markets, and this creates additional pressure for supplier co-location within regional-scale production systems. On a general basis the supply chain of the automotive industry is organized according to a multi-tier pyramidal structure (figure 1). The Original Equipment Manufacturer (OEM) designs, produces and brands the car and acts as the supply chain leader, coordinating and overseeing the remaining players. While this manufacturer produces some original equipment, its main focus is on designing cars, promoting cars, ordering from vendors, and assembling the vehicles. The first-tier supplier can take on a multitude of different roles, according to its business maturity (Doran, 2004); it can act as a quality buffer, enhancer of productivity, system developer, purchase, designer or also problem solver. Tier 1 suppliers are generally companies that supply parts or systems directly to OEMs. These suppliers usually work with a variety of car companies, but they’re often tightly coupled with one or two OEMs and have more of an arms-length relationship with other OEMs. Then, there are many firms supplying parts that wind up in cars, even though these firms themselves do not sell directly to OEMs, and that fall in the category of Tier 2 suppliers. They are often experts in their specific domain, but they also support a lot of non-automotive customers and so they don’t have the ability or desire to produce automotive-grade parts. Last, the third-tier suppliers provide the

raw materials. This tier includes both suppliers providing specifical raw material for the automotive industry and suppliers with a more diversified portfolio. OEMs, Tier 1, and Tier 2 companies all need raw materials, so the Tier 3s supply all levels.

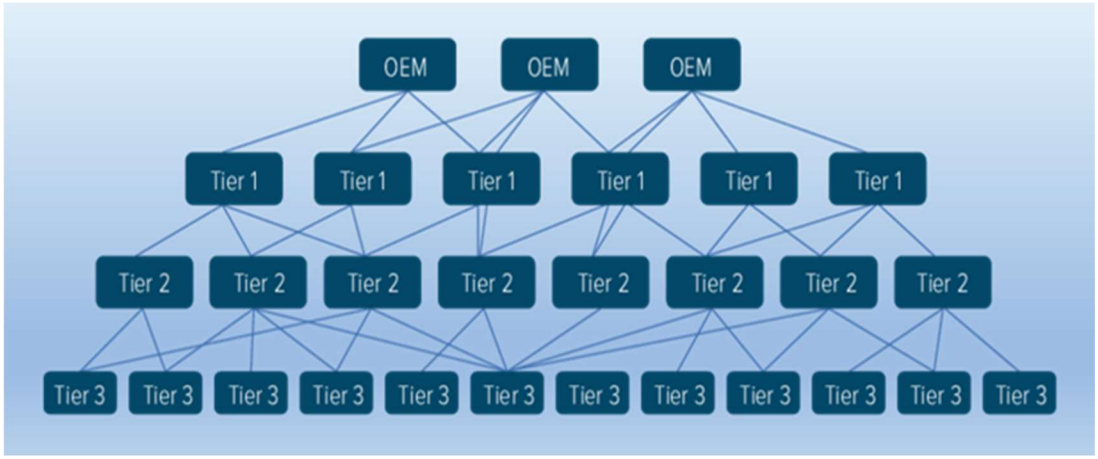

Figure 1: The automotive supply chain structure (adapted from Sheffi, 2015)

The high degree of fragmentation of the production process within such industry, clearly implies a large exposure to shocks that arise from multiple points in upstream activities and geographical areas and can create coordination problems. In order to prevent and/or defend against possible shocks switching sub-contractor does not suffice, it is in fact not only complicated but also extremely time consuming. The process needs identification and validation issues, in turn in need of extensive testing. In addition, many sub-contractors are highly specialized, reflecting the importance of relation-specific investments along the supply chains. In the EEC automotive sectors, less fragmentation and shortening of GVC could mean a greater use of local and European sub-contractors. However, this

would only materialize if shorter chains were at least as cost effective as existing arrangements. A recent Organisation for Economic Co-operation and Development (OECD) [7] empirical analysis finds that re-shoring would lead to more stability, but large efficiency losses in the automotive sector (Arriola et al., 2020).

1.4. THE ELECTRIC VEHICLES' SUPPLY CHAIN

While the classic automotive manufacturing supply chain places the OEM solidly at the top of a pyramidal scheme (Figure 2), followed by Tier 1, Tier 2 and Tier 3 suppliers respectively, the electrification supply chain resembles a conduit, more of a network than pyramid [9].

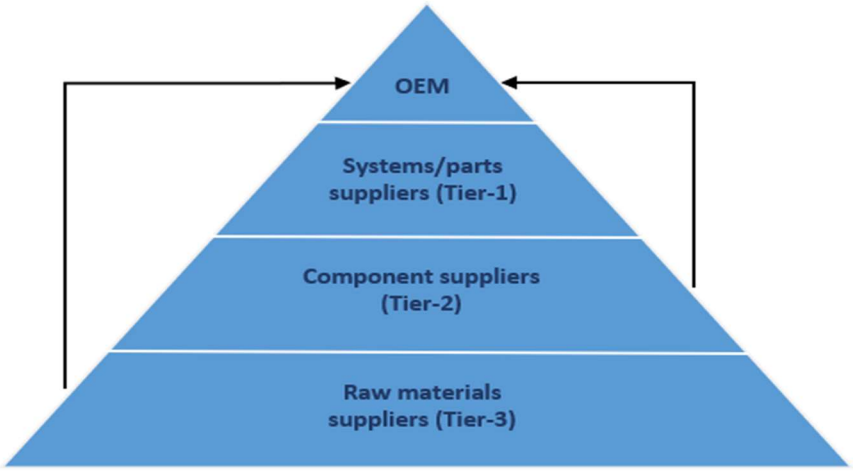

Figure 2: The automotive supply chain pyramidal structure

Electric cars require a multitude of different components, such as busbars, heat sinks, insulated-gate bipolar transistors, etc., then their counterparts. The need of diverse supply sources, with respect to the long-lasting traditional ones, compels all the automotive OEMs intended to join this parallel sector to challenge and, consequently, modify the basis of the chain itself. In fact, while the traditional automotive supply chain revolves around a mature system, whose structure was consolidated through years of efforts, the current supply chain for electric vehicles (EVs) is still in a not fully developed state, hence allowing the access to both new suppliers and competitors. However, although EVs do not yet have a fully developed global value chain (Masiero et al., 2017), such network's developing is bounded to move in a specific direction, due to some inherent characteristics common for all electric cars. As evidence of this, it suffices to consider that the main and most adopted batteries type is of lithium-ion type, whose ores are mainly mined in Australia, Argentina and Chile; cobalt, also needed for the development of batteries, is mined for 65% of its total volume in the Democratic Republic of Congo (DRC) alone [10]. The scarcity of some necessary raw materials, the technological expertise required to produce specifics modules and components, combined with the higher cost of the final product, make the EVs' supply chain development heading to the global type, with its typical drawbacks (e.g., strong dependence on specific countries and suppliers, with disruptions risk along the chain length). A typical EV supply chain usually consists of material suppliers, component suppliers, automakers, distributors and consumers (Kalaitzi et al., 2019). From a broader view, the energy (e.g., electricity and petroleum) suppliers and EV recyclers are also members of the EV industrial chain (Günther et al., 2015). Automakers as the original equipment manufacturers procure essential EV parts from the component suppliers and sell finished EV products to

distributors or directly to consumers. (Masiero et al., 2017). In addition to traditional vehicle parts (such as chassis, bodywork, interiors, etc.), EV component suppliers provide EV OEMs the core electric components (including power battery, electric motor, and electronic control). Cathode, anode, separator and electrolyte are the four key parts of power battery, which are usually made from lithium, cobalt, nickel, manganese, graphite and other materials provided by the upstream suppliers. Power battery, electric motor and electric control are the three core components of EVs, whose suppliers play significant roles in the overall supply chain. Other important players in the EV supply chain structure are the provider of raw materials coming from the mineral market. Lithium, for instance, present in the most advanced technology batteries, is a scarce ore and its mineral reserves are concentrated in a few countries, particularly in Latin America and China. For this reason, an increasingly strong tendency of companies is to seek alternative energy sources to operate these types of vehicles, thus potentially expanding the EV supply chain's borders.

2. DISRUPTIVE FORCES AFFECTING THE AUTOMOTIVE LANDSCAPE

During the last century, the automotive industry has woven a dense network of relationship enveloping an incredibly wide range of different realities. A fully developed vehicle represents, in fact, the final result of combined efforts coming from several separate fields. Electronics, mechanics and aerodynamics, to only cite the most evident ones, are all cooperating together in each and every launched vehicle. It is clear, then, that an industry with as many links and necessities such as the automotive one, results to be vulnerable to a wide variety of disruptive forces affecting the different fields of which such industry is made of. A global supply chain, as complex as the automotive one, is inherently vulnerable due the typical supply chain management practices usually adopted (Figure 3).

	Vulnerability causing factors			
Supply chain management practices	Increase in the number of exposure points	Increase in distance/time	Decrease in flexibility	Decrease in redundancy
Globalization	X	X		
Decentralization	X	X		
Outsourcing	X	X		
Sole sourcing			X	
JIT			X	X
Product/process complexity	X			
Litigation	X			

Figure 3: Supply chain management practices and vulnerability causing factors (Stecke and Kumar, 2009)

The past years, in particular, were characterized by many disruptive forces that seriously jeopardized the, at the time, current state of art, pushing the entire system toward new directions. All the actors involved in the

automotive sector were compelled to comply to the everyday more stringent regulations about vehicles' emissions and the parallel seemingly unstoppable raise of electric vehicles, to withstand economic crisis such as the 2008 one, and to perform a twofold internal/external assessment aimed at understanding their actual role and future prospects in a digitalized industry 4.0 (Reynaert, 2020; Lin et al., 2018; Pavlínek, 2012; Casper and Sundin, 2021), all in the midst of an ultra-competitive environment such as the automotive one. This industry, and consequently its supply chain, is still being challenged every day by such forces, pushing to a substantial re-shaping of the overall environment. The main players in this environment are asked to simultaneously tap into new technological fields of interest, to stay always competitive, and into their own core strengths, to be able to withstand and evolve under the pressure of the afore-mentioned forces. Among the latter, the COVID-19 pandemic represents the most recent challenge the industry has to face, providing unprecedented opportunities for transformation, growth and development [11]; thus, it was found of particular interest to solely focus on its effects and aftermath. In the light of the discussed topics, this chapter first provides a preliminary pandemic background, then proceeds by investigating its effects on the automotive industry and its supply chain, highlighting which were the inherent criticalities that allowed such disruptive force to compromise this sector all the way to its foundations. This chapter lays the groundwork for the recovery actions presented in Chapter 3.

2.1. COVID-19 OUTBREAK

In December 2019, the Coronavirus (SARS-CoV-2) and the disease COVID-19 first appeared in Wuhan, China [12]. By March 11th, 2020, the virus had spread across the globe to the extent that WHO declared COVID-19 as a pandemic [12]. As of today, over 410 million confirmed cases and nearly 6 million deaths have been reported [12]. In addition to the negative health effects, the pandemic has also led to a devastating social and economic downturn (Fonseca and Azevedo, 2020; Pato and Herczeg, 2020). Governments have been closing borders, banning travels inside and outside the individual country, and imposed lockdowns, in part or totally, in society to reduce the spread of the virus. Epidemic outbreaks are characterized by an unpredictable and long-term disruption that causes disruption in all parts of the supply chain as supply, demand, and logistics simultaneously (Ivanov, 2020). According to Ivanov and Dolgui (2020), the COVID-19 pandemic has been one of the most severe supply-chain disruptors in recent history and is likely to weaken many organizations and supply-chains globally. Governments worldwide have increasingly undertaken an inhibition strategy to contend the outbreak, relying on distancing, wearing masks, especially in public places and transport, along with various other measures in order to reverse the pandemic growth. Notably, these measures in turn have often resulted in stricter border restrictions and complete nationwide lockdowns, and in the process thereby, causing a negative short-term impact on consumer spending, investments, and disruptions to international trade and global supply chains (Kumar and Managi, 2020; Belhadi et al., 2021). The National Association of Manufacturers (NAM) conducted a survey on its 558 US member companies on the impact of the COVID-19 and found that more than 78 percent of its members expected a severe financial impact due to

the uncertainty caused by the pandemic on their businesses [13]. Another study by PwC reports that 87 percent of cross-industry companies both in Mexico and the US are very concerned about the disastrous impact of the pandemic [14]. Baldwin and Tomiura (2020) predict that the financial impact caused by COVID-19 on the manufacturing sector alone, would almost be threefold. They elaborate that the notable first is that the disease's concentration is primarily on the manufacturing heartland of the world (namely East Asia), therefore affecting other industrial powerhouses in the US and European Union (EU) due to direct and massive supply disruptions. Second, these immediate supply disruptions would cascade down to other manufacturing sectors in less-affected countries due to the supply-chain contagion effect. Third, the macroeconomic declines in aggregate demand, along with investment delays by companies, would undoubtedly generate demand disruptions (Ishida, 2020). One of the most significant supply chain disruptions caused by the COVID-19 pandemic was the one affecting manufacturing due to factory shut-downs (Baumgartner et al., 2020; Cahn 2020; Kumar et al., 2020; Queiroz et al., 2020). The disruptions started with the production and assembly halt for Chinese firms on January 25th, 2020, and February 3rd, 2020, in an attempt to contain the spread of the virus (Ivanov, 2020). Over January 2020 and February 2020 combined, industrial production in China was reduced by 13.5%, which was a higher drop than both the SARS outbreak of 2002/2003 and the financial crisis of 2008/2009 [15]. The effects of halting production and assembly are propagated through global supply chains in several ways. Firstly, European and North American industries that were highly reliant on supplies from China had to also halt production due to the component shortages that ensued from the production halt in the same country (Liuima 2020; Zhu et al., 2020). Due to long supply lead times by sea, the

effects were first felt by manufacturers in Europe and North America in mid-March 2020 [16]. The most often discussed effect on supply was drastic reductions in the availability of supplies, rendering firms unable to optimally balance supply and demand (Ivanov and Dolgui, 2020). Hassoun and Mawet (2020) highlighted that even critical activities faced significant supply disruptions due to production shutdowns at suppliers. Initially, the most affected supply chains were those that relied solely or heavily on inputs from China ([16]; Lin and Lanng, 2020; Zhu et al., 2020); it is estimated that 51,000 global companies have one or more tier-1 suppliers, and five million have one or more tier-2 suppliers in the Wuhan region [17]. However, the most impacted industry, and the one expected to withstand long-term effects, is the automotive industry due to its complex and multi-tiered supply chain, which relies on a huge number of independent global suppliers and just-in-time delivery practices (Baumgartner et al., 2020; Liuima, 2020; [18]. The epidemic outbreak in China and its subsequent spread towards the West has broken transportation links between suppliers, production facilities, and customers by reducing the availability of the different transportation modes even when suppliers were able to fill orders (Templeton, 2020). The shipping industry faced disruptions in all transportation sectors: sea, air, and road (Rojas, 2020). Sea/ocean freight was significantly disrupted by the closure of port operations in China on February 11th, 2020. According to the UN Conference on Trade and Development, China is home to seven out of the ten busiest container ports in the world [19], and Wuhan, the region most affected by the pandemic in China, is “home to the largest inland port in the country” [17]. Only in February 2020 did departures from Chinese ports decrease by 20% [16]. This caused shipping companies to increase blank sailings (Nodar, 2020; Rojas, 2020), thus skipping ports or entire strings of ports altogether. The reduction in ports’

operating hours caused delays for truckers in picking up and dropping of cargo (Rojas, 2020). The shutdown of production operations implied that companies stopped accepting deliveries from their suppliers, which increased the short-term storage of goods [20] and caused further congestion at ports (Rojas, 2020; Sharma et al., 2020; Templeton, 2020). Airfreight was significantly disrupted by restrictions on the movement of people across countries and the cancellation of passenger fights, which slashed the availability of belly cargo (Nodar, 2020; Rojas, 2020; Zhu et al., 2020). Border crossing restrictions and sanitary measures at borders also affect road transportation (Rojas, 2020). Together with restricted operations hours at ports, this caused significant delays in reaching customers (Rojas, 2020). All of these effects on the different transportation modes decreased freight volumes (Cahn 2020; Kumar et al., 2020; [21]), causing some smaller companies to go off the market and subsequently lowered overall capacity (Cahn, 2020; Chowdhury et al., 2020; Nodar, 2020; Rojas, 2020) and ultimately increased shipping costs (Cahn, 2020; Rojas, 2020). Reaching end consumers was impacted by the unexpected significant surge in online demand, which challenged businesses with insufficient inventory allocated to the online channel and caused severe shortages of last mile delivery capacity (Agrawal et al., 2020; Cahn, 2020; Ketchen and Craighead, 2020; [17]. The negative effect was compounded by virus containment measures, which implied new requirements for packaging and contactless last-mile delivery (Agrawal et al., 2020).

2.1.1. COVID-19 EFFECTS ON THE AUTOMOTIVE INDUSTRY

The effects on the COVID-19 proved to be a difficult challenge to most of the economic sectors, the automotive one makes no exception.

The automotive industry was still in the middle of recovering from the repetitive blows due global economic slowdown, rising taxes, US-China trade war, and strict environmental regulations; quarantined workforces, widespread shutdown of business, and disrupted supply chain ultimately concurred in worsening the situation.

At the outset of 2020, during what can be referred to as normal-course operations, bankruptcy likelihoods stood around 5% for the industry, generally on par with 2019 levels. As soon as COVID-19 began to spread globally in mid-March, probabilities of filings rose to near-2008 levels at 20%.

The profits and cash flow from automakers did decrease dramatically in connection with the spread of the pandemic (Chowdhury et al., 2021). This is supported by figures presented in MarketLine's (2020) report, e.g., Toyota's production volumes were cut in half, with a decrease by over 53% during the beginning of April and end of June 2020. Simultaneously, its revenues fell by 43% for the same period. This scenario is reflected from other automakers in the global automotive industry. Volkswagen saw a 32,5% drop in vehicle production, sales down by 30%, and revenue declined by over 23% during the first half of 2020 [22]. Other brands, such as Hyundai and General Motors, had similar figures for the first six months of 2020, with a 47% and 33,2% decline in revenues respectively for the companies [4]. The crisis led some of the top players in the automotive industry such as Tesla, Toyota, Hyundai, and Volkswagen AG had to cease their operations in their several production plants. This move

by leading manufacturers led to further downfall of the automotive industry.

At the same time, China, which is a prominent assembling hub, imposed lockdown in Hubei province leading to closure of production plants in the region. This then resulted to be the predominant cause of the supply chain disruption that followed. Moreover, China leads the automotive industry both in terms of production and consumption. Hence, the stringent lockdown led to the paucity of semi-finished automotive components.

For what concerns Europe, instead, new passenger vehicle registrations suffered throughout the first quarter of 2020, with a decrease of 39.7% compared to the same period of the previous year (the decrease was led by Spain (-50.9%), Portugal (-49.6%) and the UK (-48.5%), three of the countries hit hardest by COVID-19). Through the first half of 2020, none of the 27 countries showed new passenger vehicle registration growth over Q1 2019, with the majority experiencing declines greater than 30% [23]. In particular, to provide some examples, in April 2020 sales of new cars in Russia fell by 72.4% compared to the previous year, in Germany fell by 61%, the lowest monthly level since unification in 1990, while in the Czech Republic, the drop was about 53%.

Outside Europe, but affected by the same environment, there is also Britain, whose sales of new passenger cars fell by about 97% (Kufelová and Raková, 2020).

The European landscape was also impacted by the U.S. administration which threatened to levy tariffs on EU auto imports if a new trade deal cannot be reached [24]. For what concerns 2021 instead, the data referring to October of the same year shown that new passenger car registrations in the European Union contracted further (-30.3%), marking the fourth consecutive month of decline. With 665,001 units sold across the region, this was the weakest result in volume terms for a month of October since

records began. Most EU markets suffered double-digit losses, for instance: Italy (-35.7%), Germany (-34.9%), France (-30.7%), Spain (-20.5%), Poland (-19,8%), Belgium (-35,3%), Portugal (-22,7%) etc. . Over the first 10 months of 2021, new car registrations in the EU were up 2.2% compared to one year earlier, totaling around 8.2 million units. Despite the recent drop in sales due to the ongoing impact of the semiconductor supply crisis, substantial gains earlier in the year helped to keep cumulative volumes in positive territory. Likewise, demand remained positive in three out of the four key EU markets: Italy (+12.7%), Spain (+5.6%) and France (+3.1%). By contrast, Germany's year-to-date performance has worsened compared to one year ago (-5.2%).

Globally, the repercussions of the COVID-19 crisis are immense and unprecedented, leading major automobile companies to adopt cutting jobs policies to withstand the huge drop in sales: Aston Martin Lagonda Global Holdings Plc for instance, announced the downsizing of its workforce by 20% [25]. The pandemic, however, has accelerated the transformation process the automotive industry had begun several years ago. In order to address such unprecedent challenges OEMs are willing to cooperate with partners—automotive and otherwise—to reshape their foundations and not lag behind in the new normal.

2.1.2. COVID-19 EFFECTS ON THE AUTOMOTIVE SUPPLY CHAIN

In contrast to other natural or manmade disasters or infectious pandemics, COVID-19 not only disrupted the local supply chains, but it profoundly affected GSCs at all stages, from the supply sources to the final customers. COVID-19 has shown that businesses are interconnected through complex networks of GSCs in which the actors at the upstream of a supply chain are seriously affected by the almost "erratic" behavior of downstream actors, essentially large companies, who experience disruptions and very sharp variations in demand [26]. A GSC is a multitier system with numerous lower-tier suppliers who are critically important to the overall supply system. For instance, an automobile firm has more than 900 tier-1 suppliers, each having an average of over 500 tier-2 suppliers (Burns and Marx, 2014). According to the literature, only very few firms managed to keep track of their suppliers at the tier-2 or more levels. These extended networks reduce the GSCs' visibility and favor slow responses to unexpected damage (Hofstetter, 2018). The automotive supply chain, as a result of the combined effect of the COVID-19 pandemic and the related Governmental preventive actions, was put under a severe pressure. The potential risks of a global pandemic were well recognized in the literature since nearly 20 years ago (Tauxe, 2002), given the globalization and the resultant convergence of several production and consumption activities, fostering networking, and close contact among people across countries and continents. The appearance of SARS-CoV in 2002 rang an alarm of the threat to human health as well as the economic dangers of a global pandemic. These risks have increased exponentially, with advancements in transportation and communication technologies that have shortened transportation lead times, increased the amount of freight, and helped in

organizing production on a global scale, leading to even greater global networking and close human contact. The Chinese economy, which has become a global production base, bore the initial brunt of the pandemic. Global economic crises soon followed, with a domino effect. Following plant closures, Chinese industrial production decreased 13.5% in the first two months as compared with the same period in 2019 [27]. Due to global production sharing, this supply shock started a domino effect by disrupting production activities of hundreds of thousands of firms in various countries having suppliers in China. As a result, pandemic-driven economic crises began to severely deepen across the globe. Automotive producers globally were forced into a halt due to supply chain disruptions, reduced demand, and precautionary actions from the companies to protect their workforce [19]. Sources of supply chain disruptions were, for instance, the significant increases in transport prices for air-, train- and sea transports caused by the decrease in transportation capacity, further aggravating the situation the industry was in. Indeed, the consequent lack of transport modes jeopardized the delivery of various stocks (to customers, partners, etc.). Of particular importance was the choice of many airlines to suspend flights to and from China, a central manufacturing hub globally and for the automotive sector in particular. Such event, combined with the strict control exerted over travels within the country and the imposed the traffic limitations made it difficult to access ports and, ultimately, customers. Maritime transport was also severely impacted. The majority of containers, which carried critical automotive parts, were no longer shipped to Europe, mainly due to a sharp drop in demand following the shutdown of factories and assembly lines. Container carriers and producers have thus reduced their fleets on trade routes by 30%. As for the rest of the containers, they were sent to the United States where activities related to automotive production continued

with the same dynamism in accordance with the “America First” policy of the former US President Donald Trump. This situation quickly led to a shortage of containers in Europe as soon as demand gradually started to pick up. At the same time, European carmakers had to deal with an unprecedented rise in the price of maritime transport, which has increased eightfold, with demand being much greater than supply [28]. This ultimately led to a shortage of materials and components among all the manufacturers, as prices skyrocketed by several multiples, and available transport capacity was prioritized for food and medicine transports (Pato and Herczeg, 2020).The shattering of the supply chain in several points simultaneously, forced many among the major firm within the automotive landscape to implement drastic measures. For instance:

- Ford, GM and FCA suspended manufacturing in parts of the US and repurposed for production of COVID-19 medical devices.
- Nissan suspended the production in the UK because of supply chain disruption and demand reduction.
- Daimler suspended European production as supply lines are disrupted.
- Toyota halted production in Europe because of government restrictions on the movement of people, supply chain disruptions, and falling sales.
- BMW closed both its European plants and its factory in South Africa, to cope with lower demand.
- Honda closed four US vehicle plants due to anticipated decline in the market.
- Toyota Europe shattered plans across the continent.
- Renault closed plants in Slovenia, Morocco, and Romania and 12 production sites in France.
- Volkswagen suspended the production. [28]

Beginning with SARS-CoV in 2002 and evolving dramatically with COVID-19, epidemics have clearly displayed the fragile nature of GSCs, such as the traditional automotive one, and validated the expansion of global supply strategies. As previously mentioned, the underlying driving force behind a global supply chain is complying with specific production methods such as flexible and lean production, and just-in-time stock control. However, several operational risks emerge with the process of externalization of a production stage to a subcontractor without direct control of international firms. Stock management and supply risks, legal and contractual risks, institutional risks, and financial risks play a crucial role in the decision of externalization. The spread of the disease highlighted in particular how critical the dependence on a specific country was. The sudden closure of production sites in China (the city of Wuhan alone concentrates 9% of the Chinese automotive production) caused a domino effect which resulted in disruptions impacting Europe, United States, India, and South America simultaneously. Before COVID-19, having offshored their manufacturing activities to low-cost countries [29] most of the world's major automotive manufacturers were sourcing 30%–60% of their components, including modules and subassemblies, from China [13] [30]. The pandemic as clearly shown that a supply chain so deeply revolving on sites far outside of the domestic market, cannot withstand such dire circumstances. Now, many automakers and suppliers are scrambling to create a centralized management system at a single location in the supply chain. Given the sheer number of components required and the different lead times for each, the return to a centralized supply chain management system at a single location is a very complex and important challenge. OEMs, component manufacturers, and automotive subsystem manufacturers are trying to establish an alternative,

flexible, and adaptable model for a supply chain considering sourcing, assembly, and delivery from within the borders of the region's strategically centralized management system, with the possibility of establishing regional logistics hubs [31]. The ongoing COVID-19 pandemic has compelled all firms to reevaluate their supply chain strategies. In this respect, it is possible to enhance supply resilience against pandemics using innovations, such as smart manufacturing technologies, Industry 4.0, internet of things, and radiofrequency identification sensor technologies. First mover firms will be those who will deal intensively with supply and demand uncertainties in their day-to-day activities and try to find solutions.

2.1.3. COVID-19 EFFECTS ON ELECRTIC VEHCILES' SUPPLY CHAIN

Inevitably, also the EV automobile industry has suffered greatly from COVID-19, with production lines halted, supply chains disrupted, and consumer demand contracted (Ivanov, 2020). The strong dependency from the Chinese's manufacturing industry proved to be critical for the EV supply chain, as well as it did for the traditional vehicles one. After the relief of the lockdown, even though China's domestic production of components including electric motor has recovered rapidly, the production recovery of special EV components such as power battery lagged behind. The cause is to be found not only in the supply pressure from the lack of

upstream raw materials (e.g., cobalt and nickel), but also due to the demand contraction in downstream markets caused by the pandemic itself. Lithium, cobalt, nickel, and manganese ores are the four types of key mineral resources for lithium-ion battery production that highly depending on imports in China. Despite China suffering nor lithium nor manganese supply shortage, due to the surplus inventory and timely replenishment from diverse sources (Kaunda RB, 2020), the supply of cobalt and nickel had been hit tremendously. To cope with the potential shortage of some of the upstream mineral materials and some high value-added components (e.g., separators and IGBTs), many Chinese producers were driven to develop substitutes for non-domestic materials and to improve technologies for high-end component production. The likelihood of having scarce resources affected not only the supply side, in fact several EV producers including BYD and Tesla decided to pursue new directions, for instance by exploring the possibility of cobalt- and nickel-free batteries [32]. In the meantime, the production of EV OEMs has been inevitably disrupted due to the lockdown policy for preventing pandemic diffusion, especially in the badly hit areas. The global pandemic has stopped firms from building factories overseas, pushing them back to the fierce competition of domestic market. These boundary conditions made EV OEMs paying more attention to large car models, embedded with inner-car air purifiers, air circulation systems and air quality monitors, as they are earning growing attentions after the pandemic and particular focus is given to developing differentiated products targeting different consumer groups. In addition, direct selling and online selling models would be further developed and applied, potentially forming integrated online EV trading platforms. From an integral perspective the EV industry, the increasing competition caused by the economic effects of COVID-19 combined with the harsh environment has shrunk the market in the hand

of the main EV OEMs and upstream component producers. In the long term, domestic EV component R&D and material exploitations will be strengthened for constructing a more reliable and flexible EV supply chain (Wen et al., 2021). In light of this, it results interesting how the pressure from COVID-19 may help to accelerate technological improvement through the EV supply chain. As a matter of fact, even though the supply of certain special EV material and component was worse interrupted than the traditional vehicle parts and that the downstream EV market was more affected by the pandemic than Internal Combustion Engine Vehicles (ICEVs), the growth rate of EV production has been far higher than ICEV in the second half of 2020.

3. WHAT TO DO NEXT IN THE AUTOMOTIVE INDUSTRY

In the present chapter the criticalities arisen due to COVID-19 outbreak will be addressed by presenting the different main paths at disposal to undertake in order to both recover and prevent COVID-19 related disruptions. It was chosen to specifically focus on OEMs first, as they always represent the tip of the automotive supply chain (Jacobides et al., 2016), hence they exert major pressures on the remaining players along the chain, and, subsequently, on the Tier1 suppliers, identified as the main actors on which centering our study.

3.1. HOW TO DEAL WITH COVID-19 DISRUPTIONS

The advent of COVID-19 seriously compromised the automotive industry, now in the midst of facing the numerous disruptions affecting all the functions working within its frame. The limited supply of vehicle parts, the shutdown of manufacturing facilities, the decline of working capital/liquidity and the drop in new vehicle sales, are all examples of pandemic consequences that are in need to be addressed properly in order to ensure a positive new normal [5]. Moreover, while withstanding the impact of the pandemic, OEMs were compelled to comply to the everyday more stringent low carbon emission targets, even amid crisis. As automakers have created global networks to leverage low-cost labor,

while on parallel, striving for zero inventory to minimize working capital, the risks related to their supply chain has been compounded. The strong dependency of the global auto production on China has shown its drawbacks as soon as the of the bullwhip effect began to spread. Supply storage in fact hit all the assembly lines in NA and Europe, other than, obviously, in Asia. The historical over-reliance on cost efficiency when designing supply chains, resulted fallacious when assessing the risks brought by globalization. The dependance on Chinese suppliers and the lack of flexibility of the supply chains in the automotive industry are consequences of the prioritization of cost efficiency over other features. The quest for cost-efficiency motivated companies to pursue strategies such as lean manufacturing, offshoring, and outsourcing [16] which during the pandemic resulted in the inability to continue operations due to the different shocks in manufacturing, supply, and logistics. Therefore, the coronavirus crisis taught supply chain managers that the cost-optimality of supply chains has to be balanced with preparedness, responsiveness, and resilience ([33]; Garner, 2020; [16]); Zhu et al., 2020). The resulting configuration of the automotive industry, shaped by the necessity to comply to all the demands related to the cost-efficiency policy, and its supply chain certainly managed to harness all the most favorable conditions for what concerns cost-efficiency, enabling economies of scale, but failed to be resilient enough to withstand unprecedent forces. The pandemic outbreak, a surely not foreseeable event, highlighted the complete lack of risk management strategies, able to mitigate possible disruptive forces, for some firms and the lack of depth of such strategies for others when such strategies were already being implemented. The literature identifies building Supply Chain Resilience (SCRes) as the most optimal mean of facing supply chain challenges.

3.1.1. BUILDING SUPPLY CHAIN RESILIENCE

Building SCRes to COVID-19 has already attracted a great deal of attention from scholars today (Kumar and Managi, 2020; Ivanov and Dolgui, 2020). Several researchers and practitioners have been calling for an enhanced supply chain management, capable of dealing with the severe disruptions caused by the raging pandemic (Jacobsen, 2020). Supply Chain Resilience refers to the supply chains' ability to prevent and absorb changes and regain the initial performance level after an unexpected disturbance (Hendry et al., 2019), and, as a strategic tool, it can be used both proactively and reactively. Proactive strategies are primarily technology-driven strategies that rely on developing technical infrastructures, such as digital connectivity and supply chain automation to avoid future disruptions (Ralston and Blackhurst, 2020; Tan et al., 2019; Hofmann et al., 2019). Iakovou et al. (2014) highlighted localization and regionalization of sourcing, while Zhu et al. (2017) talked about integrated approaches for supply chain risk management. Other authors have proposed social-related strategies with social supply chain focus (Iakovou et al., 2014) and human capabilities (Blackhurst et al., 2005). Reactive strategies mainly rely on a real-time information system and are based on data-driven decision-making (Kamble and Gunasekaran, 2020; Belhadi et al., 2019; Belhadi et al., 2018), creating virtual marketplaces (Sharifi et al., 2006) and using supply chain simulation (Hofmann et al., 2019). Again, according to Belhadi et al. (2021), the overall manufacturing industry's level of SCRes would depend on how they have digitalized their supply chain operations, while, in turn, the firm ability to select an appropriate strategy will depend on the SCRes level. The theoretical background suggests that the automobile industry perceived that the best strategies to mitigate COVID-19 risks were to develop

localized supply sources and use advanced industry 4.0 technologies (Belhadi et al., 2021). In addition to suppliers' re-localization and to the use of digital technologies, embracing an Enterprise-to-Enterprise (E2E) transparency philosophy was also found as a viable path when dealing with disruptions prevention and recovery.

BUILDING E2E TRANSPARENCY

The concept of SCRes is deep, it envelops and cluster together all the possibly implementable strategies within itself and, thus, embrace a broad spectrum of practical actions, representing the actuation of the afore-mentioned strategies. Within the boundaries containing such spectrum, the research found particularly interesting, as well as of primary importance, when dealing with supply chain disruptions the pursue of E2E transparency. Transparency can be defined as the extent to which all supply chain stakeholders share a common understanding of, and have common access to, product-related information that they request, without loss, noise, delay and distortion (Trienekens et al., 2012). The lack of visibility, especially beyond tier1 suppliers, proved to be critical for the automotive supply chain. In fact, the disruption in Asia was difficult to assess and manage due to the lack of transparency over indirect suppliers that might be located in Asia [16]. Visibility and collaboration are key when preparing and responding to disruptive forces, as a joint effort enables to monitor disruptions more precisely, to develop warning indicators and overall to build more robust systems. Belhadi et al. (2021) note that goals and information sharing among supply chain members can

contribute to powerful coordinated strategies, which, in turn, foster faster recovery. This, however, requires that supply chains overcome their current transactional type of engagement and move towards aligning, building trust and sharing both losses and gains ([34]; Chowdhury et al., 2020; De Sousa Jabbour et al., 2020; Sharma et al., 2020a). As of today, many companies are beginning to recognize that rebuilding supply networks around the core principles of efficiency and resiliency is not only possible, but overdue and important to remaining viable in a transforming global automotive sector. Traditionally, it has been very difficult to create a line of sight through an entire automotive supply chain for a variety of reasons, including a lack of trust and communication between stakeholders, reliance on poor volume forecasts and outmoded data management systems. The result is an unknown number of potentially disastrous threat vectors that remain buried until it's too late to avoid them. This lack of visibility is also insufficient to uncover structural bottlenecks that exist at sub-tier levels of supply. For example, the global semiconductor supply chain is governed by a consolidated and cost-effective but ultimately brittle "diamond-shaped" structure where global vehicle manufacturers are wholly dependent on a larger number of Tier 1 component integrators who are, in turn, supplied by a small number of global semiconductor providers who rely on a handful of Tier 3 wafer manufacturers. In addition, most OEMs have not yet adopted systems or processes to enable a real-time exchange of information with their suppliers. Hence, large fluctuations in production planning volumes happen at sub-tier levels in response to even small shifts in customer demand. This is typically known as a "bullwhip effect" where delayed communication between stakeholders at each tier in the supply chain are often amplified by judgements placed on the demand signals received. Multi-tier supply-chain mapping can bring transparency to each supplier

tier within an integrated network. If OEMs are able to successfully map sub-tier relationships, they are better able to identify issues and work with affected stakeholders proactively. Some OEMs are sharing both short- and long-term forecasts with suppliers to help them model their capacity and identify constraints early. More importantly, they are trying to ensure that the entire supply chain for a given set of commodities is operating off the same synchronized demand signals. In return, they get visibility into critical operational metrics such as cycle times, shifts, capacities and lead times. The intent is to try and stabilize any demand variability and better manage supply requirements. However, the concept of supply chain transparency extends beyond the dyadic OEM-tier1 supplier relationships, enveloping also sub-suppliers and providers of raw materials. Developing SC transparency enables all the players along the chain, especially the upstream ones, to have a better and, at the same time, deeper understanding of the overall structure of the chain itself. As a matter of fact, a project study about increasing transparency in the cobalt supply chain shown that the investigated tier1 supplier of a chosen OEM, provided the latter with a SC mapping considering only about 22% of the actual actors, thus neglecting a huge part of them due lack of visibility (Fraser et al., 2020). Conscious of this only partial understanding of the extensiveness of their SCs, OEMs are already pressuring their Tier 1 suppliers to provide more information regarding their sub-suppliers, sourcing locations and even pricing information [35]. However, although the general trend is to enhance SC visibility, being that obtaining this level of detail about suppliers' operations may be useful for navigating future issues and mitigating supply chain disruptions, automotive suppliers will still be reluctant about providing certain pricing and cost details that might allow a competitor OEM unwelcome insight into a supplier's pricing model or even present antitrust issues in the automotive industry.

SUPPLIERS' RE-LOCALIZATION

Together with the just discussed transparency, SCRes revolves around ensuring business continuity, hence diversifying supply chains from a geographic perspective to limit risks from any country or region where possible, securing multi-sourced key commodities to reduce reliance on individual suppliers, and implementing inventory systems to mitigate against supply chain disruption. Between the several measures that can be taken to reduce the risks surrounding the automotive supply chain, in this pandemic aftermath, it is quite evident that priority should be given to an appropriate relocation of the supply sources and the manufacturing of automotive parts to the same geographic area with the final client (carmaker). This will allow automotive actors to have more real-time visibility along the entire supply chain; in particular, some production sites could be also partially, or even entirely, moved from Asia to Eastern Europe for instance. In literature, multiple sourcing is referred to as mean to increase supply chain flexibility, allowing the latter to be shielded against the vulnerabilities arising from the reliance on foreign suppliers. However, the concept of flexibility itself is more complex, clustering within the border of its definition also the idea of manufacturing flexibility, meant as manufacturing layout and process flexibility, and employees flexibility, namely the ability to adjust their own work. In the upcoming future, as manufacturing intensity increases, fueled by innovation, technology and consumer demand, vehicle manufacturers will want more than ever to see their Tier 1 suppliers operating locally. Ideally, automobile companies want their suppliers to operate in every jurisdiction in which they have a manufacturing presence. In this situation, with a particularly thin market, rather than utilizing a decentralized management with a structure that is unevenly distributed among specific countries (i.e., China), it only makes sense to shift to a centralized management model

that takes advantage of the inherent strength of a closed-integral setup, with greater proximity to the producing countries as much as possible. In fact, the traditional automobile production feature of revolving around "meta national" companies, in order to secure global superiority by developing global operations and effectively utilizing the management knowledge accumulated in countries around the world (K. Ichijo and F. Kohlbacher, 2007), has eventually become a hindrance when dealing with unforeseeable disruptive forces, like the pandemic one. However, it is important to understand that the solution has to be found in a correctly balanced distribution between off- and near-shored suppliers, being that the cost efficiency granted by the offshore manufacturing sites is still far from being matched by the solutions the domestic environment has to offer. In the years to come, the automotive industry will have to focus on building flexible and resilient supply chains that allow a rapid reorienting when responding to severe disruptions.

BECOMING DIGITAL

The transformation should be driven through the digitization of supply chains, mapping supply networks, rethinking supply chain strategy (such as multisourcing vs monosourcing; nearshoring vs offshoring), stress-testing critical supply chain partners, and boosting sustainability. Investment in digital solutions, in particular, emerged as the most often discussed long-term strategy for protecting the supply chain from large-

scale pandemic-caused disruptions and not only. Digitization will bring significant improvements to the value chain by boosting efficiencies, reducing costs, and generating greater collaboration and innovation. It will make it possible to evolve from business-to-business approaches through their dealerships to a business-to-consumer model, with new ways of engaging with customers and partnerships with suppliers interacting through data. Several technologies can, in fact, be proposed as part of the resilience-driven solutions to the future operation of global supply chains. IoT-enabled production lines can increase production capacity (Agrawal et al., 2020; Kumar et al., 2020), while IoT-enabled delivery can optimize logistics processes by anticipating bottlenecks, accelerating gate-in and gate out processes, and optimizing inventory (De Sousa Jabbour et al., 2020; Johnson, 2020; Sharma et al., 2020). Together with artificial intelligence and machine learning, they can also assist in quickly finding alternative suppliers in case of disruption (Lin and Lanng, 2020; Zhu et al., 2020). Process and physical automation (robotics, Robotics Process Automation (RPA), automated guided vehicles) can supplement or replace labor capacity in manufacturing and delivery, improve monitoring, and increase efficiency (Agrawal et al., 2020; Chowdhury et al., 2020; [33]; De Sousa Jabbour et al., 2020; [36]; Ivanov and Das, 2020; Liuima, 2020; [37]; [21]). Three-dimensional printing can increase manufacturing flexibility by enabling the in-house production of complex, low-volume spare parts and customized products (Liuima, 2020) which will reduce transportation costs by enabling production closer to the customer, as well as reducing dependency on suppliers [37]. Augmented reality can enable remote assistance in equipment installation and maintenance, replacing the need for travel (Agrawal et al., 2020; De Sousa Jabbour et al., 2020). A successful digitalization of the supply chain may to not only improve operational efficiency but also to increase traceability and transparency in

operations. This supply chain transformation is strictly related to certain technologies, particularly relevant in the path toward a full digital conversion:

I. *Internet of Things (IoT)* allows objects to communicate their physical context information, making them aware of their surroundings and enabling a more productive internal flow of sub-products and resources.

II. *Cloud computing* enables convenient, on-demand access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort (Mell and Grance, 2011), potentially providing applications for customers, suppliers, sales organizations and internal operations.

III. *Big Data Analytics (BDA)* investigate critical business data, allowing enterprises to better understand their business and market and make timely business decisions (Chen et al., 2012) (e.g., by collecting and analyzing cycle times of assembly stations to derive process optimization possibilities, leading to optimized workflows for logistics and assembly operators).

IV. A *Blockchain* is a ledger that records transactions between two parties in a verifiable and permanent way, across a supply chain manifold it can boost logistics process efficiency and data transparency (Kückelhaus and Chung, 2018).

V. *Robotics* involves machines capable of automatically carrying out a complex series of movements, providing the possibility to implement a largely automated material flow. This technological improvement may, for instance, streamline procedures about order preparation, which typically represents half of the storage and handling costs (van Marwyk, 2016).

VI. *Automated Guided Vehicles (AGVs)* are fixed area means of conveyance with their own drive, mainly used to tow and/or carry raw materials inside plants and warehouses. Their application increases picking speed and efficiency, reduces aisles space between shelves and automate regularly scheduled pick up tours to ensure a constant material supply.

A supply chain characterized by the adoption of the afore-mentioned solutions can greatly enhance the information exchange of critical businesses, making it a completely automated procedure, shorten material lead time and improve the inventory planning, enabling just-in-time delivery schedules. All the changes currently taking place in the automotive-supplier industry, have increased business uncertainties and turned decision making that used to be straightforward into a much more complicated process. From new lighting technologies to breakthrough powertrain solutions, suppliers not only have to withstand the pandemic aftermath but they also have to manage the frontlines in an attempt to find superior solutions for their OEM customers, exerting pressures due their prominent bargaining power. At the same time, they are also responsible for roughly 70 percent of the industry's costs, placing them front and center in the continuing effort to boost productivity, hence they are the first actors along the chain suffering from cost-cutting policies. According to McKinsey [38], a successful digital transformation of the supply chain should revolve around six core areas, where all six are interdependent. The first step in the transformation process is identified as developing a suitable digital strategy. The latter can be defined as suitable only if it accounts for new ways value can be created with digital technology, without neglecting neither external nor internal opportunities. On the external side, any new digital strategy must contend with a series of disruptions generally characterized with the acronym ACES: autonomy,

connectivity, electrification, and shared mobility. These changes mean suppliers have to think about a wide range of potential new approaches for engaging with customers. Most suppliers have traditionally sold only on a B2B basis to OEMs, but now can consider how they might interact directly with end users. But regardless of the customer being targeted, any external digital strategy has to be anchored on delivering a superior experience. Internally, the primary sources of value reside in the cost-intensive areas of procurement and manufacturing. Internal strategy should focus on how digital technology can optimize underlying business processes. For example, this might mean a supplier applying advanced analytics to identify sources of manufacturing defects or digitizing the ordering process for OEM customers. Given the myriad disruptions in the automotive industry, success today requires an ability to collaborate in new ways with former competitors from the auto sector and new digital players, in order to both tap into all the newest technological "hot-spot", arising in this transforming scenario, and to find the most optimal balance between the different strategies available (Table 1), able to enhance their inner degree of resilience.

STRATEGY	STRATEGY OUTLINE
TRANSPARENCY	*E2E transparency along the whole supply chain enables a deeper understanding of all the product-related informations, a more coordinated implementation of strategies and a lower likelyhood of structural bottlenecks at sub-tier level. Needs to overcome the traditional lack of trust between stakeholders*
RE-LOCATION	*Re-locating suppliers in order to diversify a supply chain from a geographic perspective, secures key commodities multi-sourcing, thus reducing over reliance on specific foreign locations and individual suppliers. Balance is to be found between off- and near-shored suppliers, matching SC flexibility*
DIGITALIZATION	*SC digitalization brings value chain improvements by boosting efficiencies, reducing costs and enabling greater collaboration, by means of several digital resilience-driven solutions. Digitalization is a expensive process, requires a proper analysis of costs and benefits*

Table 1: Outline of the strategies to build SCRes

4. SURVEY

In the course of the present chapter, it will be described the methodology adopted to develop the survey. In particular, the questions the survey is intended to answer are discussed, then the questionnaire development is presented. Finally, the definition of the players in the reference market who will constitute the sample of the potential respondents as well as the questionnaire administration are debated.

4.1. SURVEY PURPOSE

The aim of the survey was to understand how much the theoretical literature and the actual practices coincide when it comes to deal with unexpected and unprecedented event, such as the SARS-CoV-2 pandemic, and to highlight common behaviors for what concerns the implementation of the afore-mentioned strategies (Table 1) when dealing with disruptions. The questionnaire (Appendix A) was customized in order to fit all the different queried realities, in order to highlight their belonging to Tier-1 or Tier-2 type of supplier, their different sizes and their geographical location, hence coherent sections where structured, each adjusted for clarity's sake, complying to the underlying need of reaching the broader audience possible.

4.2. QUESTIONNAIRE CONSTRUCTION

The questionnaire was developed in late 2021 and it was structured in order to positively influence a future response rate. An unfitting length, for instance, as shown by the evidences in the literature, especially for the business-oriented studies, has negative influence on survey response rate (Jobber and Saunders, 1993), and represents one of the main reasons for businesspersons' non-response (Tomaskovic-Devey et al., 1994). For these reasons the survey's dimension was optimized in order to give and retrieve the right amount of information with the smaller number of questions possible. One questionnaire was sent, completely in English, to all the identified companies and ,alongside it, a cover letter (Appendix B) explaining the aim of the study was attached. Consulting experts from a wide variety of geographical background, belonging to different sized companies, allows to portrait a bigger picture of the overall situation of the automotive supply chain. This way of proceeding allowed to underline how firms dealt with the pandemic crisis according to their location, size and characteristic features (e.g., company's size, Tier-1 or Tier-2).

4.2.1. QUESTIONNAIRE SECTIONS AND QUESTIONS

The questionnaire is conceptually divided in two main parts: a first smaller one regarding the assessment of the respondent own characteristics, and a following more robust one intended to assess both the pandemic's effects and how the companies approached the strategies cited in Table 1. The first part was structured in order to retrieve fundamental information about the participants. In particular, the respondents were asked to provide details about the role within the company of the specific individual in charge of answering the survey, about the firm's size according to the number of employee (The Commission of the European Communities, 2003), about the company geographical location and lastly about the type of supplied resource, thus allowing to define whether they belong to Tier-1 or Tier-2 suppliers. For what concerns the second part, instead, it was furtherly divided into four lesser areas. The first subsection was developed aiming to understand which was the most affected area by the pandemic and how much such area actually suffered because of it, in order to explicitly understand how serious the impact of the pandemic on the potential respondents was. The second sub-section, instead, questioned the opinion of the inquired about the likelihood of moving closer their own downstream supply base and of moving themselves closer to the OEM of reference. This way, it was possible to investigate the suppliers' consideration about the effectiveness of such re-shoring processes when dealing with the pandemic effects and what are the main impeding factor that may jeopardize these geographical re-localizations. The purpose of the just cited section is to figure out the actual viability of such a strategy together with its perceived utility. Proceeding in order, the following third sub-section asked the participant to assess, according to their opinion,

their level of transparency toward the supply chain the company is part of, where was the point along the chain which was most lacking visibility, the helpfulness transparency can provide when dealing with unforeseeable events and how much, from a practical standpoint, a complete and common understanding of product-related information was actually viable. Once again, aim of this part of the survey is to understand how much the existing literature contributions were able to correctly identify the right feature for a company to enhance in order to build up its own resilience, and quantify the viability of a greater visibility from the interviewed standpoint. Lastly, the fourth sub-section aimed at assessing the firm's level of digitalization, which digital tools are being implemented at the moment and which ones, instead, are considered to be then implemented in the near future. A firm level of digitalization, as discussed in the previous Chapter 3, was highlighted by the literature as another relevant feature a company should invest on in order to be better prepared to face unforeseeable events. The purpose of this questionnaire's part is, in fact, to retrieve a clearer picture about the respondents common behaviors about such a topic. The whole questionnaire consisted in 20 questions, 3 belonging to the first macro-area and the other 17 belonging to the second one, of which 15 were close-ended and 5 were short open-ended. The survey was thought in order to have at least 10 questions whose answers could have been evaluated according to a Likert Scale.

4.3. SAMPLE DEFINITION

The companies investigated for the purpose of the thesis belong to two main categories: Tier1 suppliers, or also referred to OES, namely those who directly provide automakers with parts or systems, and Tier 2 suppliers, that supply parts that wind up in cars, even though they do not sell directly to OEMs. This choice was endorsed by different factors affecting the research. First, even if the players identified as the most interesting ones from the research standpoint, are certainly the Tier1 suppliers, that as previously stated supply OEMs directly, it was found practically not possible to select only firms falling exclusively in this category. Despite some suppliers are certainly fitting the description, the vast majority of them presents a diversified portfolio; their businesses are mostly intended toward satisfying the OEMs, but it is still common practice to supply other players, both within and outside the industry (e.g.: Robert Bosch, ZF Friedrichshafen AG, Continental Corporation, etc.), according to each own core competencies. As a result, the complete exclusion of underlying Tier 2 suppliers was not doable. Second, again by applying a practical approach, was deemed as more appropriate for the research itself to not rely only on the biggest/global Tier1 suppliers, considering their difficult availability when it comes to survey administration. Tier 3 suppliers, on the other hand, were excluded from the selection of the potential respondents, being that they supply raw materials not only the automotive industry. In order to retrieve reliable results, it was decided to focus on specific countries belonging to the European Union, in order to overcome the complications related to extending the research to countries outside the EU's borders, like time and likelihood of response. An exception was made for the UK whose suppliers belonging to the automotive industry were included as well. This

clustering, comprising both EU and UK, was considered relevant enough for the purpose of the present study, considering its relative weight when assessing the most involved countries in the automotive industry overall [39] (Figure 4).

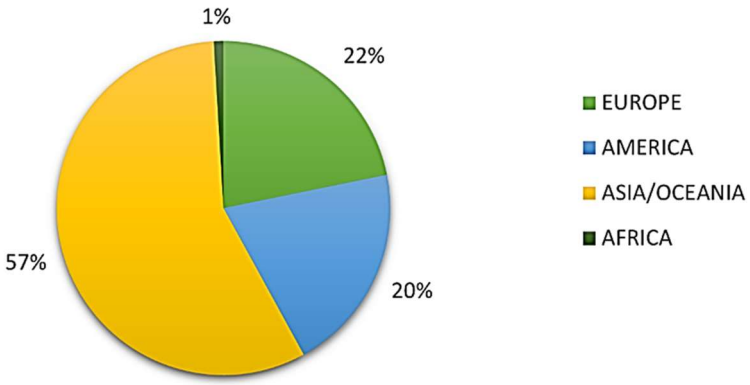

Figure 4: World motor vehicle production by continent (adapted from OICA, 2020)

In order to find and select a quantitatively suitable, and at the same time proper, sample of survey potential participant it was decided to rely on the information platform MarkLines [40], an automotive industry portal containing information on a wide range of companies. Such a platform contains a database clustering together more than 60,000 suppliers and provides its members with essential information about suppliers' sales and production statistics, reports on technology and market trends, model plan data including forecasts, and more. The afore-mentioned portal allows to filter suppliers according to parts or production process, customers, country. For the survey purpose it was chosen to perform a filter according to country, shrinking the original number of suppliers at disposal down to the ones solely belonging to both West-, Est-Europe and to the UK. Between the multitude of possible participants, the author randomly

selected samples of Tier-1 and -2 suppliers coming from all the different countries belonging to the EU and to the UK. The random sampling procedure was preferred, with respect to a systematic one, being that when the population size is small or the size of the individual samples and their number are relatively small, random sampling provides the best results since all candidates have an equal chance of being chosen [41]. By means of this approach 612 companies were selected. The retrieved information where then promptly stored in a Google worksheet (Appendix C), allowing a fast pace when dealing with the questionnaire administration.

4.4. QUESTIONNAIRE ADMINISTRATION

The COVID-19 pandemic represented an unprecedent event, unforeseen by any risk management strategy and with unpredictable effects on the world economy. Each different sector needed some time to break down the implication of the crisis, and the automotive one made no exception. Being that the questionnaire was developed between December 2021 and January 2022, namely in what can be considered already the new normal, it was possible to receive more realistic responses by the queried for what concerns the pandemic effects and its aftermath. For the vast majority of

them, in fact, the time span from the onset of the pandemic and the questionnaire administration was sufficiently large to permit the implementation of what were the most appropriate solutions for retrieving a proper working pace [42]. The administration process relied on GMass, a Google Chrome extension usually used by businesses to run mass email campaigns through Gmail. This tool works in tandem with Google worksheet, directly retrieving from the latter all the previously stored e-mails and allowing to simultaneously administer the survey to all the identified suppliers. Another important implemented feature, surely useful when performing such activities, was the option automatically send follow-up e-mails to all the firms whose answer was missing. For the present study, it was decided to send two follow-up emails, whenever there was an absence of response after a scheduled time frame of 10 days.

5. STATISTICAL ANALYSIS/ SURVEY RESULTS

In this chapter the data collected from the respondent are studied, the findings are analyzed and interpreted, then conclusions are drawn about the criticalities in the automotive supply chain encountered by first- and second- tier suppliers during the Covid-19 pandemic.

5.1. COLLECTED DATA

The research led to the collection of 612 potential participants, of which only 397 were found to be actually reachable (Appendix C), belonging to almost all the countries of the EU and of the UK. The firms were then contacted by email containing a link to the Google Docs questionnaire and a cover letter explaining the aims of this study. The data collection began in January 2022 and lasted up to the 22nd of February. Due to the nature of the topics at hand, the respondents were invited to deliver the questionnaire to the most appropriate business functions. Overall, 35 questionnaires were collected, providing an average response rate of approximately 9%. These results are not surprising, international mail surveys aiming at an industrial population have a history of very low response rates. For regular mail surveys without a telephone follow-up/pre-contact, response rates typically vary between 6% and 16% (Harzing, 1997). The data collected were studied, the findings were

analyzed in light of the existing literature, and conclusions were drawn about the current situation of the automotive supply chain.

5.2. ANALYSIS OF RESULTS

In the following paragraphs, sorted accordingly to the different sections of the survey, the collected data were first organized according to the information retrieved in the different sections of the administered survey, and then analyzed according to two diverse types of clustering: a first one made by dividing the participants according to the company size, and a second one done on the basis of the type of product supplied.

5.2.1. ASSESSMENT OF THE PARTICIPANTS' CHARACTERISTICS

As described in Chapter 4, the first part of the questionnaire was developed for the very purpose of assessing the participants' characteristics in order to be able, later on, to discern whether some practices were commonly adopted or whether their adoption was driven by the firms' distinctive features. To extrapolate such information the participants were firstly asked to state their role within their company (Figure 5). As shown below, the respondents held different roles within their companies. The highest number of participants belonged to the commercial department, followed, in order, by CEOs and directors. Lower

was the number of inquired holding the remaining roles with 3 owners, 2 supply and 2 office manager, and just 1 HR administrator and 1 quality assurance manager.

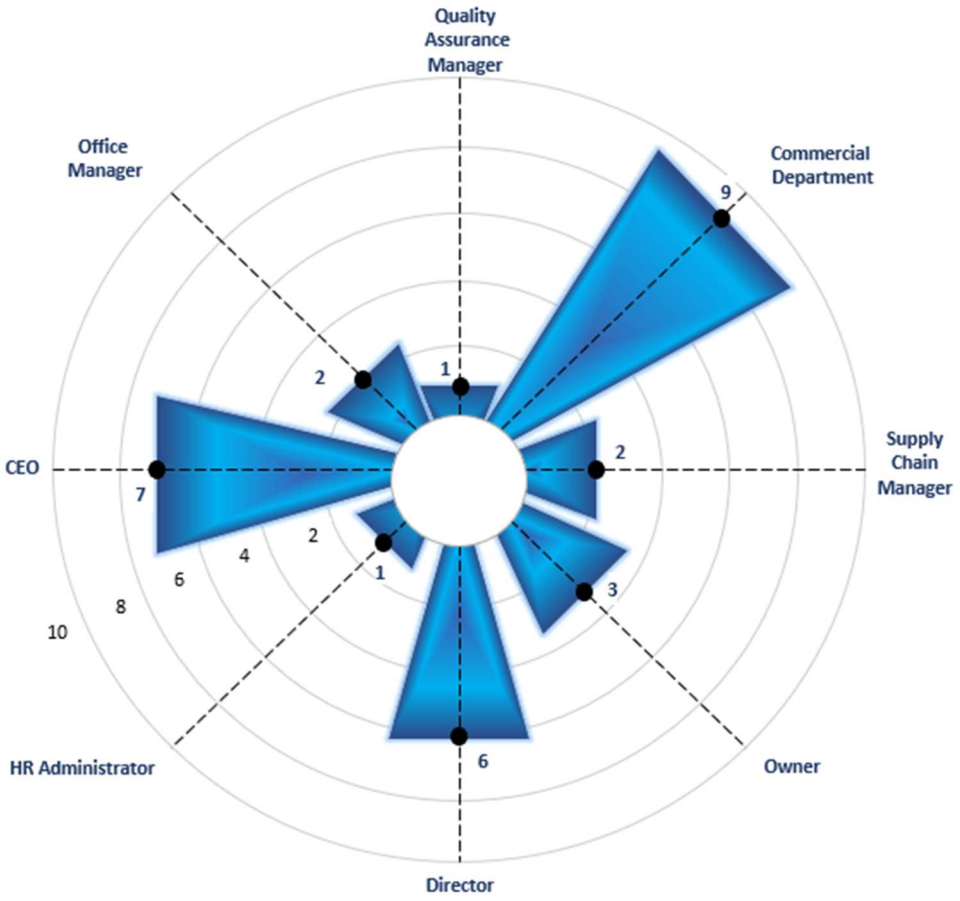

Figure 5: Roles of the Respondents

Following this more personal type of characterization, the inquired were asked about the size of the company of belonging, to be assessed on the basis of the number of employees, and in which country their firm was mainly located. On how to distinguish between different sized companies the author decided to refer to what stated in the "Commission Recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises" [43]. On this matter, the previously mentioned recommendation suggested to divide companies according to size by defining micro-sized companies, with less than 10 employees,

small-sized companies, with less than 50 employees, medium-sized companies with less than 250 employees, and lastly large-sized companies, with more than 250 employees. This type of clustering allowed to divide the respondents to the administered survey as shown below (Figure 6).

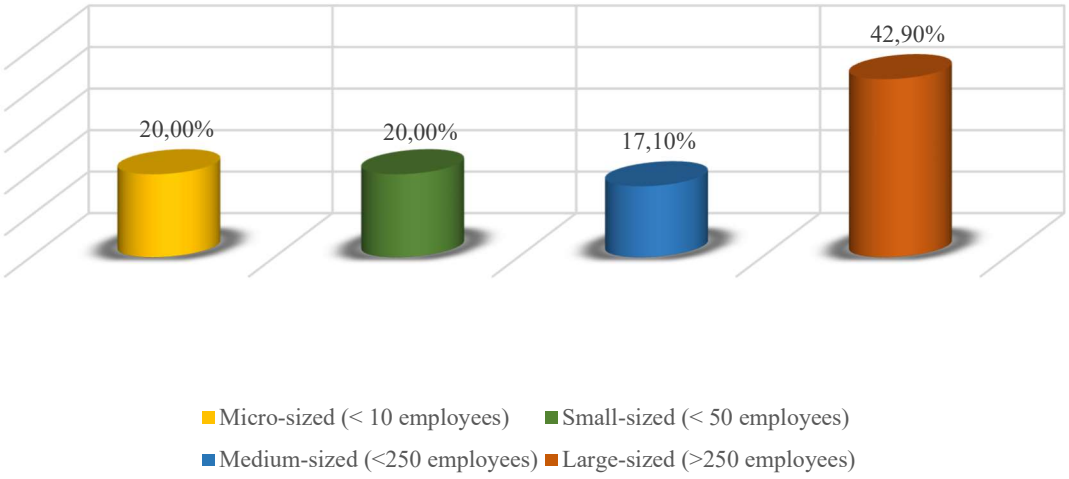

Figure 6: Respondents' company size

The greatest percentage of answers came from large sized companies, while the lowest from the medium sized firms. Tied, instead, was the number of respondents belonging to micro and small sized companies. Alongside the previous distinction, it was found interesting to divide the respondents according to the type of contribution to the automotive industry, in order to understand how many of the inquired could be considered as Tier-1 suppliers, hence providing products strictly related to the automotive word, and how many could be considered as Tier-2 ones instead. The results of the survey shown that the vast majority of the respondents, 80,1% of them, were Tier-1 suppliers and only a smaller fraction, 19,9%. was representing the Tier-2 ones instead. In this still early

phase of preliminary assessment of the survey, it was also asked the interviewed to provide information about the main location in which the firm they were representing was prevalently based. Despite the original identified sample tried to involve a broader audience, as it is shown below only 12 were the country whose firms were actually addressable (Figure 7).

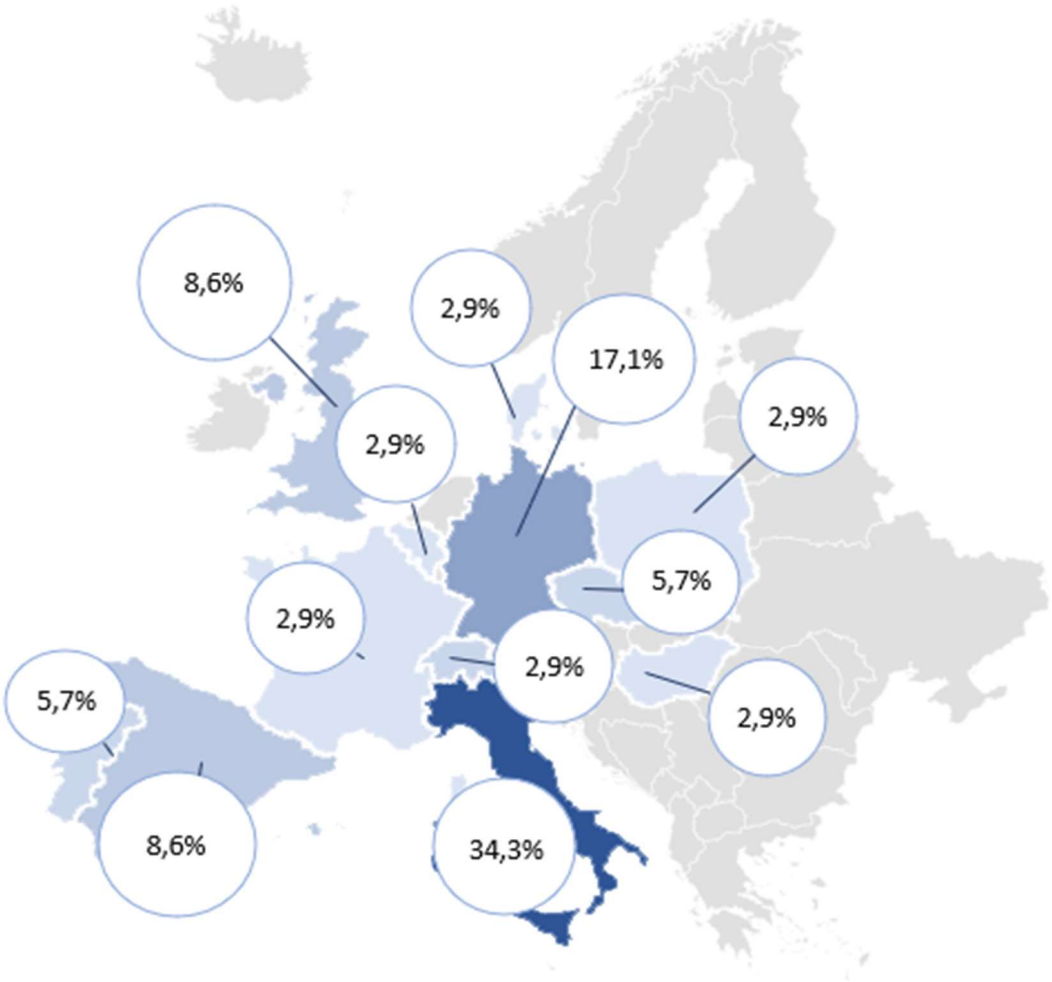

Figure 7: Respondents' country of belonging

5.2.2. ASSESSMENT OF THE PANDEMIC'S EFFECTS

After this preliminary assessment about the respondents and their companies main characteristics, it is possible to move further to the second part of the questionnaire. As already mentioned, this part represented the most important one, being that thanks to its results conclusions could have been drawn regarding the difference between what was identified by the literature and what instead was decided by the players along the Automotive Supply Chain. First of all, the interviewed were invited to define which was the area most impacted by the pandemic. As shown in Figure 8, 6 different main areas did arise from the results of the questionnaire, within which the most affected ones were certainly the production area, the area related to the lack of supplies and the area related to the lack of orders.

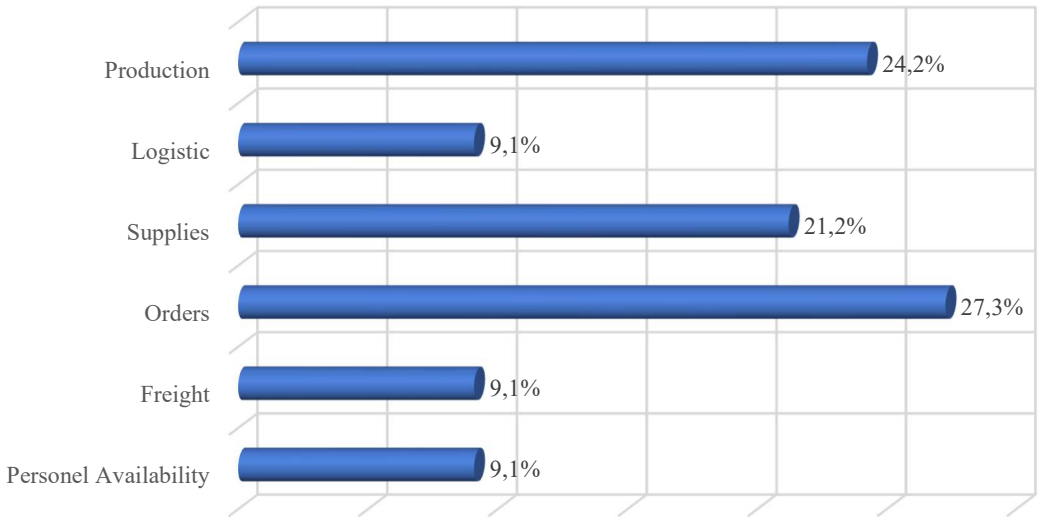

Figure 8: Areas most impacted by the pandemic

The same individuals were subsequently interviewed on how much the impact of the Covid-19 actually impacted the areas they just pointed out, and, as expectable, the results lead to the conclusion that the vast majority of them greatly suffered from such an unforeseeable disruptive event (Figure 9).

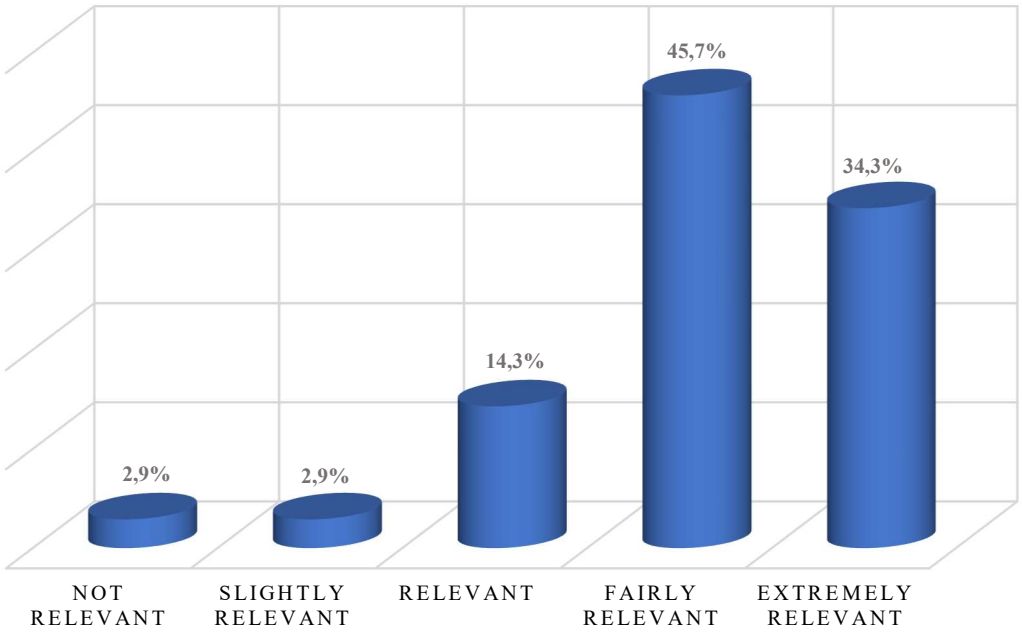

Figure 9: Relevance of Covid-19 impact

If the same data are addressed through a different perspective. Hence by dividing them according to the company size and the type of suppliers, it is possible to understand that the impact of the pandemic was felt in completely different fashions (Figure 10). In fact, as the survey results pointed out, while the most affected area was the one relative for the orders

for what concerns large sized company (31,25%), for the small sized ones the most affected was the productive one, as stated by 42,86% of them. Slightly different is the situation for the medium and small sized firms. As matter of fact, the medium ones where equally affected, 20% each, in the areas of supplies, productions, orders and personnel availability, while the micro sized ones, stated that they mostly felt the impact of the pandemic in the production and order area, in the same manner (28,75% and 28,57%).

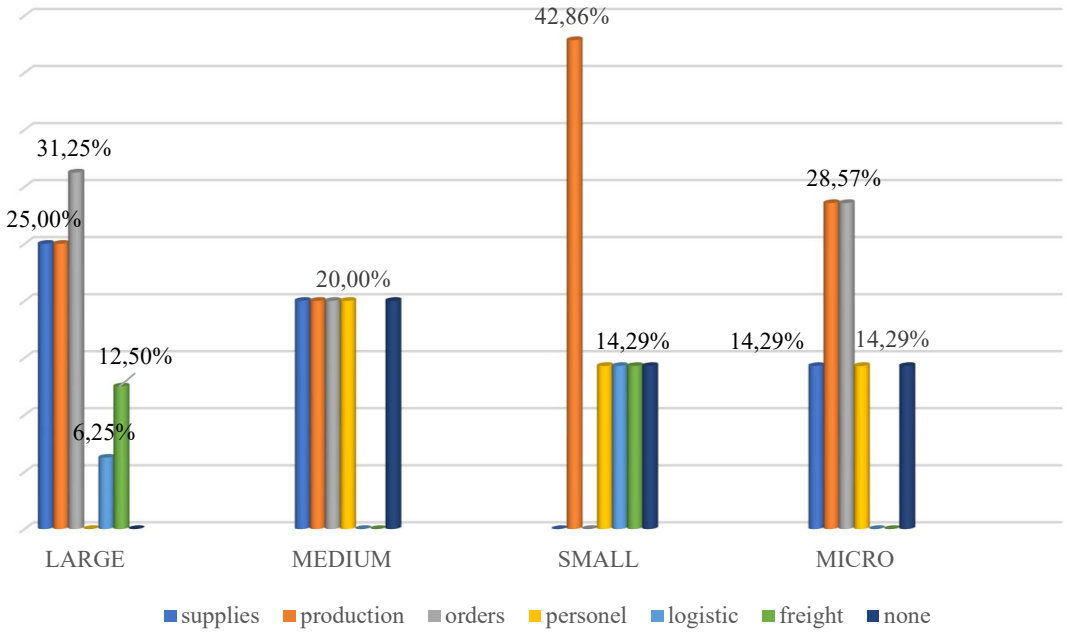

Figure 10: Areas most impacted by the pandemic according to companies' size

The most affected areas change when clustering the involved queried according to the type of supplied product: if for 33,33% of the companies producing automotive parts the production was the most critical one, for the companies outside this spectrum the most affected area was the personnel availability one. As preannounced by the literature the impact

of the pandemic on the automotive was undoubtfully critical. Indeed, the vast majority respondents, when asked about the gravity of the impact of COVID-19 answered assigning 4 points out of 5, regardless of their company size or of the type of supplied product (Figure 11).

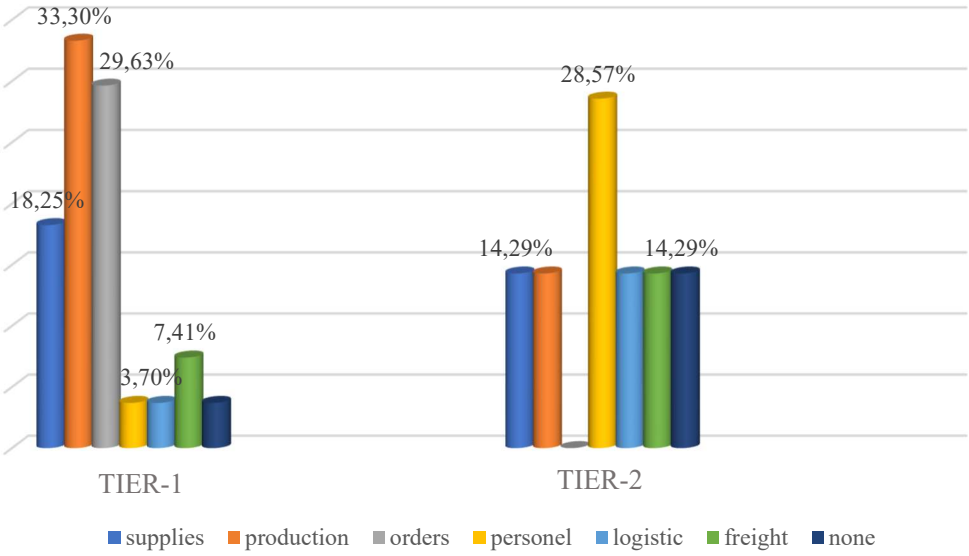

Figure 11: Areas most impacted by the pandemic according to type of supplier

5.2.3. SUPPLIERS RELOCATION

Following this early stage of the second section of the administered survey, there is the actual principal part in which the different methodologies identified by the literature as fundamental when building SCRes are tested against the actual practices implemented by the different companies. Suppliers re-localization, E2E transparency and digitalization, as previously discussed in Chapter 3, were the main features identified in

this study that are necessary for firms in order to level up their SCRes level and be prepared to withstand better possible unpredictable disruptive forces. The questionnaire addressed the afore-mentioned features, in the very same order, testing their perceived utility and their viability from the participants standpoint. Thus, this it was chosen to firstly address the topic of the supplier re-localization. In particular, being the inquired Tier-1 and Tier-2 suppliers, it was decided to look at the matter from a twofold perspective, namely by asking the involved firms to express their opinion about a re-localization of their own supplier base in favor of a closer one, and about their own possible re-shoring closer to the OEM of reference. On this matter the overall opinions of the interviewed were quite clear. As it is possible to understand by looking at Figure 12, for what concerns the possibility of moving closer to their respective OEM the quasi-totality of the respondents shown a high unlikelihood in doing so. Slightly different is the situation regarding the possibility of re-shoring their own supplier base; in this case in fact the retrieved opinions were mainly split between firms that are not considering such possibility, 39,4% assigned 1 out of 5 on the relative Likert scale, and other that are definitely taking this possibility in consideration, 33,3% assigned 5 out of 5 instead.

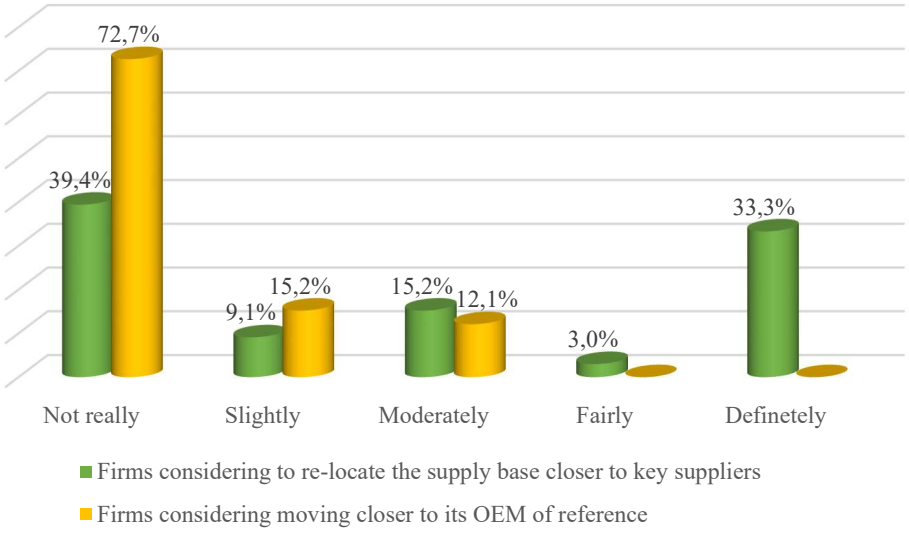

Figure 12: Likelihood of a re-shoring process

Moreover, the firms were also asked to express their opinion about which are the main impeding factors that can jeopardize a potential re-shoring process, hence making of such an activity a not doable one. In Figure 13 and Figure 14 are clustered the results of the survey on this topic.

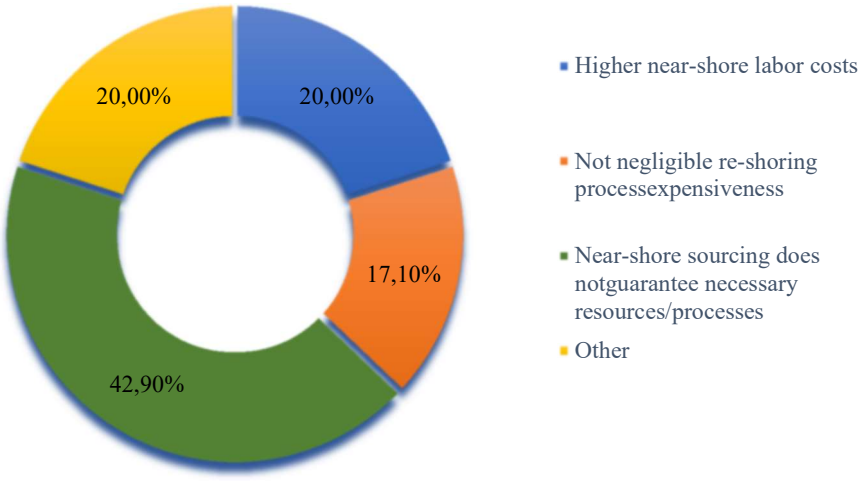

Figure 13: Difficulties in re-locating the supply base

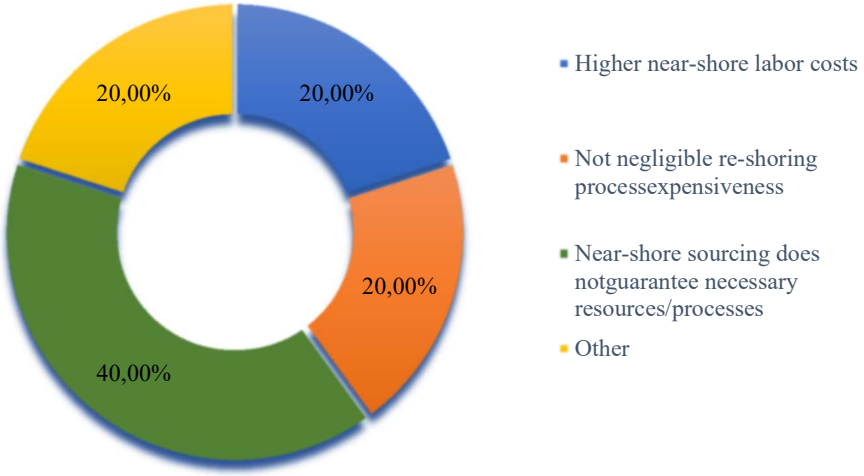

Figure 14: Difficulties in moving closer to the OEM

It is clear then, that even if in slightly different percentages, the main impeding factor is represented by the lack of necessary resources and

processes that is to be faced by the interviewed suppliers when moving closer their own supply base and when re-shoring themselves closer to the OEM of reference, respectively. To further highlight the retrieved results, it was decided to analyze the previously displayed data in light of the two above-mentioned different perspectives. In fact, if the same data are approached by looking at the results after having divided them according to the companies size and to the type of contribution to the Automotive Industry, namely on the basis of the inquired being Tier-1 or a Tier-2 supplier, it is possible to identify to specific trends. As a matter of fact, how much the interviewed companies are actually considering moving closer their supply base strictly depends on how big they are (Figure 15). As shown by the survey results while the medium, small and micro sized companies mostly assigned 1 point out of 5 at this possibility, 33,33%, 42,86% and 71,43% respectively, the large sized ones shown a completely opposite trend displaying a strong interest for the matter. In fact, 46,67% of them assigned 5 point out of 5 to the very same subject.

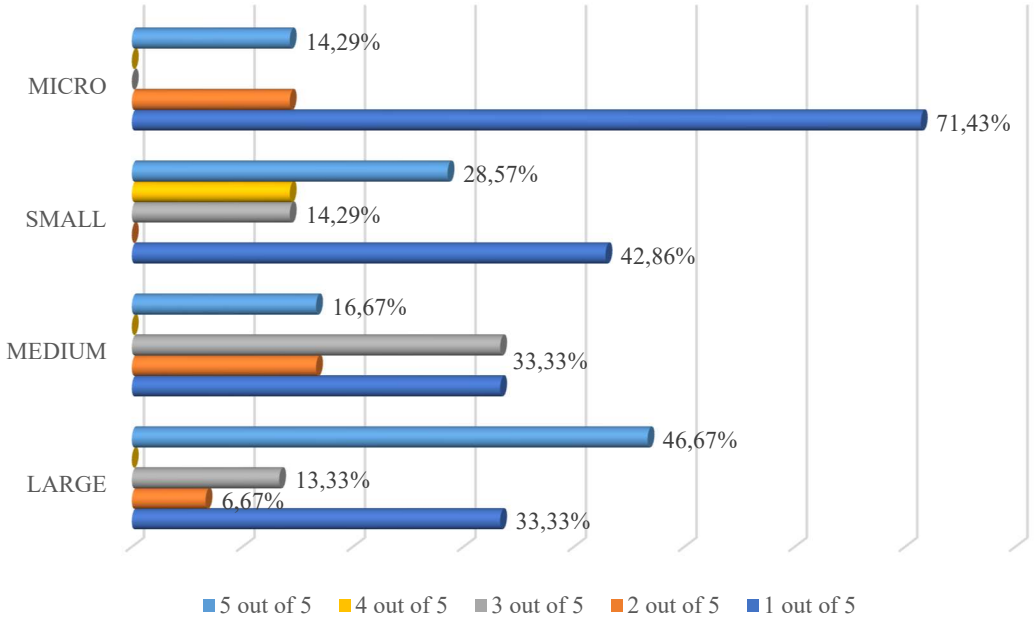

Figure 15: Likelilood of re-shoring closer the supply base according to companies' size

Such evidence strongly coincides with the question right after, that asked the participants to state how much a closer supply base would have been helpful when dealing with covid related disruptions. The large sized companies mostly gave a 3 point out of 5, 53,33% of them did so, while 66,67% of the medium, 57,14% of the small and 71,43% of the micro sized companies assigned no more than 2 points (Figure 16).

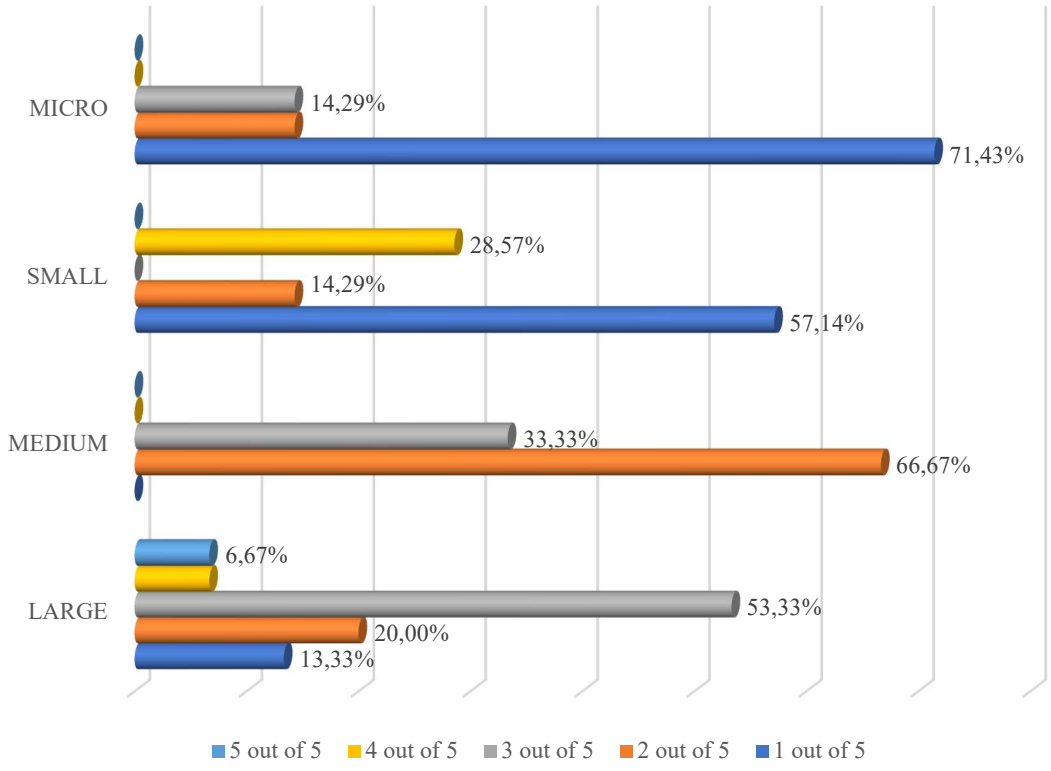

Figure 16: Helpfulness of re-locating the supply base closer according to companies' size

If the topic is addressed by looking at the greater picture, hence by dividing according to the type of supplied product it is possible to see that 35,71% of the participants providing automotive related products assigned

a score of 3, while 42,86% of the participants not providing products of the same category assigned a 1 instead (Figure 17).

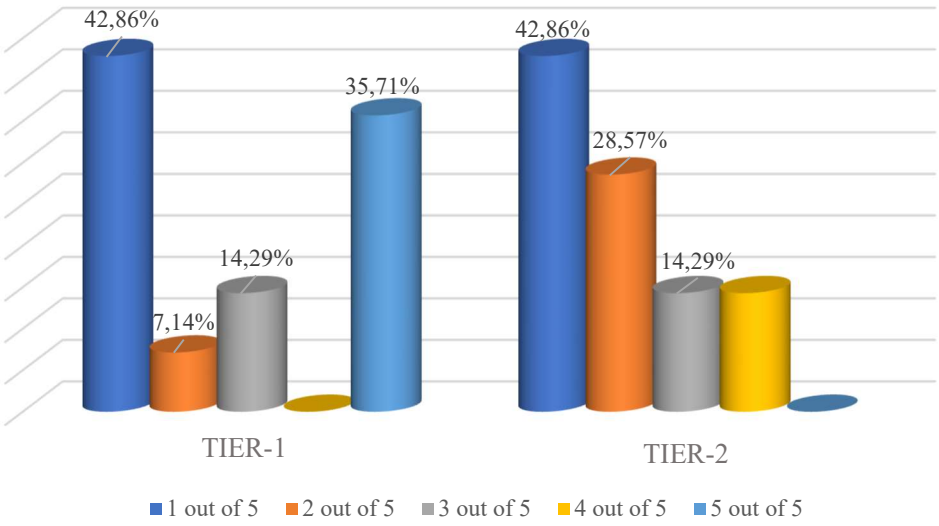

Figure 17: Likelilood of re-shoring closer the supply base according to type of supplier

With respect to what previously stated, as it is shown below (Figure 18), while the Tier-2 suppliers were displaying a negative conception about the utility of moving closer the supply base, as stated by 42,86% of the participants that voted 1out of 5, the Tier-1 ones were almost equally distributed between assigning 1, 2 or 3 out of 5 points on the same matter, with the greatest percentage (35,71%) referred to the latter score.

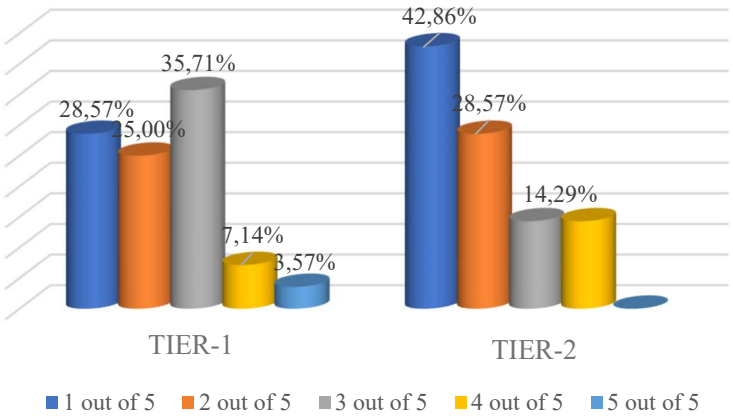

Figure 18: Helpfulness of re-locating the supply base closer according to the type of supplier

The survey shows that for both large and medium sized companies the greatest impeding factor, when considering moving closer their own supply base is represented by the fact that near-shore sourcing does not guarantee necessary resources and/or processes, as stated by 53,30% and 66,67% of the interviewed respectively (Figure 18). For small sized firms, instead, the problem was mostly due the higher near shore labor cost, problem identified by 42,86% of the participants belonging to this category. Lastly, for micro sized companies the problem is to be found elsewhere, considering that 57,14% of them pointed out that the greatest impediment was not included in the list of possible answers drafted by the author.

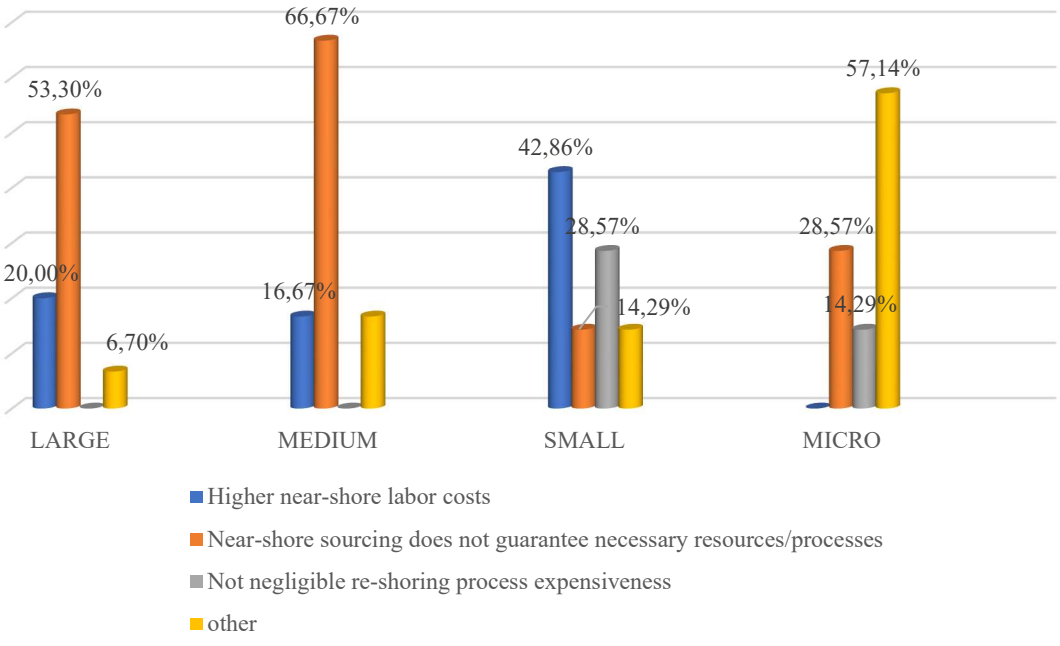

Figure 19: Difficulties in re-locating the supply base closer according to companies' size

In this scenario despite the type of contribution to the automotive industry (Figure 20), 46,43% and 46,30% of the respondents pointed out that the

lack of necessary resources/products in their vicinity represents the greatest problem.

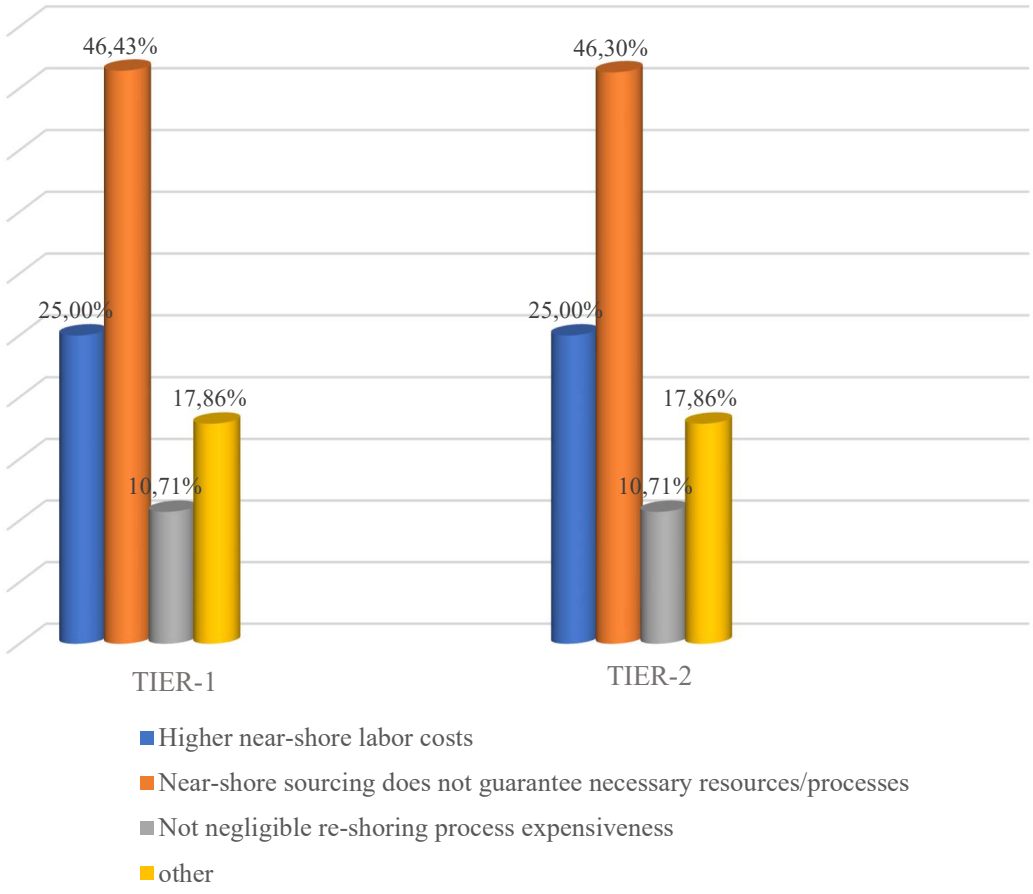

Figure 20: Difficulties in re-locating the supply base closer according to the type of supplier

On the other hand, the likelihood of moving closer to the OEM of reference, and the potential helpfulness such closeness in facing the pandemic, received a clear unanimous answer from the interviewed (Figure 21). In fact, for 80% of the large sized firm, 66,67% of the medium sized, 57,14% of the small sized and 85,17% of the micro sized ones,

moving closer to OEM was utterly out of discussion, being that such percentages are all referring to a score equal to one.

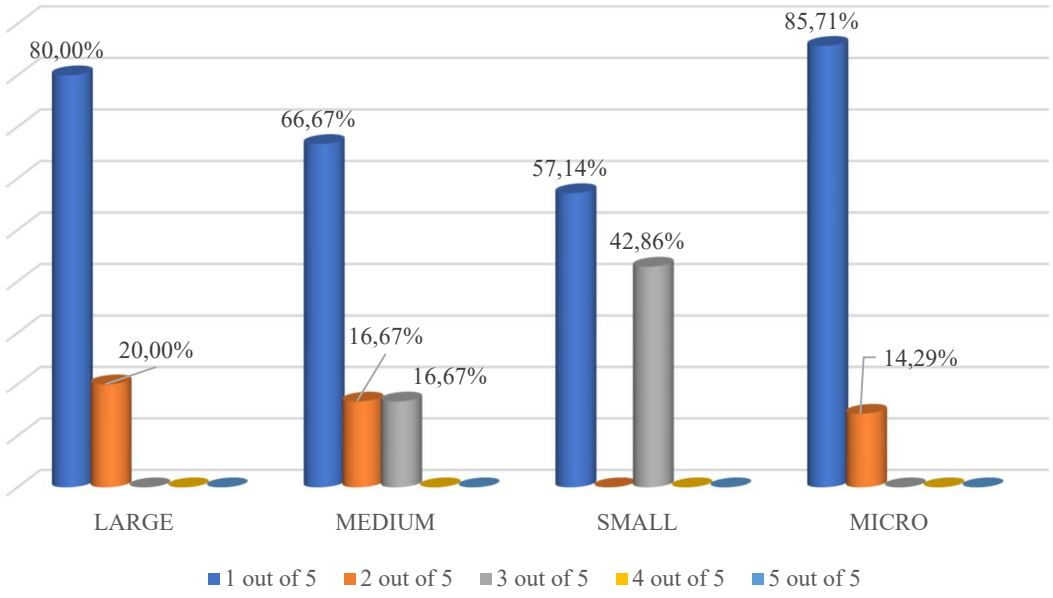

Figure 21: Likelihood of moving closer to the OEM according to companies' size

The same results hold when evaluating the retrieved scores related to the helpfulness of such a re-shoring, being that despite the difference of size the vast majority of the inquired assigned a score no greater than 2 (Figure 22).

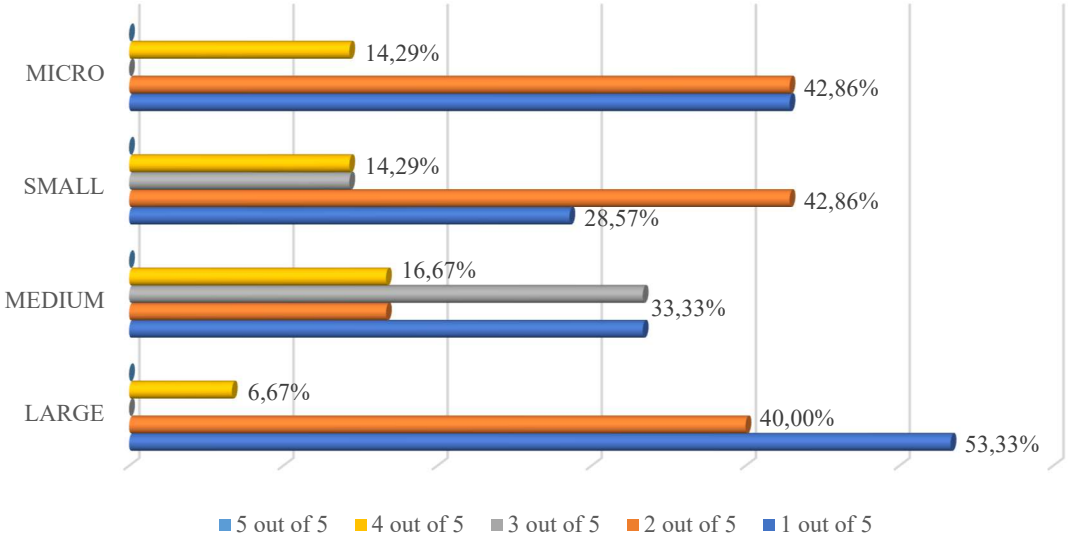

Figure 22: Helpfulness of moving closer to the OEM according to companies' size

The same trend of the above Figure 21 held when comparing the opinion of Tier-1 and Tier-2 suppliers (Figure 23). On this topic, in fact, the vast majority of the participants of both groups, 78,57% and 57,14% respectively, preferred to give 1 out of 5 possible points, clearly displaying that in their opinion such re-shoring process is unjustified.

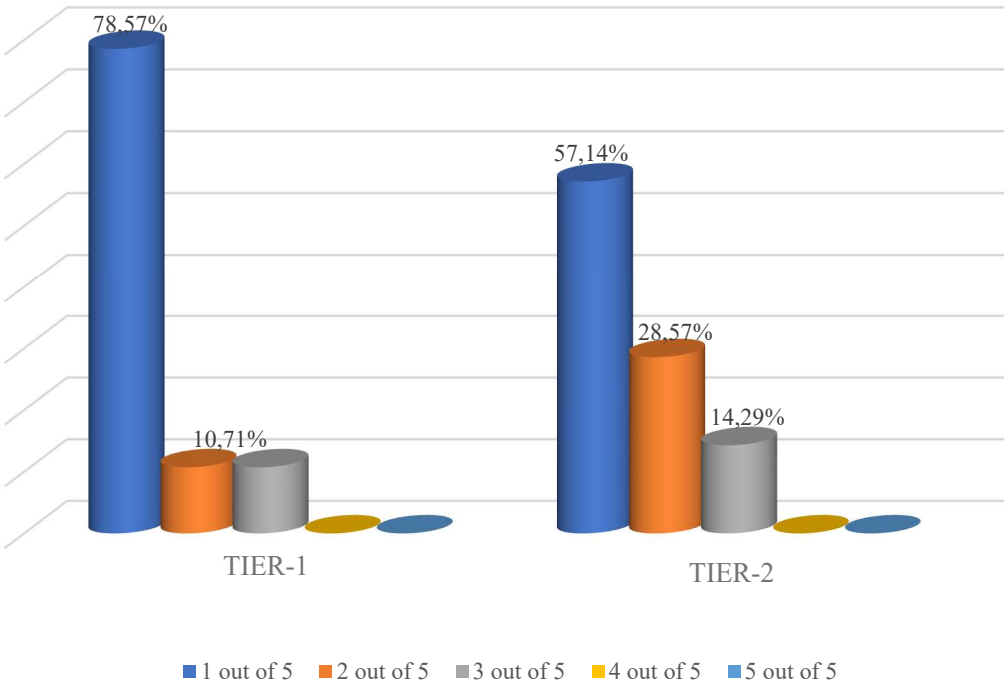

Figure 23: Likelihood of moving closer to the OEM according to the type of supplier

Different are the trends for what concerns the helpfulness of being in the vicinity of the OEM of reference (Figure 24). As a matter of fact, while once again Tier-1 suppliers were almost unanimous on the negligibility of such a re-location, as portraited by the combined 89,29% of respondents assigning 1 or 2 points, the Tier-2 ones were not so decisive on the same subject. Their opinion, in fact, was split between scores equal to 1, 3 and

4, showing now a greater percentage of inquired, 57,14% combined, positively thinking about being closer to the OEM.

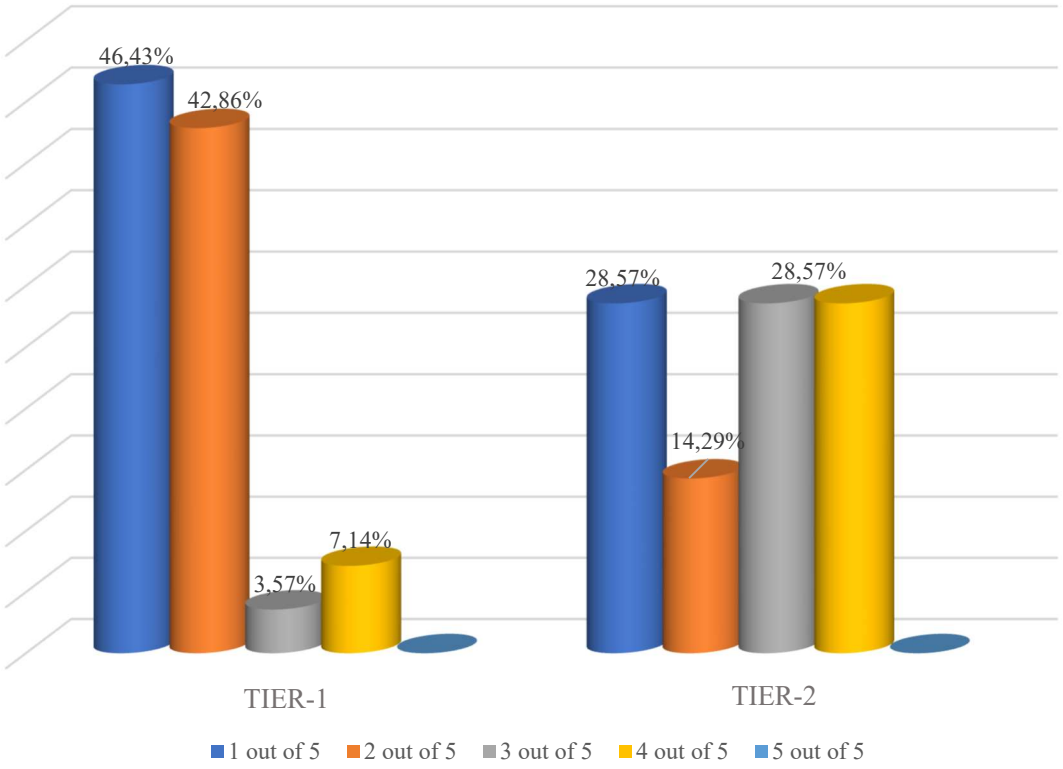

Figure 24: Helpfulness of moving closer to the OEM according to the type of supplier

The results coming from the administered questionnaire shown that, while for the large sized companies the greatest problem when considering moving closer to their OEM of reference was due to near-shore sourcing does not guarantee necessary resources or processes, as stated by 53,30% of the respondents, for the medium and small sized firms, 33,33% and 42,86% respectively, the greatest impediment was given by higher near-shore labor cost (Figure 25). The micro sized companies represented a stand-alone sample, being that 57,14% of them pointed out that the

greatest impediment was not included in the list of possible answers drafted by the author.

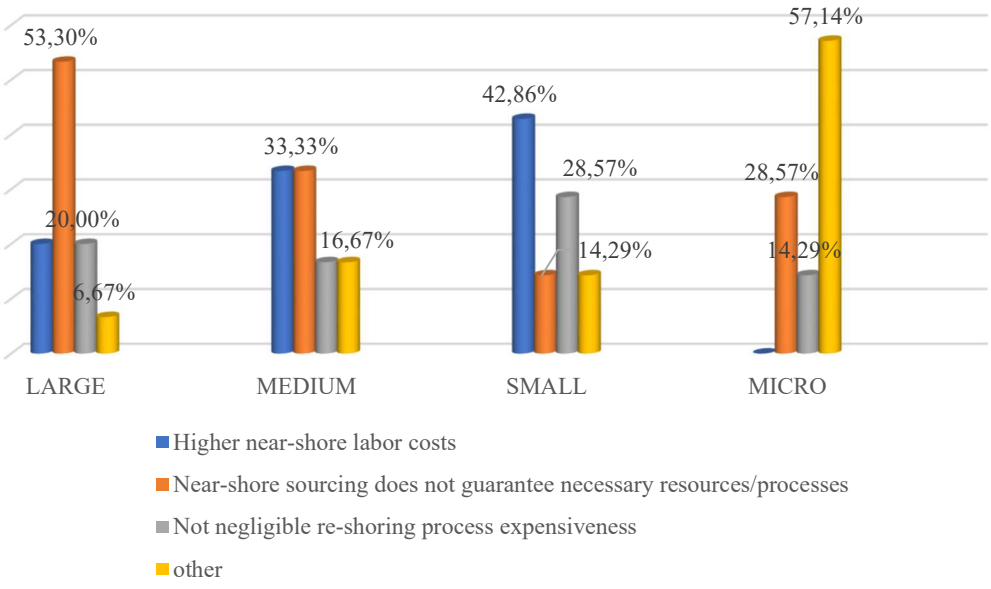

Figure 25: Difficulties in moving closer to the OEM according to companies' size

On the other hand, the scenery changes when the participants are divided according to the type of supplied product, because in such circumstances while for Tier-1 suppliers the most important problem was still represented by the lack of necessary resources/process nearby the OEM, for the Tier-2 ones the most impacting factor was to be found in the not negligible expenses of a re-shoring process (Figure 26).

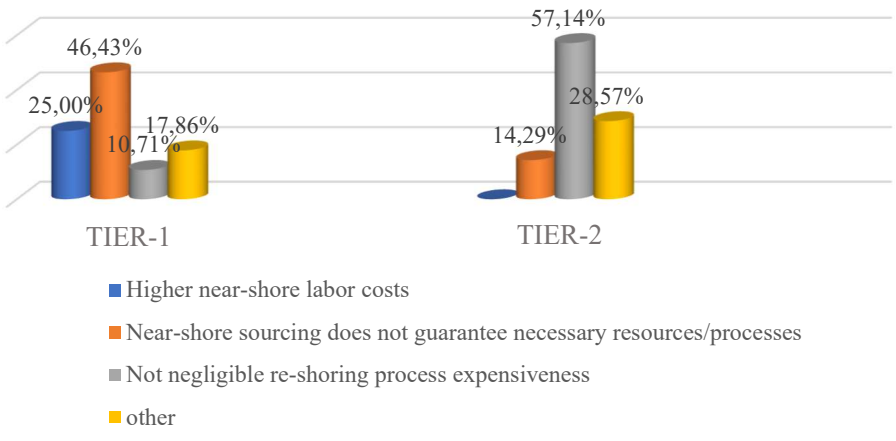

Figure 26: Difficulties in moving closer to the OEM according to the type of supplier

5.2.4. E2E TRANSPARENCY

Following the part of the survey concerning the suppliers re-localization, there is the sub-section regarding the E2E Transparency. As in the previous case, the results will be first analyzed according to a wider perspective and subsequently according to the firms' size and the type of supplied products. This sub-section begins by asking the participants to assess, according to their own believes, which was their level of transparency. In doing so, 87,5% of the inquired stated a high level of transparency, oscillating from "Moderately" to "Definitely", hance between 3 and 5 out of 5 on the corresponding Likert scale respectively (Figure 27).

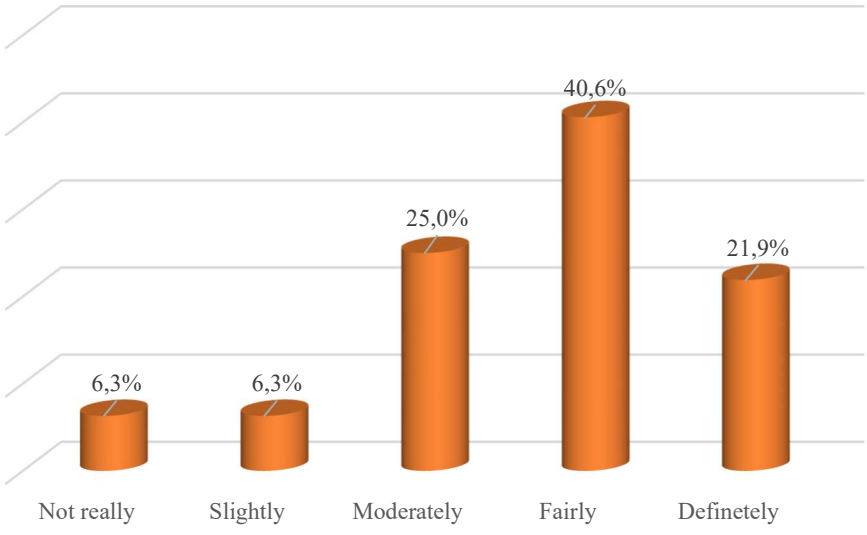

Figure 27: Firms' assessment of their transparency level

Right after, the respondents were asked to identify which were the areas, along the SC of which they are part of, where the lack of transparency, if present, was the most severe (Figure 28). The analyzed data confirmed what was predicted by the literature, according to which along the classical supply chain characterizing the automotive scenery the lack of transparency was clearly evident whenever moving beyond the Tier-1 suppliers.

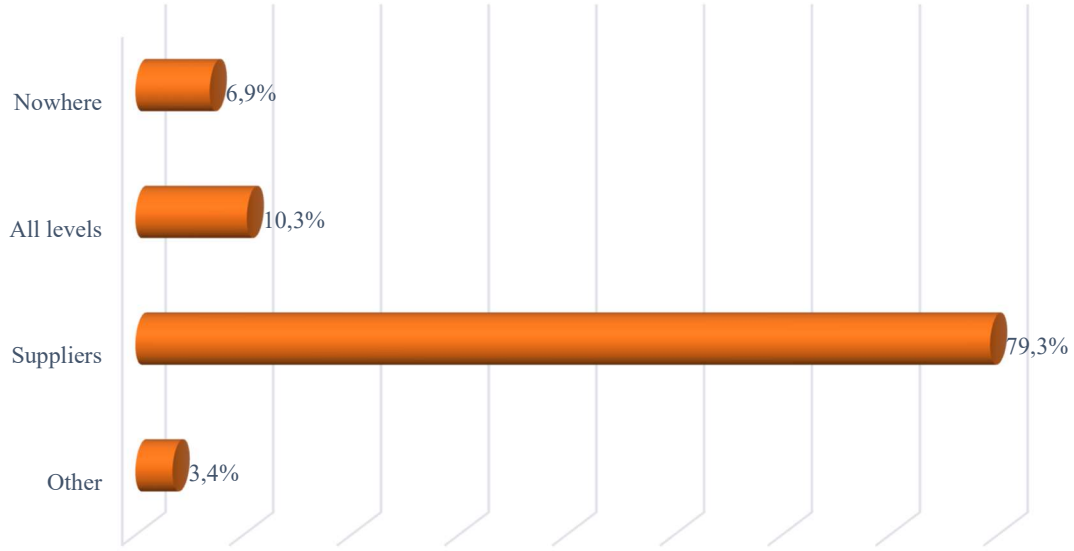

Figure 28: Areas of lack of visibility

Furthermore, it was considered interesting to question the inquired about how much, according once again to their personal believes, E2E Transparency represents a truly useful feature when facing disruptive events such as the pandemic one (Figure 29). On this regard, despite a noticeable 18,2% of participants stating a not actual usefulness of an

enhanced transparency, 63,6% of them deemed the same feature as "Moderately" helpful. Taking into consideration that another 6,1% of the answers scored a 4 out of 5, "Fairly" helpful, and the another 6,1% scored a 5 out of 5, "Definitely" helpful, it is safe to assume that an overall of 75,8% of participants took such feature in high regard.

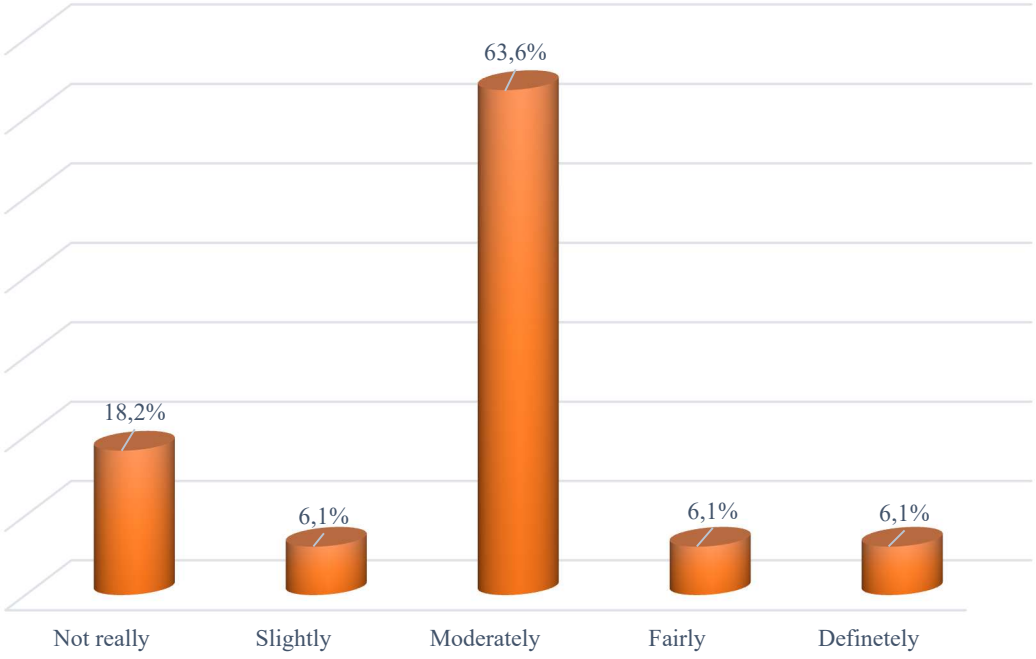

Figure 29: Firms' evaluation of the helpfulness of a higher transparency when dealing with Covid-19 impact

Lastly, on the same topic, the interviewed were asked to assess how much a SC can actually be transparent, taking into considerations potential impeding problems such as the lack of trust. Surprisingly, the vast majority of the involved participants, 84,8% of them in particular,

displayed a positive attitude toward the matter (Figure 30). Is to be noticed that, within this percentage, the highest part was referring to a "Moderately" viable transparent supply chain, showing that possible underlying problems are still responsible for the lack of visibility.

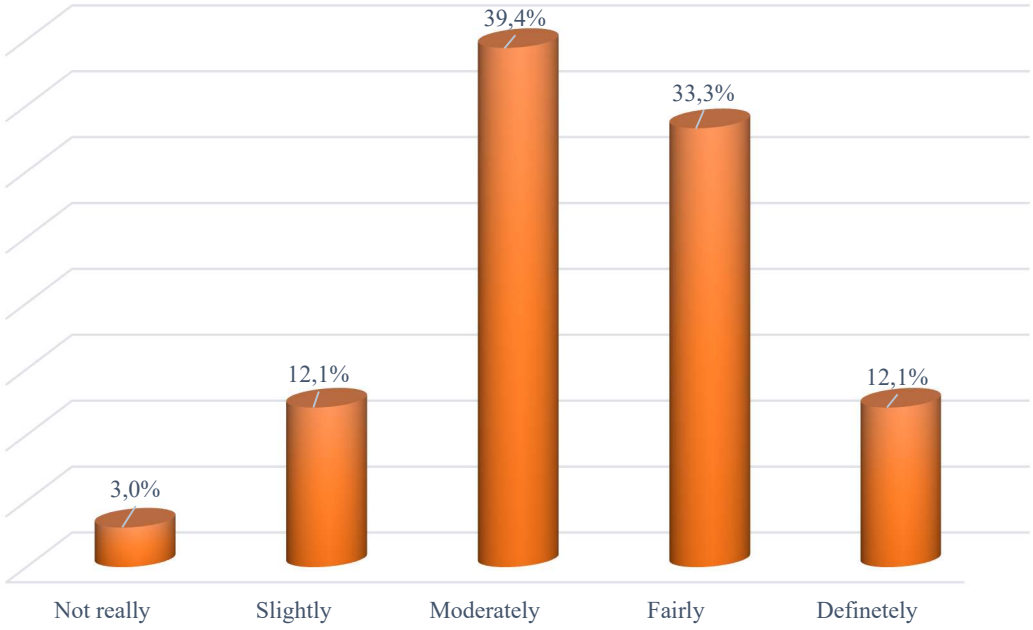

Figure 30: Viability of a truly transparent SC

Surprisingly, as previously mentioned, even though the literature identified E2E transparency as one of the most important features on which the firms belonging to the automotive SC should work on, in order to enhance their overall SCRes, the analysis of the survey's results shown that the highest percentage of the interview did not lament any lack of visibility along the chain. In fact, exception made for the micro sized companies whose scores about the transparency level were equally

distributed between 3, 4 and 5 points out of 5, all the other sized firms assigned a score of 4 or 5 (Figure 31). In particular, 60% of the large sized companies gave 4 points, 50% of the medium sized gave a 4 as well and 42,86% of the small sized assigned 5 out of 5 points.

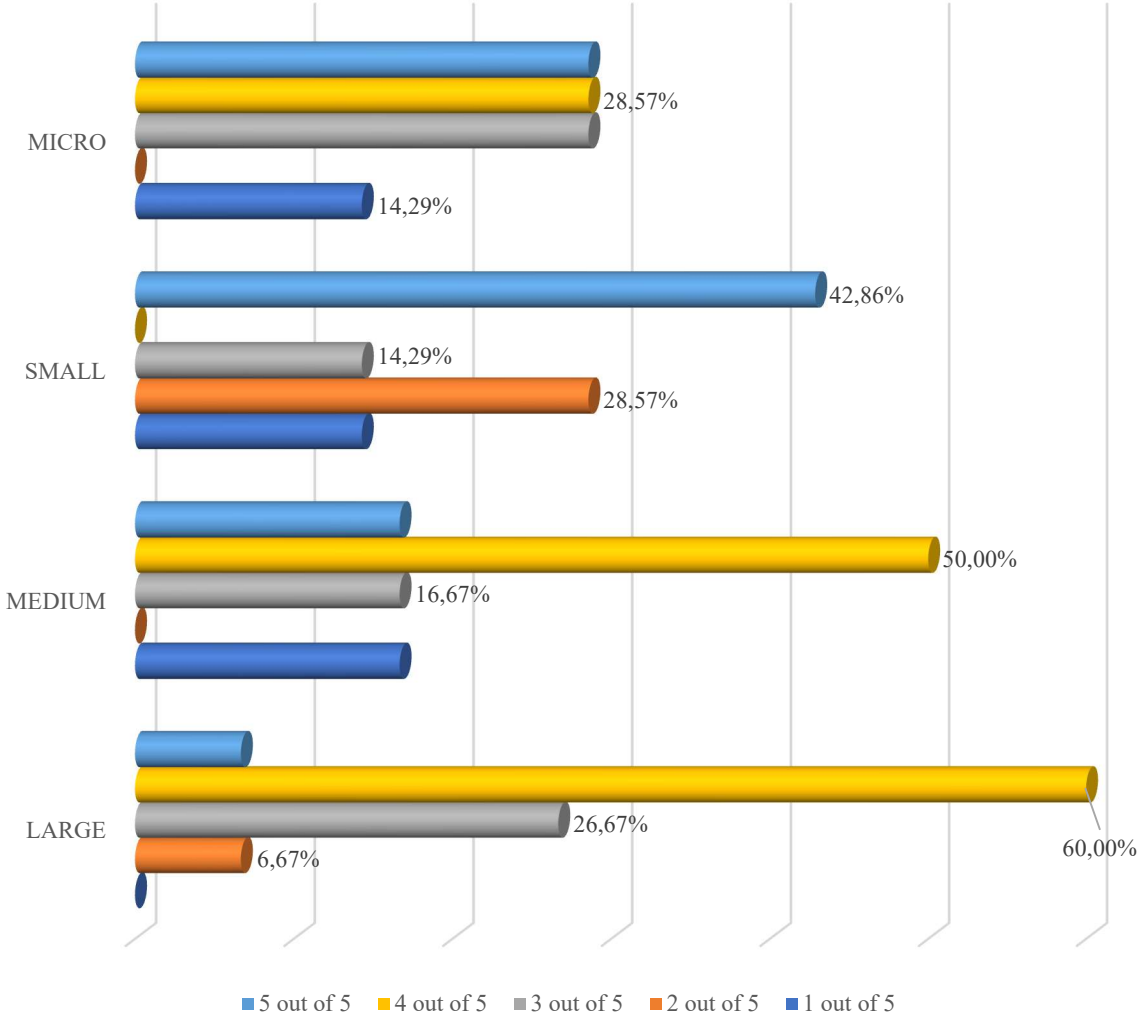

Figure 31: Firms' assessment of their transparency level according to their size

If the same self-assessment is divided by type of supplied products instead, it is possible to highlight a slight difference between the transparency level of Tier-1 suppliers, whose majority (50%) chose 4/5,

and Tier-2 suppliers, whose majority (42,86%) chose 3 instead (Figure 32).

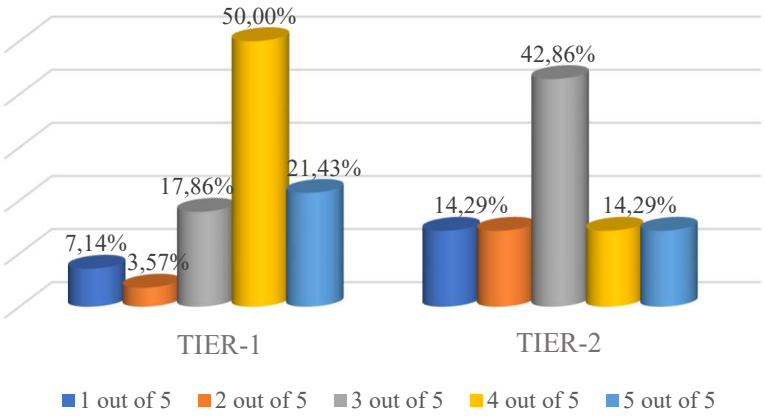

Figure 32: Firms' assessment of their transparency level according to the type of supplier

These results were compatible with the ones coming from the question regarding how much an actual transparent SC was truly viable (Figure 33). As a matter of fact, while for the large, medium and small sized ones the viability was mostly oscillating between a score of 3 and 4, 57,14% of the micro sized ones has chosen to give a 1 out of 5 on the same matter.

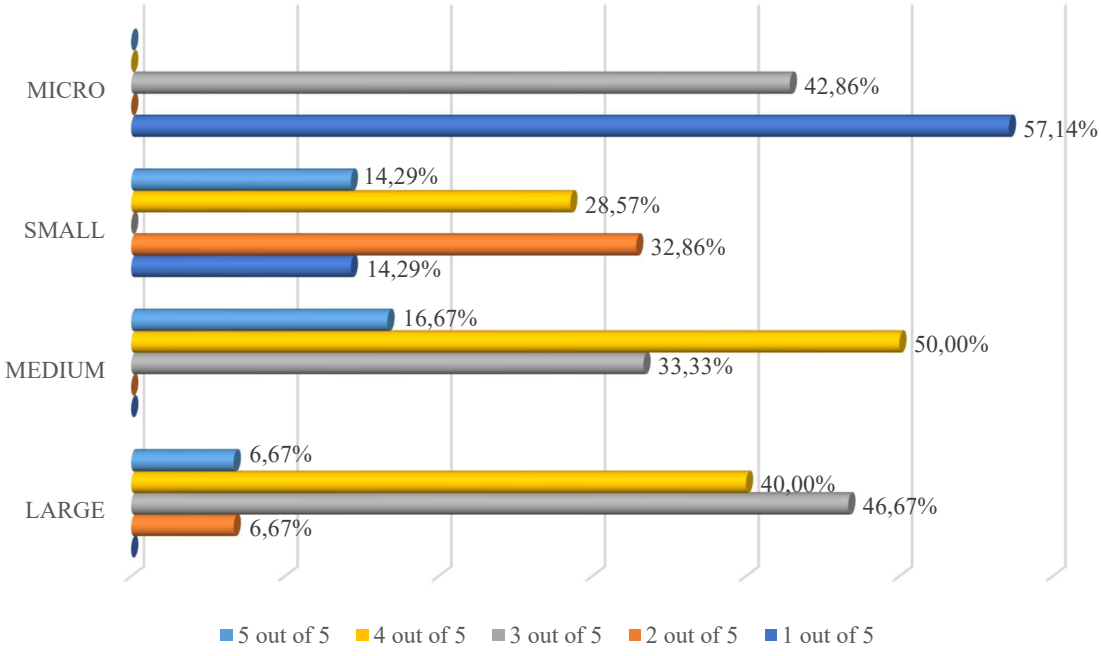

Figure 33: Viability of a truly transparent SC according to companies' size

As previously happened in the case of the transparency level self-assessment, in this case as well, the evaluation coming from the inquired divided according to the type of supplier products was not so different (Figure 34). Both automotive grade and non-automotive grade parts supplier stated that a truly transparent SC in actually viable. If the retrieved results are combined considering the score from 3 to 5 as showing a positive attitude toward the afore-mentioned viability, then it is possible to state that a combined 78,56% of Tier-1 suppliers and a combined 100% of Tier-2 suppliers considered the transparency as a truly achievable feature.

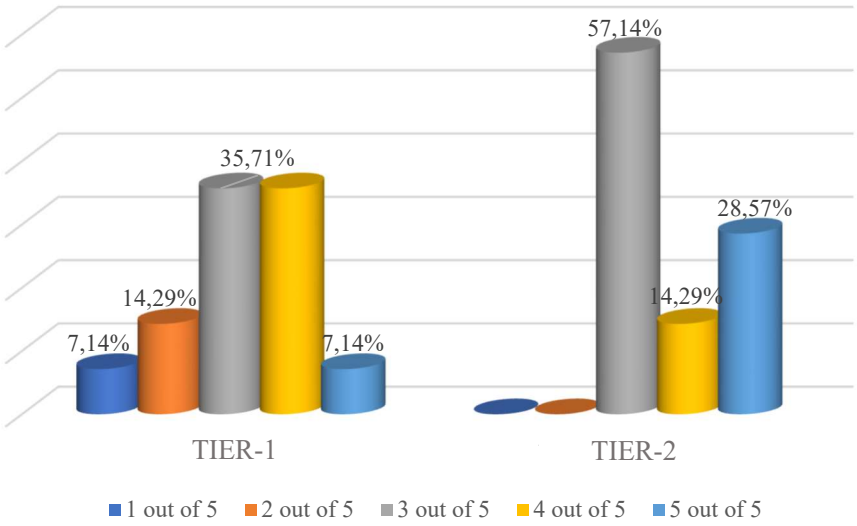

Figure 34: Viability of a truly transparent SC according to the type of supplier

The same trend held when the participants were asked to assess the utility of a more transparent supply chain when facing disruptive forces such as the pandemic one (Figure 35). For instance, 80% of the large sized and 71,43% the small sized ones assessed the transparency as being a relevant feature; of the same opinion were the medium sized participants but with a smaller percentage of 33,33%, still widely above the average. Once again, a different opinion was expressed by the micro sized inquired,

57,14% of which regarded the transparency as a “Not really”, 1 out of 5, relevant feature at all.

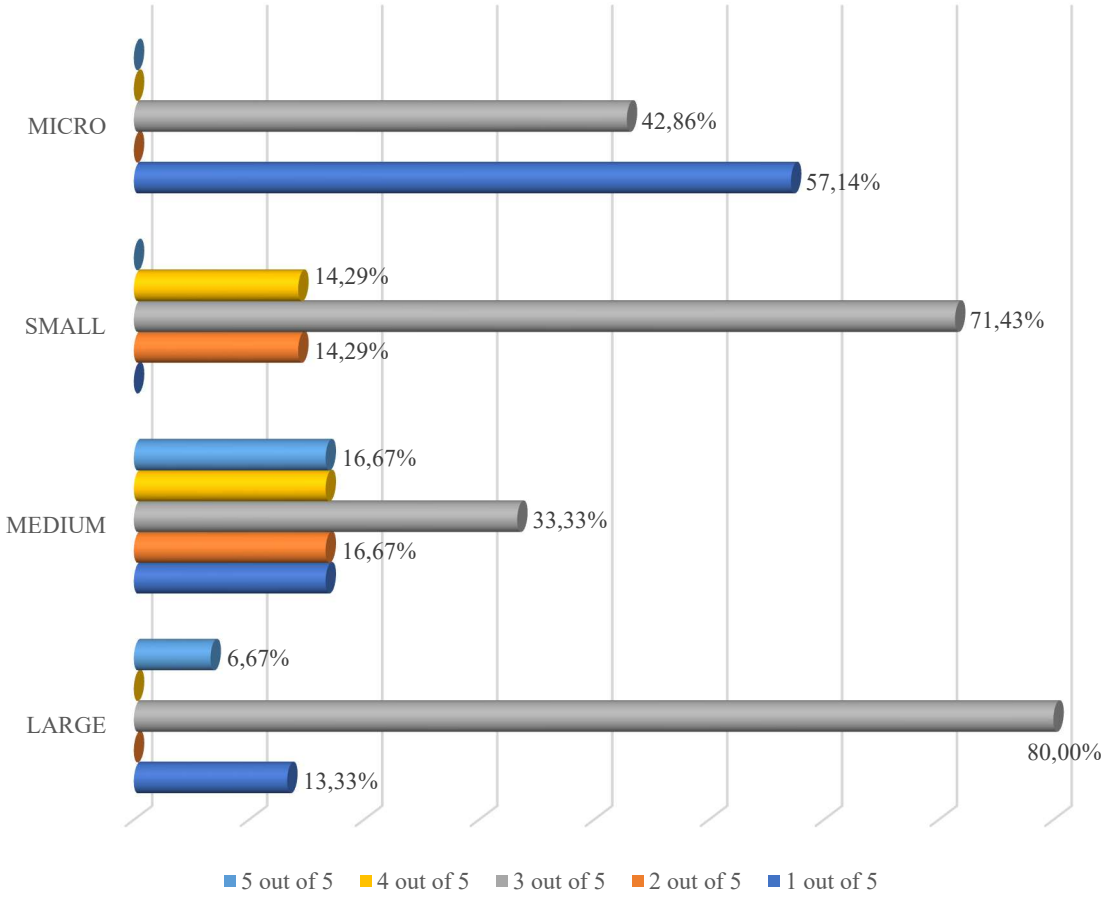

Figure 35: Firms' evaluation of the helpfulness of a higher transparency when dealing with Covid-19 impact according to their size

If the viewpoint shifts toward the division according to the type of supplied product, it is possible to denote a clear difference between the Tier-1 and Tier-2 suppliers (Figure 36). 67,86% of the former assessed the

transparency as a relevant feature, while, in contrast, 57,14% of the latter deemed the same feature as not relevant at all.

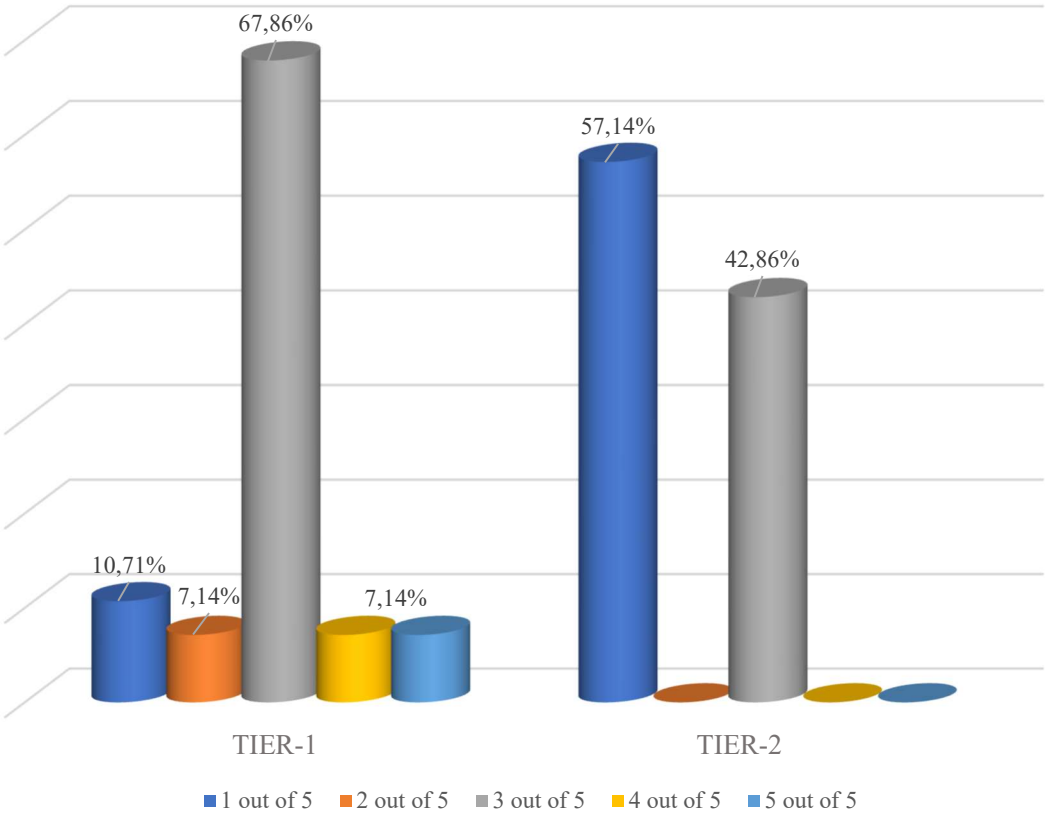

Figure 36: Helpfulness of a higher transparency when dealing with Covid-19 impact according to the type of supplied product

As shown in the reviewed literature, the greatest lack of visibility is encountered as soon as we move beyond Tier-1 and, especially, Tier-2 suppliers. As a matter of facts, all the respondents, regardless of belonging to different sized companies, claimed that the highest areas of lack of transparency where the ones coinciding with the suppliers beyond Tier-2, especially when it comes to raw materials provider (Figure 37). In fact, a relevant peak was found by the large sized inquired, 92,31% of which

pointed out the same area as particularly critical when it comes to visibility.

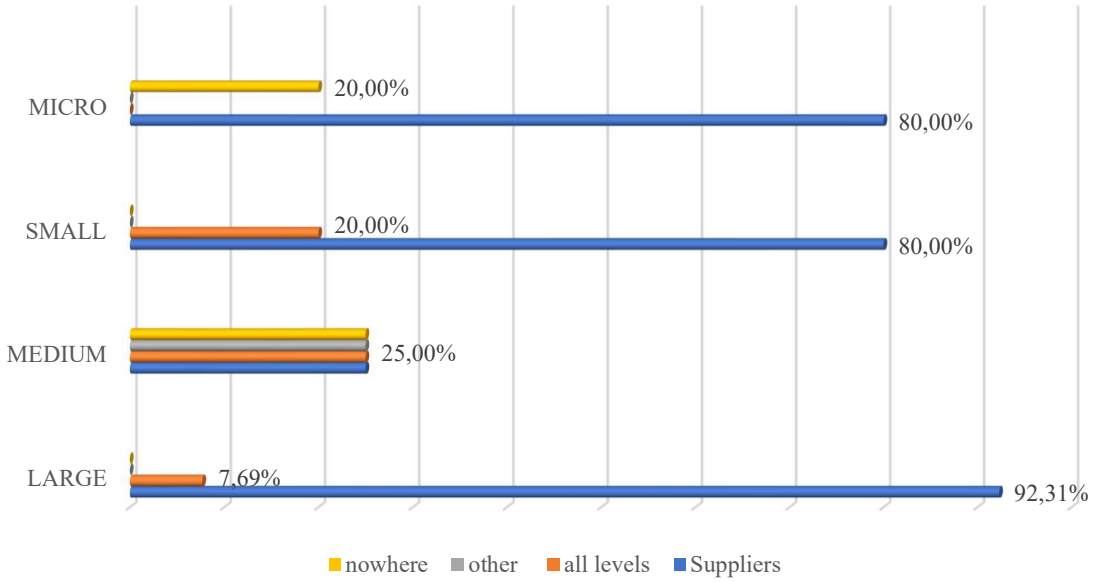

Figure 37: Areas of lack of visibility according to companies' size

Such patterns remain unaltered even in the case of a division by type of contribution to the automotive industry. For both 78,26% Tier-1 and 75% of Tier-2, once again, the lack of transparency was to be found within their own supply base (Figure 38).

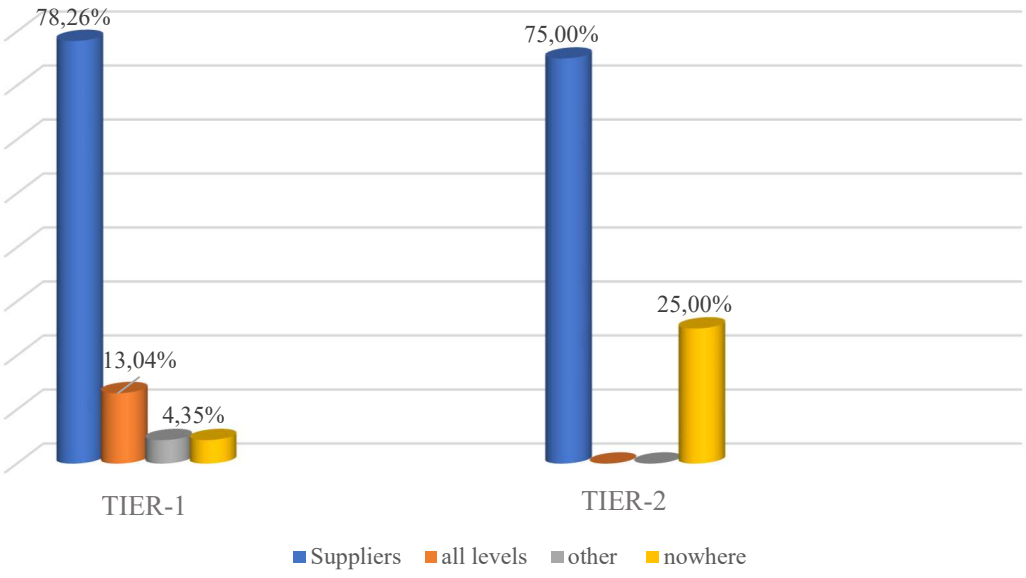

Figure 38: Areas of lack of visibility according to type of supplier

5.2.5. DIGITALIZATION

The last sub-section concluding the second section, is about the enhancement of the digitalization level of a company, sought by a greater implementation of industry 4.0 tools, by means of which strengthen its own level of resilience. In this section, similarly to the previous ones, the participants were first asked to assess their own level of digitalization (Figure 39). Surprisingly enough, a high percentage of the interviewed referred to themselves as either "Moderately", "Fairly" or "Definitely" digital, showing an already present interest on the topic.

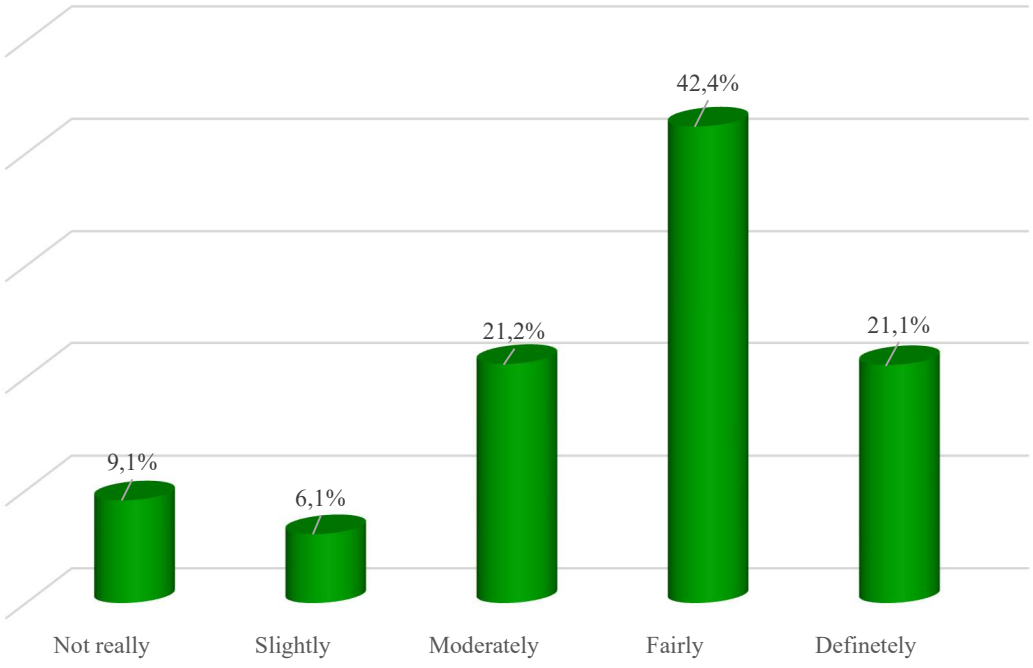

Figure 39: Firms' assessment of their digitalization level

Subsequently, the participants were to state how much in their opinion the impact of the pandemic provided a fostering effect on the implementation

of digital technologies (Figure 40). The results lead to the conclusion that such unforeseeable event greatly shown how much the players involved in the automotive industry were actually lacking in this regard and, thus, how necessary was to start increasing the number of digital solutions to be implemented or to enhance the use of already used ones.

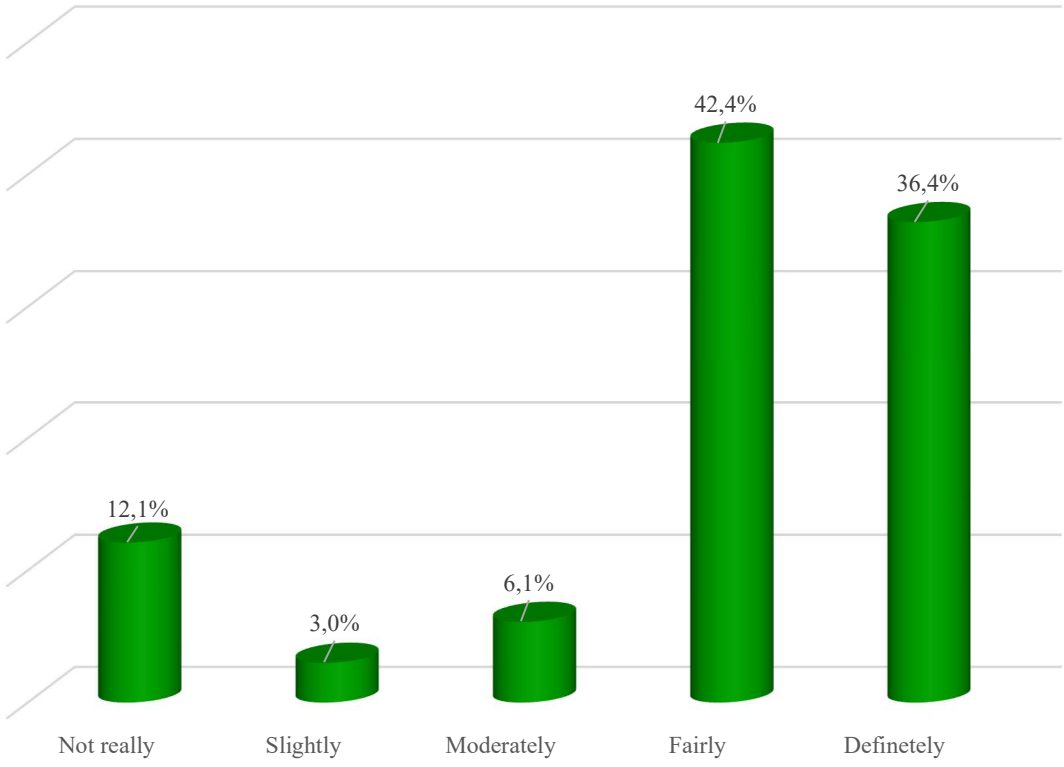

Figure 40: Firms' evaluation of the fostering effect of Covid-19 on the usage of digital technologies

Followingly, it was chosen to interview the respondents about which were the currently implemented digital tools and which, instead, were the ones that were going to be implemented in the near future. As it is possible to understand by looking at Figure 41, even though the highest percentage was referring to the voice "None", clearly displaying an absence of currently implemented digital technologies, a great deal of attention is

currently paid to Cloud Computing and Additive Manufacturing, with Big Data Analytics and Customer Relationship Management Tools close at the third fourth place.

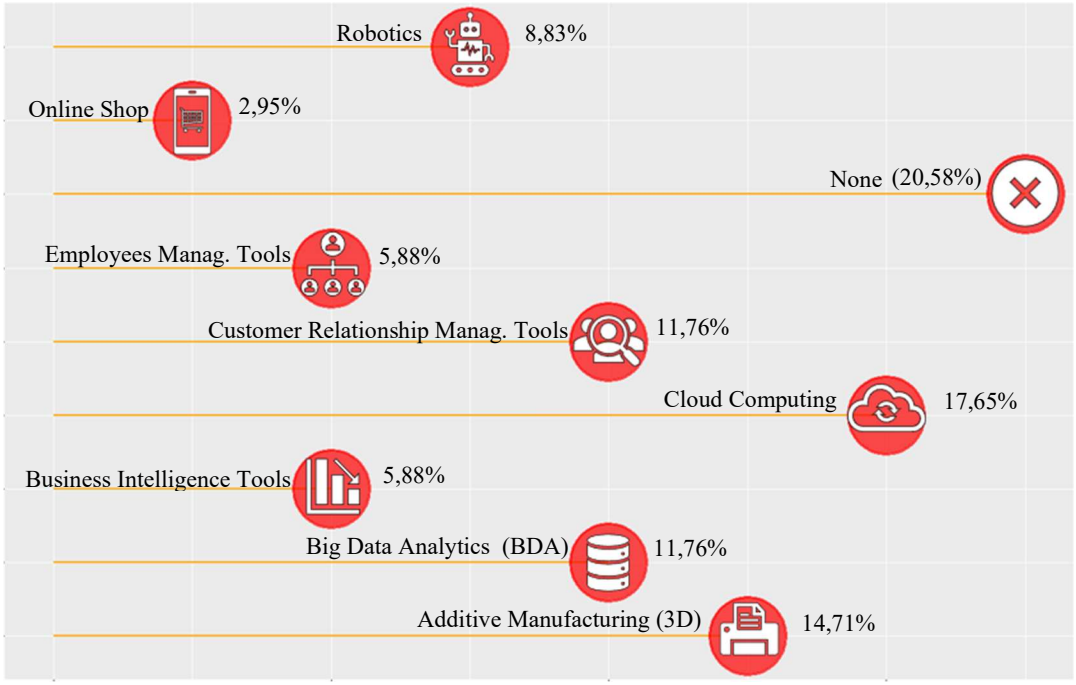

Figure 41: Currently implemented digital tools

For what concerns the digital technologies to be implemented in the future, the inquired displayed the greatest percentage of attention to Robotics and to Additive Manufacturing (Figure 42). Right after Internet of Things and Big Data Analytics resulted to be the preferred choice, while other digital tools such as Cloud Computing, Blockchain, Automated Guided Vehicles and Machine Learning/AI were basically completely disregarded. Moreover, it is important to highlight that a not negligible percentage of respondents shown their preference for the category of

"Other", expressing interest in digital technologies outside the scope of the review literature.

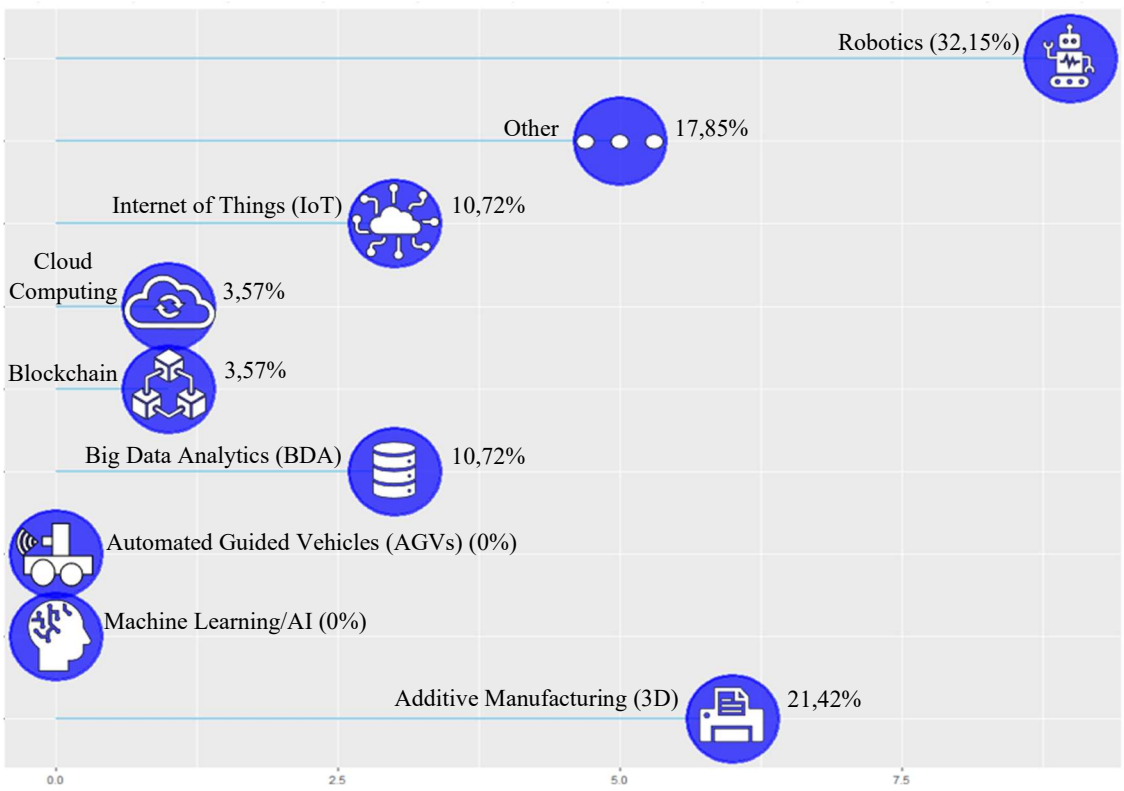

Figure 42: Digital tools to be implemented in the future

As expected, the digitalization level, being strictly related to the economic resources of a company, changed accordingly to the size of the interviewed company (Figure 43). As a matter of fact, 66,67% of the large sized firms assessed themselves as highly digital, with a score of 4 out of 5. On the other hand, the medium sized firms, 33,33% of them in particular, were divided between a score of 2 and 3, hence they referred to themselves as "Slightly" or "Moderately" digital. Of a different opinion were the small sized respondents, 42,86% of which gave a score equal to

1 out of 5, thus, showing a quasi-complete lack of digitalization. The micro sized companies instead figured as a stand-alone case being that 28,57% of them assessed to be only “Slightly” digital, 2/5 points, 28,57% “Fairly” digital, 4/5 points, and 28,57% “Definitely” digital, 5/5.

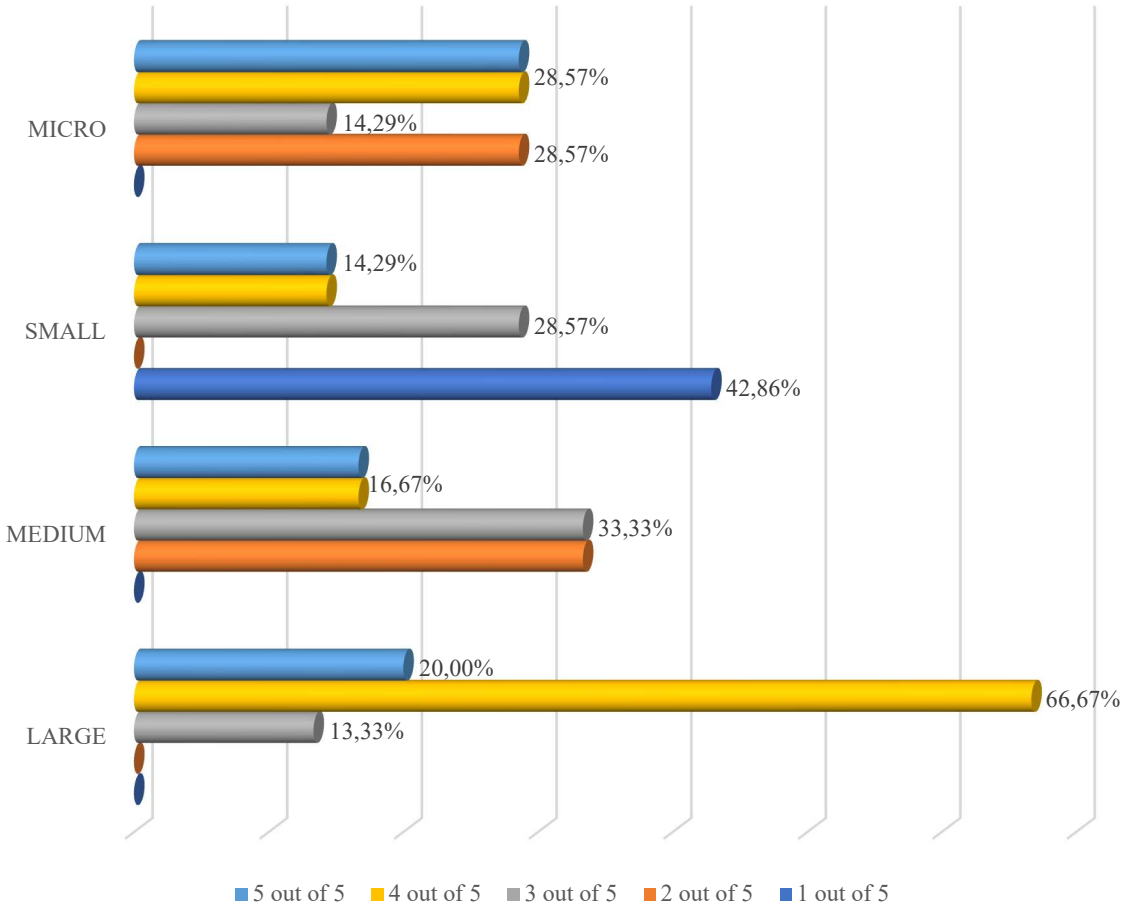

Figure 43: Firms’ assessment of their digitalization level according to their size

The results about the self-assessment of the digitalization level, when looked at by considering the two different tiers involved in the questionnaire, show that in both case the interviewed think about

themselves as from “Moderately” to “Highly digital, when it comes to the implementation of industry 4.0 tools (Figure 44).

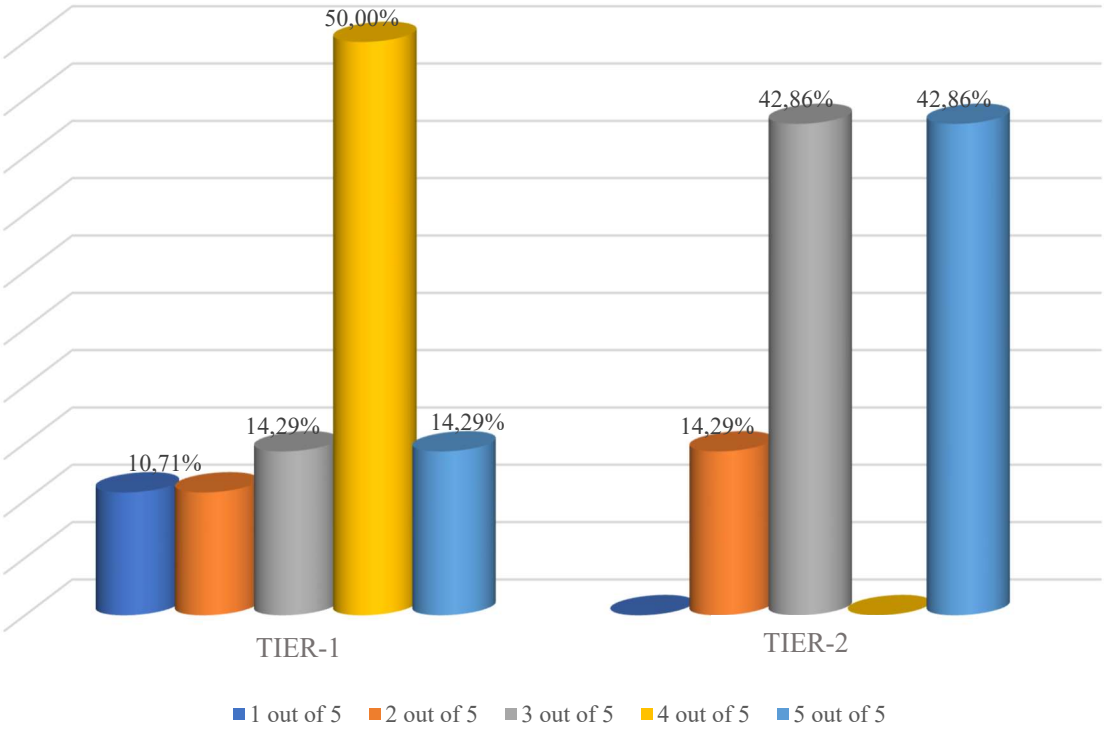

Figure 44: Firms’ assessment of their digitalization level according to the type of supplier

These scores displayed that when it comes to such small realities the decision of how to develop is strictly internal and personal. The pandemic opened the eyes of all the players involved in the automotive sector for what concern the utility of implementing digital tools. In fact, the pandemic effects were such to greatly foster the implementation of industry 4.0 solutions (Figure 45). About this matter, the retrieved the highest percentage were 4 out of 5 or 5 out of 5 in all cases. In particular, 53,33% of the large sized and 57,14% of the small sized companies

assigned 4 out of 5 points, while 33,33% and 71,43% of the medium and micro sized companies assigned 5 out of 5 points respectively.

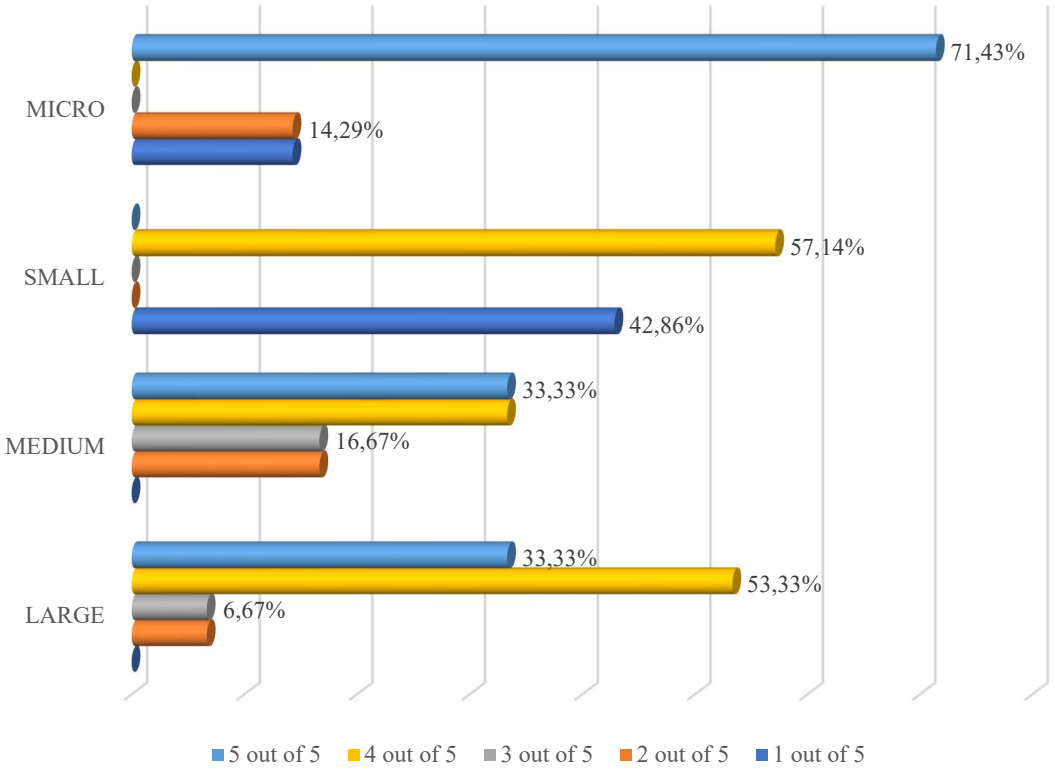

Figure 45: Firms' evaluation of the fostering effect of Covid-19 on the usage of digital technologies according to their size

The effect of the pandemic was such to highlight the necessity of implementing digital technologies, despite all company sizes all the possible type of supplied products (Figure 46). As a matter of fact, the players contributing to the automotive industry providing strictly automotive related components assessed for the highest percentage, 39,29%, that such was the effect of COVID-19. Similarly, the Tier-2 suppliers admitted the fostering effect of such a disruptive force, with the difference that in their case the effect was even greater. Indeed, 42,86%

assigned 4 out of 5 and 57,14% assigned 5 out of 5, displaying that in the Tier-2 case 100% of the inquired felt the necessity to implement digital technologies.

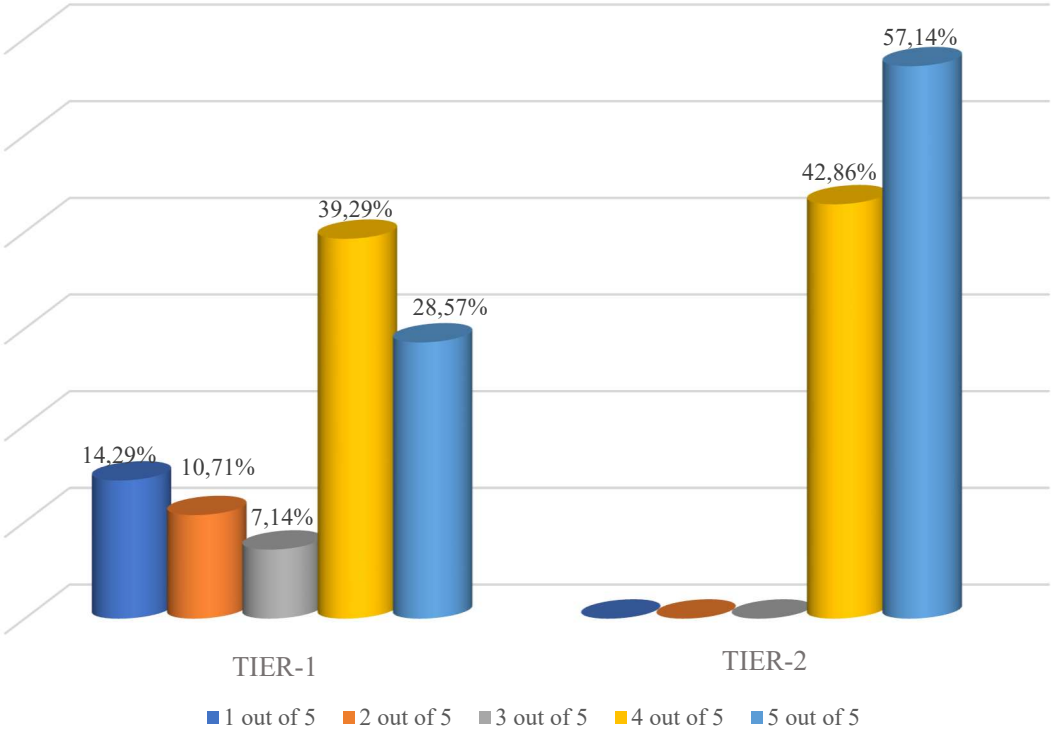

Figure 46: Firms' evaluation of the fostering effect of Covid-19 on the usage of digital technologies according to the type of supplier

For what concerns the currently implemented digital technologies the survey shown different trends according to both company size and the type of supplied product. The participants belonging to large sized companies mostly implemented cloud computing (33,33%), while the ones belonging to small sized firms are, for the vast majority of them, currently implementing additive manufacturing (40%). Medium sized companies were found to be currently equally divided between implementing BDA, Business Intelligence Tools and Employees Management Tools (25% for each one). Different is the behavior shown by the micro sized companies

that in 40% of the cases prefer to make use of Customer Relationship Management Tools (Figure 47).

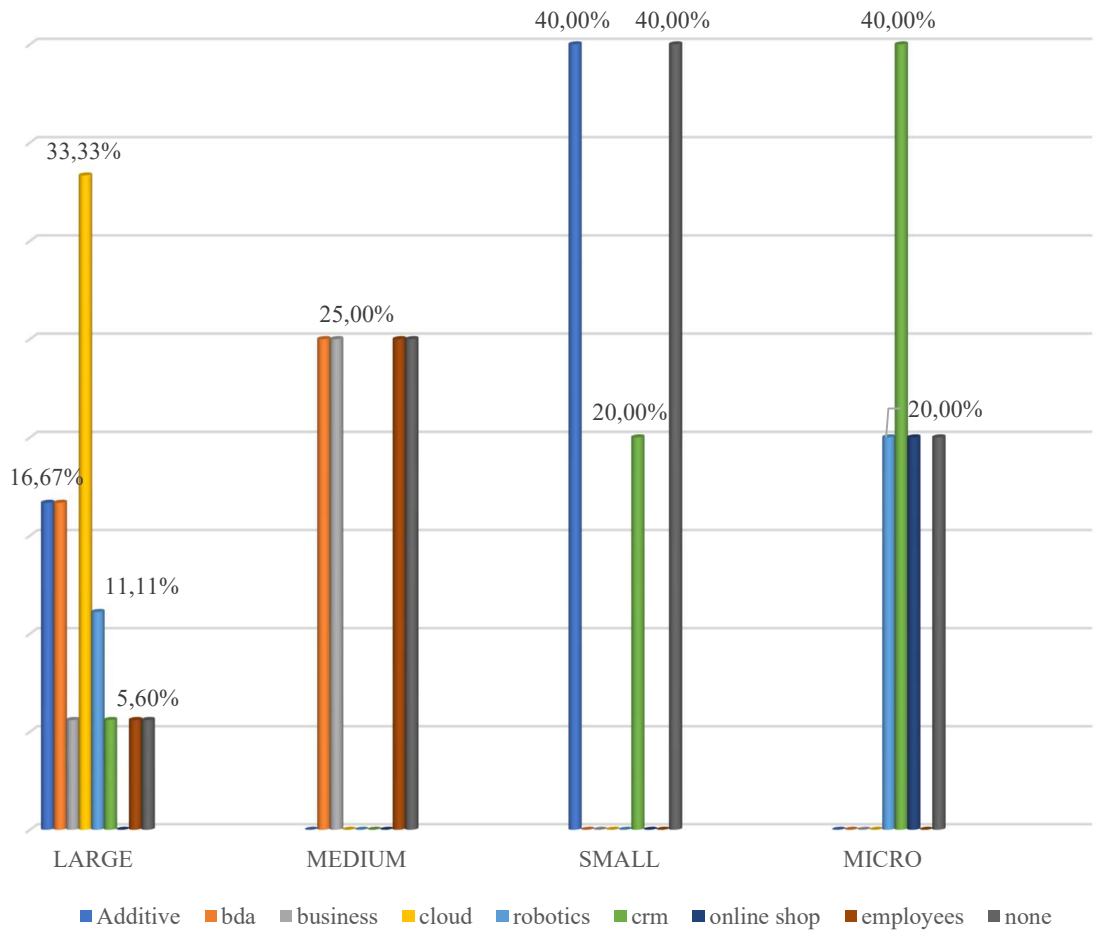

Figure 47: Currently implemented digital tools according to companies' size

By looking at the picture from a wider perspective, hence by clustering the participants in two main categories according to their tier of belonging, it's clear that for whom provide automotive strictly related parts the highest percentage of interest, 21,43%, refers to the Cloud Computing, while for whom provides products not solely related to the automotive

industry, the highest percentage of interest refers to the Additive Manufacturing (40%) (Figure 48).

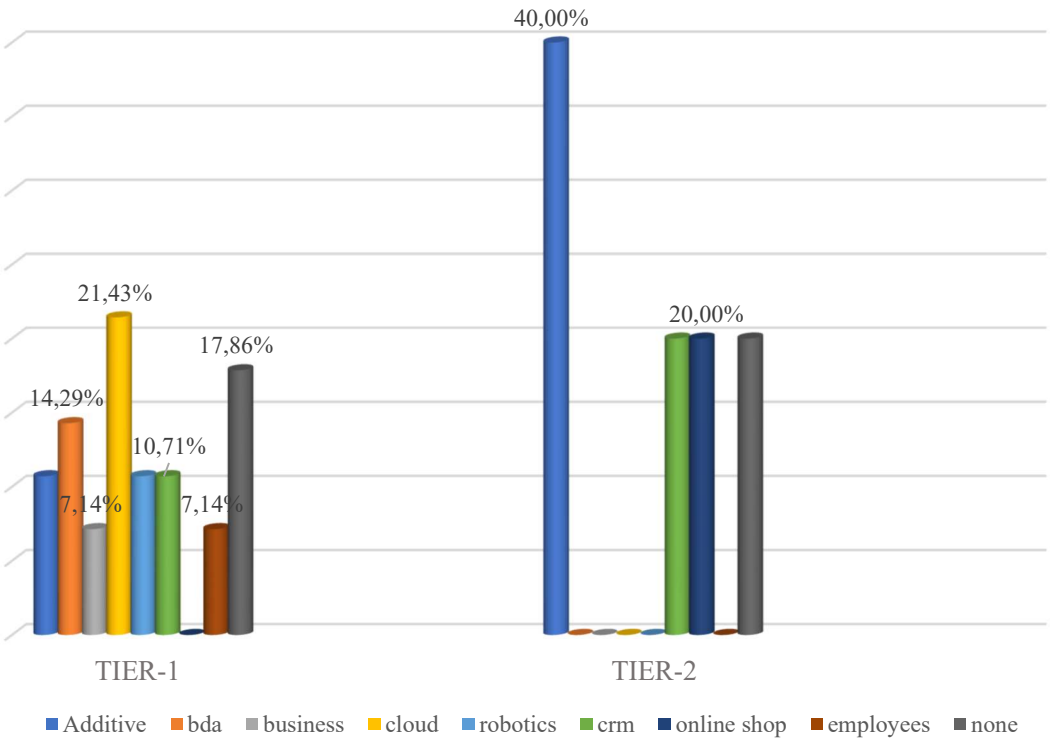

Figure 48: Currently implemented digital tools according to type of supplier

The respondents, divided according to their company size, shown different tendencies for what concerns digital technologies to be implemented in the next future (Figure 49). While for the large companies it was found more important to invest in Robotics, as stated by 50% of the respondents, for the small sized ones the focus for future implementations was directed toward Additive Manufacturing (57,14%). On the other hand, for what concerns micro sized companies the attention was equally divided between Cloud Computing, Robotics, Additive Manufacturing and

"Other" not identified digital tools (25% each). The medium sized participants, instead, represented a stand-alone case, having shown the most interest toward other digital technologies not included in the list retrieved as the most likely according to the reviewed literature.

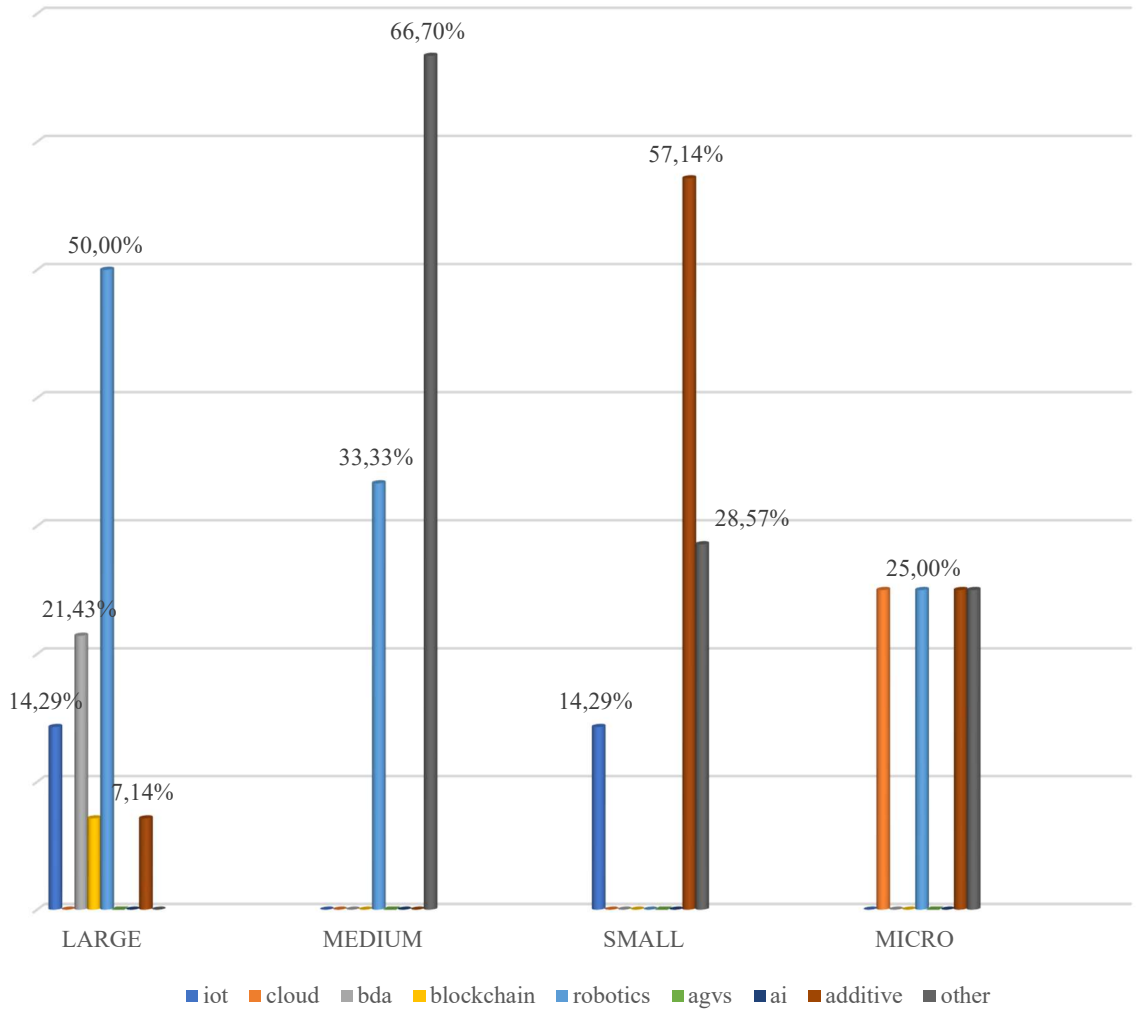

Figure 49: Digital tools to be implemented in the future according to companies' size

If a division is performed according to the type of contribution, the highest percentage of are reached by Robotics, for Tier-1 suppliers, and by

Additive Manufacturing, for Tier-2 ones, with 37,50% and 50% respectively (Figure 50).

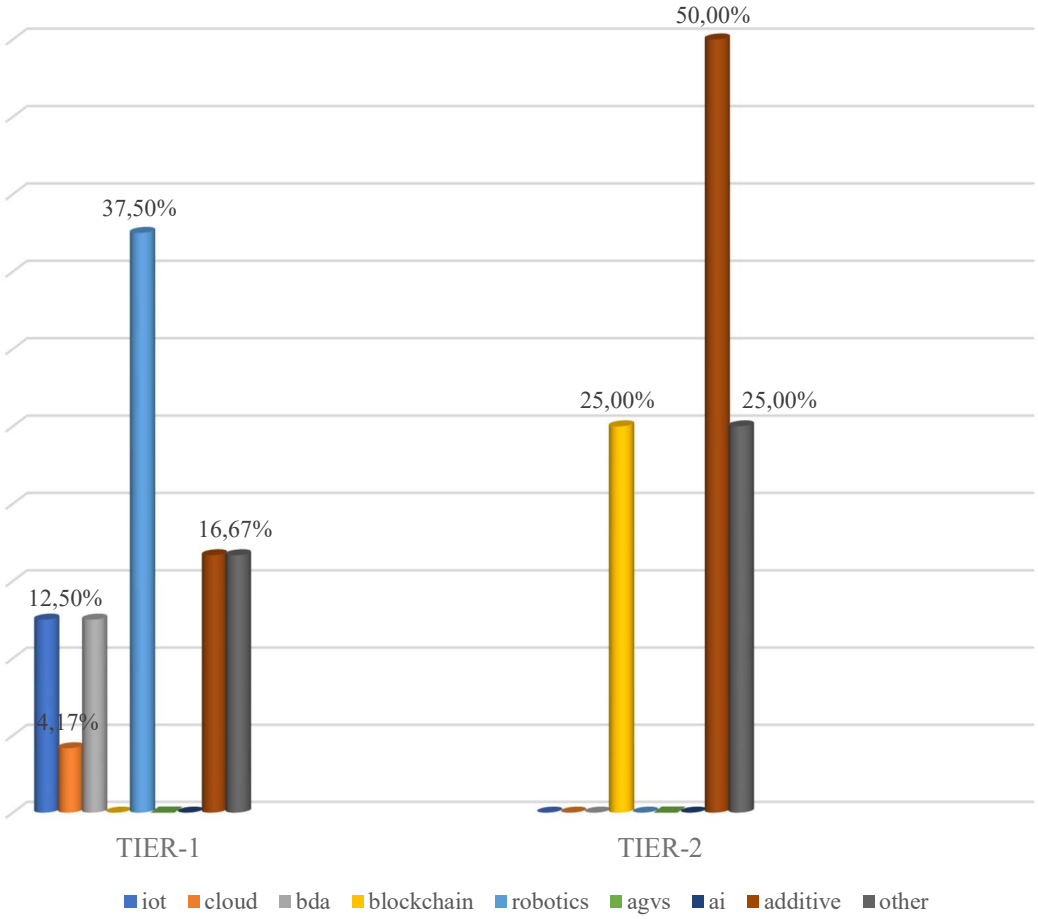

Figure 50: Digital tools to be implemented in the future according to type of supplier

5.3. EMERGING TRENDS

In the light of what highlighted in the previous paragraphs, the processes of supplier relocation, enterprise-to-enterprise transparency enhancement and digitalization will be addressed under the more particular point of view of each specific group identified before. Thus, it will be possible to define a link between different behavioral patterns and different company characteristics, whether they are the firms' sizes or whether they refer to the type of supplied products. Lastly, at the end of the chapter, by means of Table 2 it will be possible to display a summarizing representation of the survey results.

5.3.1. LARGE SIZED COMPANIES

The large sized companies, for whom the impact of the pandemic was mostly translated as a lack of orders, shown a strong interest in moving their own supplier base closer while they displayed a clear reluctance on moving in the vicinity of their OEM of reference, mostly due the absence of necessary products and resources that would arise in case of such a near shore sourcing. The literature identified as an appropriate relocation process, in order to increase the overall supply chain flexibility, the one granting a company suppliers from both near and far countries, with a steady domestic network as the basis. However, the interviewed large sized companies were adamant in assigning 1 point out of 5 possible to the question related to the helpfulness of being closer with the OEM when dealing with disruptions arising from the pandemic. This displays how the literature perspective had a focal point set elsewhere, disregarding the large sized companies necessity in such a matter. The firms belonging to

this category, considered an enhanced E2E transparency a moderately useful feature, showing how the research background precisely identified a way through which improve the supply chain course of operations. An increased visibility would have been particularly appreciated if present beyond Tier-2 suppliers, especially the provider of raw materials. In case of the latter, in fact, the lack of visibility was the more critical, accordingly to what was stated by the reviewed literature. Even if they already represent strongly digital players, as it was foreseeable for large sized firms, the virus doing was such to further push the attention of this group of inquired toward a more profound implementation of digital tools. They are currently considering implementing, if absent, or increasing, if already present, the use of Robotics, possible thanks to their often-larger economic base. On the other hand, the large sized firms are showing little to no interest for the other industry 4.0 technologies identified by the literature.

5.3.2. MEDIUM SIZED COMPANIES

For what concerns the medium sized companies, they figured as the interviewed that equally felt the pandemic effect in the most numerous numbers of areas. As matter of fact, they participants stated they indiscriminately suffered in supplies, production, orders and personnel availability. In their opinion, moving closer the supply base and moving closer to their OEM of reference is, in both cases, a negligible activity, mostly due to the potential lack of necessary resources and processes and the higher labor costs that an either re-shoring activity would bring. Once again, then, the literature findings seem to be focused solely on the OEM, neglecting the needs of the smaller players. As in the case of the large sized firms, this interviewed as well identified their own suppliers has

coinciding with the areas with the greatest lack of visibility and with visibility itself being an important aspect if enhanced, proving what stated in the literature Chapter 3. The medium sized firms assessed themselves as not really digital and as currently being involved mostly with Big Data Analytics, Business Intelligence Tools and Employees Management Tools, while seeking for the implementation of Robotic tools in the next future. Hence, their current implemented solutions are outside the range of possibilities of the reviewed digital technologies, revealing an initially lower but now increasing interest toward the opportunities that the industry 4.0 can provide.

5.3.3. SMALL SIZED COMPANIES

The small sized inquired were mostly affected in the production area. As well as the previously mentioned group of suppliers, they prefer to do not take into consideration neither of the two proposed re-shoring activities. As a matter of fact, none of both alternatives, in their opinion, would have been useful when facing COVID-19 related disruptions. Even in this case, the survey's findings coincided with what was anticipated by the existing literature, namely that it is present a lack of visibility along the supply chain and that it is mostly felt beyond Tier-2 suppliers. For what concerns the trend related to the use of digital technologies, these interviewed shown the greater interest toward Additive Manufacturing/3D Printing, which is currently implemented and at the same time continues to represent the most relevant digital tool in the next future as well. For the small sized firms too, the pandemic effects resulted in an increased

necessity of adopting industry 4.0 technologies, choosing, between the myriad of available ones, the one identified by the theoretical background Additive Manufacturing, showing a potential need of improving manufacturing flexibility by enabling in-house production of customized products.

5.3.4. MICRO-SIZED COMPANIES

The smaller participants, the micro sized ones, felt the pandemic doing especially in the areas related to production and orders. Similarly to medium and small sized firms, their interest toward any re-shoring process was absent and the identified area presenting the most serious lack of visibility was certainly the suppliers one. The micro sized firms revealed themselves as having numerous differences within one another, even if belonging to the same group. Their transparency level, in fact, was widely varying between absent and moderate. Unanimous was, however, this clustering opinion about the viability of a truly transparent supply chain, scoring the lowest score possible on the provided Likert scale. The literature background was in this case again on point, having foreseen as the greatest visibility lacking area the one related to the raw materials suppliers. Particular is the case regarding the implementation of industry 4.0 tools. As previously mentioned, the micro sized participant distinguished themselves for the variety of opinions expressed about the digitalization matter, displaying how different can be their behavior according to their own inherent characteristics. As matter of fact, they referred to themselves as either slightly, fairly or highly digital, but their

opinion was unanimous about the great fostering effect the COVID-19 had on the necessity of implementing digital technologies. Between the multitude of technologies proposed by the literature, despite currently using, for the vast majority, customer relationship tools, the displayed trend shown a great interest in a future implementation of Additive Manufacturing/3D Printing and Robotics.

5.3.5. TYPE OF SUPPLIED PRODUCT

The trends assume a slightly different shade when the participants are divided in Tier-1 and Tier-2 suppliers. In fact, both types displayed a lack of interest about the likelihood of moving closer to the OEM of reference, as well as the likelihood of moving closer their own supplier base, proving one more that the literature decided to refer on this topic on the OEMs. The opinion of this grouping's participants about the viability of a transparent supply chain was slightly different, showing that Tier-1 suppliers have more faith on the subject with respect to the other ones. One underlying reason can be that first-tier suppliers are generally used to a "arm's length" type of relationship with the OEM, hence they are already accustomed in sharing a great deal of information. On the other hand, the second-tier ones do not benefit of the same type of relationship, thus a greater uncertainty on the topic can be justified. The same was, for either group, the area relative to their own suppliers was the more transparency-lacking one. For what concerns the digitalization matter, the indirect suppliers were found to be more conscious about the necessity of boosting

their inner digital content, with respect with the direct one, even if the latter as well recognized such a process as having great importance. The reviewed theoretical background proposed a wide spectrum of possible new technologies by means of which a company can push toward highest summits. Within such a spectrum, while in their future the Tier-1 supplier seek the implementation of Robotics, the Tier-2 ones are more interested, as stated by the highest percentage within such a grouping, in keep on using the already implemented Additive Manufacturing.

			LARGE	MEDIUM	SMALL	MICRO	TIER-1	TIER-2
SUPPLIERS RELOCATION	Re-shoring closer the supply base	Likelihood	●●●●●	●○○○○	●○○○○	●○○○○	●○○○○	●○○○○
		Helpfulness when facing COVID-19 disruptions	●●●○○	●●○○○	●○○○○	●○○○○	●●●○○	●○○○○
		Impeding problems	Near-shore sourcing does not guarantee necessary resources/ processes	Near-shore sourcing does not guarantee necessary resources/ processes	Higher near-shore labor costs	Other	Near-shore sourcing does not guarantee necessary resources/ processes	Near-shore sourcing does not guarantee necessary resources/ processes
	Moving closer to the OEM of reference	Likelihood	●○○○○	●○○○○	●○○○○	●○○○○	●○○○○	●○○○○
		Helpfulness when facing COVID-19 disruptions	●○○○○	●○○○○	●●○○○	●○○○○	●○○○○	●○○○○
		Impeding problems	Near-shore sourcing does not guarantee necessary resources/ processes	Near-shore sourcing does not guarantee necessary resources/ processes	Higher near-shore labor costs	Other	Near-shore sourcing does not guarantee necessary resources/ processes	Not negligible reshoring process expensiveness
E2E TRANSPARENCY	Transparency level		●●●●○	●●●●○	●○○○○	●○○○○ ●●○○○ ●●●○○	●●●●○	●●●○○
	Viability of a transparent SC		●●●○○	●●●●○	●●○○○	●○○○○	●●●●○	●●●○○
	Helpfulness when facing COVID-19 disruptions		●●●○○	●●●○○	●●●○○	●○○○○	●●●○○	●○○○○
	Areas of lack of visibility		Suppliers	Suppliers/ Other	Suppliers	Suppliers	Suppliers	Suppliers
DIGITALIZATION	Digitalization level		●●●●○	●●●○○	●○○○○	●●○○○ ●●●○○ ●●●●●	●●●●○	●●●○○
	Fostering effect of COVID-19 on the use of digital tools		●●●●○	●●●●●	●●●●○	●●●●●	●●●●○	●●●●●
	Currently implemented digital tools		Cloud Computing	BDA/ Business Management tools/ Employees Management tools	Additive Manufacturing	Customers Relationship Tools	Cloud Computing	Robotics
	Digital tools to be implemented in the future		Robotics	Robotics	Additive Manufacturing	Additive Manufacturing/ Robotics/ Cloud Computing	Robotics	Additive Manufacturing

Table 2: Survey's most relevant results

6. CONLUSIONS

In this last chapter are discussed the benefits brought by the thesis work to the state of the art of the literature, concerning the effects of the COVID-19 pandemic on the automotive supply chain under the Tier-1 and -2 suppliers' perspective. Subsequently, the limits of the thesis will be analyzed together with the future steps that the research on the topic should deal with, starting from the thesis work.

6.1. BENEFITS OF THE THESIS WORK

As highlighted in Chapter 5, the present study represents a link between what was identified by the review literature and what are the currently adopted practices by the players participating in the Automotive Supply Chain. Such a comparison between theory and reality allows to understand which are the underlying reasons driving a company to act in a certain way. A company size, for instance, and its relative economic power, can push the decision-making process toward more conservative solutions, with respect to what was theoretically identified as the best way of proceeding. When dealing with disruptive forces of the same magnitude of the pandemic one, a firm has in fact first to assess which are its own possibilities, along with its own capabilities, before undertaking any suggested path. As matter of fact, a company size is often directly proportional to its economic clout. Micro and small sized companies, leaving apart the cases when there is a lack of interest, are not in the same position of a large sized one when considering investing in digital technologies proper of industry 4.0, especially when facing the blunt hit of COVID-19. The same consideration stays valid when evaluating the

other features of supplier re-location and E2E transparency. In either case, there is a fundamental lack of bargaining power the often holds back these type of companies from the sole worrying about such matters. Highlighting such deep differences can push the research toward a less broad audience, shrinking the scope of the literature and making it focus on smaller realities with the respect to the always more addressed bigger ones. Furthermore, this thesis work shows that some features identified by the literature as being of prominent importance were actually disregarded. This is the case in particular of the possibility of moving closer to the OEM, that evidently is an occurrence that assumes a major importance only when considering the point of view of the OEM themselves, while, according to the opinion of the interviewed, holds little to none value at all whether it is the case of thinking about re-shoring to the OEM or whether it is the case of evaluating its usefulness when dealing with the pandemic aftermath. Moreover, the present thesis work allows to highlight which actually were the companies' areas most affected by the pandemic. These findings can potentially aid the firms involved in the automotive industry in better addressing arising disruptive events, according to their own sizes or, more generally, to their supplied products, by placing more attention on shielding specifics areas with respect to less vulnerable ones.

6.2. LIMITS OF THE THESIS WORK

Like the vast majority of survey-based researches one main critical limitation is the response rate, which is about 9%. The best approach possible was surely to analyze the supply chain as a whole, under the

widest scope at disposal, namely involving all the actors participating in the automotive industry. However, it was considered as a more suitable sampling process clustering the multitude of suppliers according first to a geographical standpoint, preferring closer locations with respect to further ones, and second to the characteristic of such sector, within which some actors are way more accessible than others. In particular, reviewing the literature displayed clearly that some countries, especially relevant for the whole automobile industry, e.g., China, were difficult to came in contact with and therefore they were excluded in advance. Moreover, greater sample and a subsequent higher number of possible respondents would have allowed the implementation of statistical tests such as the Kruskal-Wallis one, not implementable in the present study due to the inequality in the number in participants once divided according to the previously mentioned clustering methods. Obviously, the use of statistical tests of such type is, in turn, subject to inherent problems, one being for instance the over reliance on the p-value. Nevertheless, the addition of a further method to investigate the retrieved results, if properly adopted, could have positively enhanced the content of the present study

6.3. FUTURE RESEARCH

The present study has highlighted which were the criticalities arisen due to the COVID-19 outbreak, how such criticalities translated and impacted the automotive industry and how the different players belonging to the categories of Tier-1 and Tier-2 suppliers should act according to literature. The findings then were cross-checked by looking at the actual practices

adopted by the above-mentioned suppliers in the pandemic aftermath, by means of a survey. As stated in the previous chapter 6.2., regarding the limitation of the work, future researches should focus on enlarging the scope of interest to then compare and identify whether there are differences in SC management patterns according to different geographical groupings. Alternatively, future research work could investigate the resilience of this supply chain by addressing different key features with respect to suppliers re-localization, E2E transparency and digitalization. In the current always changing landscape characterizing the automotive environment, future research should focus on how the construction of supply chain resilience mutates according to the everyday more prominent presence of electric vehicles or to the development of new digital tools, enabling previously not available solutions. Finally, the thesis also underlines how companies acts in different fashion depending on how large they are, suggesting room for more in dept researches regarding sub-categories of suppliers, performing a division between players belonging to the same tier for what concerns the type of supply, but with substantially separate behavioral patterns due their dimensions or geographical location.

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APPENDIX

Appendix A. Scheme of the questionnaire used for data collection

Section 1 – Respondents' features assessment:

Q.1. What is your role within your company?

……..

Q.2. What size is your company?

- Micro-sized (< 10 employees)
- Small-sized (< 50 employees)
- Medium-sized (<250 employees)
- Large-sized (>250 employees)

Q.3. Where is your company located?

……..

Q.4. In which way does your company contribute to the automotive industry?

- It supplies automotive parts and systems
- It supplies non-automotive grade parts

Section 2 – Pandemic's impact assessment:

Q.5. Which was the most affected area by the pandemic within your company?

……..

Q.6. How serious was the impact on the previously mentioned area?

	1	2	3	4	5	
Not relevant	○	○	○	○	○	Extremely relevant

Section 3 – Suppliers' location importance assessment:

Q.7. Is your firm considering to re-locate its supply base in order to have key suppliers closer?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.8. How much, in your opinion, a closer supply base would have helped when dealing with COVID-19 related disruptions?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.9. What are the main difficulties that may arise when trying to re-locate your supply base?

- Higher near-shore labor costs
- Not negligible re-shoring process expensiveness
- Near-shore sourcing does not guarantee necessary resources/processes
- Other

Q.10. Is your firm considering moving closer to one of its Original Equipment Manufacturer (OEM, e.g., vehicle assembler)?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.11. How much, in your opinion, being closer to the OEM of reference would have helped when dealing with COVID-19 related disruptions?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.12. What are the main difficulties that may impede moving closer to the OEM of reference?

- Higher near-shore labor costs
- Not negligible re-shoring process expensiveness
- Near-shore sourcing does not guarantee necessary resources/processes
- Other

Section 4 - Supply chain transparency assessment:

Q.13. Enterprise-to-Enterprise (E2E) transparency can be defined as the extent to which all supply chain stakeholders share a common understanding of, and have common access to, product-related information that they request, without loss, noise, delay and distortion. With respect to such definition, how transparent is the supply chain your firm is part of?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.14. At which point along the supply chain your company is part of there is the most evident lack of visibility?

……..

Q.15. Do you think a deeper understanding of the participants of your supply chain would have been useful when dealing with the pandemic related disruptions?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.16. Is, in your opinion, E2E transparency a viable option for your supply chain or do you think there are features (e.g., lack of trust) impeding it?

	1	2	3	4	5	
Not viable	○	○	○	○	○	Completely viable

Section 5 - Firm's level of digitalization assessment:

Q.17. How much your company can be considered digital?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.18. Did the pandemic foster the use of digital technologies to prevent/respond to unforeseeable disruptive events?

	1	2	3	4	5	
Not really	○	○	○	○	○	Definitely

Q.19. Is you firm currently implementing any digital tool? (If yes, please insert its/their relative name/names)

……..

Q.20. Is your firm considering implementing one of the following digital tools in next future? (Select more than one option if needed)

- Internet of Things (IoT)
- Cloud Computing
- Big Data Analytics (BDA)
- Blockchain
- Robotics
- Automated Guided Vehicles (AGVs)
- AI/Machine Learning
- Additive Manufacturing (3D Printing)
- Other

Appendix B. Cover Letter

Date 18/01/2022

Dear Participant,

my name is Alessandro Ciavarella and I am an Automotive Engineering student at Polytechnic University of Turin, Italy. For my Master's Degree final project, I am investigating the effects of the SARS-CoV-2 pandemic on the supply chain of the automotive industry. The aim of the research in particular is to understand how resilient the afore-mentioned chain was from the first- and second- tier suppliers' point of view, by assessing the overall Enterprise-to-Enterprise (E2E) transparency along the chain, their reliance on specific supplier locations, and their degree of digitalization.

Therefore, in the light of the valuable experience of your Company, I kindly ask you to complete the questionnaire attached to the mail, it will require approximately five minutes. The questionnaire consists of 20 questions, mostly close-ended, regarding the previously mentioned topics and it was built in order to be quick and essential, hoping to encourage a higher response rate. If you choose to participate to this survey, please answer as honestly as possible, conscious that no critical information will be necessary throughout the questionnaire, and make sure the survey is delivered to the most appropriate professional.

Please, do not include your name. Your anonymity is further protected by not asking you to sign and return a consent form, your completion of the questionnaire will serve as your consent.

If you need any further information, please contact me at the same address from which you are receiving the present email.

Thank you for your participation.

Sincerely,

Alessandro Ciavarella

Appendix C. List of the participants' electronic addresses

verkauf@abmetallwaren.at	airfren@airfren.com	jaroslava.porsova@autozavod.cz
Sensing@abelektronik.de	supplier.diversity@celanese.com	sales@celikel.com
verkauf@abw-drehteile.at	sales@cellbond.com	media.inquiry@autoneum.com
office@ach-solution.at	contact@cellcentric.net	contact@customcells.org
textil@a-haberkorn.at	sales@baileymorris.co.uk	enquiries@cellularmouldings.co.uk
eloxal@heuberger.at	datenschutz@atarax.de	vaclav.jindra@brano.eu
office@akg.at	sales@bancroft.co.uk	geral@celoplas.pt
office.at@alu-menziken.com	p-pietsch@bandstahl-schulte.de	sales@cirteq.com
md-amag@amag.at	bumar@bumar.gliwice.pl	Dana.LiveSource.com
office @ arvai-plastics.at	contact@bumet.com	sales@balseal.com
office@atzlinger.at	bb@bureaubaterias.com	exidemkt@exidegroup.com
office@audio-mobil.com	boysen@irs.uni-stuttgart.de	office.bda@bannerbatterien.com
office @ becom-group.com	kontakt@burgtec.de	sales@bantboru.com
b.behr@begalom.at	contact@atm-plasturgie.com	ceva@ceva-tech.com
sales.berkhamsted@buntingmagnetics.com	enquiries@admpressings.co.uk	bewerbungen@baertle-cnc.de
bossard@bossard.com	pcb@baskidevre.com.tr	edith.schilk@c-f-maier.de
office@boxmark.com	contact@cgr-international.com	biuro@admot.com.pl
office@burg-design.com	chemetall.polska@basf.com	welcome@chmueller.com
biuro@chemiplastyka.pl	sekretariat@adomeitgroup.com	techhelp@belf.com
contact@groupe-courbis.com	verkauf@certoplast.com	biuro_konst@coko-werk.de
service@corteco.de	unbrakosales@unbrako.com	comforsa@comforsa.com
u.slotczinski@awab.de	ctc.c@airbus.com	richard.sebek@brano.eu
bzenec.personalni@kyocera-avx.com	milena.vittone@cfita.it	sales@componenta.com
tim.kaldeuer@asmetal.de	office@curtisinst.de	chen@connector-switch.de
vevosz@auguszt.axelero.net	order@curtisab.se	sekretariat@dsse.daicel.com
moc.yaborua@olleh	itorders@curtisinst.it	contact@cmd.fr
lindenberg@scharnau.de	f.chauzu@cqfd-composites.com	snab@avtoltd.com
marketing@bf1systems.com	handlowy@autopart.pl	buh@avtoltd.com
nina@nonwovenn.com	awloszczyna@autopart.pl	sale@avtoltd.com
mail@bfr-wisskirchen.de	ape@ape.com.pl	autosattlerei_jansen@yahoo.de
inforao4.0@rao.it	sales@auto-plas.co.uk	sales@autosplice.com
prosperilavsrl@gmail.com	mlysiak@ape.com.pl	kuehler@bergmeir-seitz.de
officinalanotte@tiscali.it	engineering@bsh-vs.com	info@tmtsrl.com
amministrazione@cargosrl.it	info@domygo.it	info@inoxcar.it
rcmromeo@tiscali.it	contatti@blocksystem.it	verbo.ribaltabili@libero.it
info@silor.it	info@deltaservicedieselengines.com	info@volantiluisi.it
commerciale@bmcarpenteriesrl.com	dianaauto@libero.it	amministrazione@beond.net
emmetimmobiliaresrl@gmail.com	tiberiauto@alice.it	postmaster@eosplant.it
info@htlfitting.com	gl@evolvo.org	assistenza.centrautotopputo@gmail.com
info@novatecgroup.it	export@officine-bontempi.com	dim@molle.com
amministrazione@novatecgroup.it	info@biesseturbo.it	tecnomeccanica@ombgroup.it
gnmarketing@geesinknorba.com	francesco@effediemme.co	premec@premec.net
info@covein.com	info@effegiauto.it	morel@morelitalia.com
ifcomposites@gmail.com	INFO@FRASMA.IT	cabelauto@gmail.com
info@giomar.eu	info@rekar.it	info@ivt.it
info@imasaf.it	sales@erbitaly.it	vendite@procarmilano.it
info@byernest.it	liverani@liverani.com	info@aret-engineering.com
com@onnivan.it	info@cevansrl.com	sales@globalsystemfiltri.com
info@gallesi.it	info@officinefava.com	info@sacirest.com
r.scanu@asc-cawi.de	info@cbspecialcomponents.com	info@ribaltabiliomgb.com
autogasitalia@autogasitalia.it	info@lapaservizi.it	comforsa@comforsa.com
p.schlittenbauer@as-industrietechnik.de	p.cogiel@cwbearing.de	richard.sebek@brano.eu
t.kerschbaum@as-industrietechnik.de	engineering@cwbearing.de	sales@componenta.com
gmachin@as-sl.com	p.lelkes@cwbearing.de	chen@connector-switch.de
service@solarcarporte.de	thomas.koch@kochgmbh.de	sekretariat@dsse.daicel.com
kiriarte@as-sl.com	mail@czarny-ries.de	contact@cmd.fr
export@asso.com.pl	alabuga@coskunoz.ru	mail@cmasa.com
jnawrotkiewicz@astromal.pl	sales@ctgplc.com	cechy@construct.cz
atd@atd-gmbh.de	mikfil@mikfil.com	chrenka@construct.cz
fahrzeugaufbau@atlas-leipzig.de	sales.extrusion@constellium.com	pittner@construct.cz
torgau@atlas-leipzig.de	swerner2@cotarko.com	david@construct.cz

ml@lindenberg-ael.de	jschnie3@cotarko.com	zenata@construct.cz
contact@bcomp.ch	sales@cotec-gmbh.com	contact@vitesco.com
rainer.sziebert@bkm-praezision.de	sales@cwpl.net	Inquiries@corning.com
juergen.pleiel@bkm-praezision.de	ina.tedden@asmetal.de	Anja.Schmidt@antec-online.de
fachseminare@boellhoff.com	radevormwald@arburg.com	angelika.hack@antec-online.de
cs@bijurdelimon.com	arfesan@arfesan.com.tr	snab@avtoltd.com
f.bolley@bolley-gmbh.de	g.wende@asc-cawi.de	buh@avtoltd.com
vertrieb@binder-tecsys.de	biuro@aures.pl	sale@avtoltd.com
creativetapes@scharnau.de	office@arvai-plastics.at	autosattlerei_jansen@yahoo.de
technical@bip.co.uk	j.maiwurm@asc-cawi.de	sales@autosplice.com
adrian.bisson@nonwovenn.com	amsterdam@coatinc.com	kuehler@bergmeir-seitz.de
abuettgen@herpertz.de	nederland@coatinc.com	info@tmtsrl.com
technik@herpertz.de	demeern@coatinc.com	info@inoxcar.it
verkauf@herpertz.de	groningen@coatinc.com	verbo.ribaltabili@libero.it
technicalassistance@dirna.bergstrominc.com	cgr.verkoop@coatinc.com	info@volantiluisi.it
berger-holding@aberger.de	prega.nl@coatinc.com	amministrazione@beond.net
info@frigovan.it	kontakt@ct-formpolster.de	postmaster@eosplant.it
info@collerock.com	rhein-main@coatinc.com	assistenza.centrautotopputo@gmail.com
luca.rangoni@tecnodomsport.com	peine@coatinc.com	dim@molle.com
info@rhapis.it	becker@coatinc.com	tecnomeccanica@ombgroup.it
info@balsamoscambiatoritermici.it	siegen@coatinc.com	premec@premec.net
dpo@etraspa.it	prega@coatinc.com	morel@morelitalia.com
info@ilgommaio.it	wuerzburg@coatinc.com	cabelauto@gmail.com
info@tmracing.it	malacky@zinkpower.com	info@ivt.it
produzione@mollificiogr.it	r.varisco@cwbearing.de	vendite@procarmilano.it
amministrazione@evotech-rc.it	warehouse@cwbearing.de	info@aret-engineering.com
info@fcmdicalandrini.it	r.kvist@cwbearing.de	sales@globalsystemfiltri.com
info@lanzonicarinteriors.it	sales@cwbearing.de	info@sacirest.com
surflex@iol.it	doga@doga.es	info@ribaltabiliomgb.com
infoalubi@gmail.com	enquiries@advanced-plastics.co.uk	mail:comercial@burlet-tecnic.com
info@mach3srl.com	atbadm@benevenuta.it	cm@comercialdelmotor.com
info@trasmatic.com	post@andorit.de	sales@comp.co.uk
info@romanital.com	rma@antec-online.de	grupo@grupocopo.com
sales@seltap.it	welcome@andritz.com	werdersystems@sunrise.ch
ecocarsud@libero.it	anga@anga.com.pl	cts@cts-france.com
info@rmcarsrl.it	sales@antec-online.de	sales@copely.com
vertrieb@bb-gruppe.de	sales@barksdale.com	sales@copwash.co.uk
wilfried.boomgaarden@baumgarten.de	andreas@baude.de	jani.saarenpaa@coreplast.fi
burkhard.strauch@baumgarten.de	contact@coretec.eu	info@daicospa.com
pressoffice@beckers-group.com	commerciale.lamiera@cornaglia.com	info@emecar-srl.com
wzb@beck-formenbau.de	commerciale.cortubi@cornaglia.com	info@demaxsrl.it
henrik.kristensen@beijerind.se	eindhoven@aalberts-st.com	csv.sistemi@gmail.com
johnny.lund@beijerind.se	service@hoefert.de	info@roresas.com
belis@belis.eu	eschenbach@aalberts-st.com	info@cb-srl.com
bewerbungen@boegra.com	office@tielke.de	info@zetaerre.parts
mauro.soncin@bonfiglioli.com	sales-automotive@amk-group.com	info@medicistyle.it
x.leroy@bollore.net	geral@ammoldes.com	lamadei@modenamotori.it
e.fossorier@bollore.net	acc@amorim.com	abernardi@modenamotori.it
marketing@brink.eu	distribution.literature@analog.com	mferrari@modenamotori.it
calidad@brugarolas.com	hello@amtepower.com	epapower@epapower.com
comercial@brugarolas.com	barbara.butz@huber-drehteile.de	info@h2o-performance.com
pedidos@brugarolas.com	helfrich@antec-online.de	andrea.wiedmann@baude.de
bremsscheiben@guss.buderus.de	sales@ayrshire.co.uk	Bayraktarlar@bayraktarlar.com
reinigungssysteme@buefa.de	gevelsberg@vollmann-group.com	jc.borelly@wanadoo.fr
a.kraetsch@awab.de	sales-support@calesco.se	ventas@dirna.bergstrominc.com
h.fritz@awab.de	hungary@baier-michels.com	imprint@boschrexroth.de
simong@bpw.hu	spain@baier-michels.com	rohs@bourns.com
customerservice.italia@bonfiglioli.it	turkey@baier-michels.com	info@tcsrl.it
contact@deltec.fr	italy@baier-michels.com	info@eyesontheloop.com
sales@tdz.com	planering.mekatronik@aqg.se	info@boneschi.eu
direct@uk-avt.ru	support.it@balluff.it	info@primatistsrl.com
marketing@belzan.ru	office@bannerkunststoff.com	info@thermoservice.it
nissens@nissens.com	contact@atm-plasturgie.com	graborgm@virgilio.it
cedric@azur-roulements.com	sales@anamet.nl	mail@reflexallen.com
gilles@azur-roulements.com	navi@esxaudio.de	kontakt@agor.de

ga.communication@grupoantolin.com	sales@apracing.co.uk	mazuer@cimap.fr
automotive@certoplast.com	cic.emea@analog.com	sales@aikawa.hu
Kate.Saxton@gknautomotive.com	elliematthews@apsmith.co.uk	sogefispa@sogefigroup.com
enquiry@accoatings.co.uk	erik.olsson@aqg.se	casals@casalsmd.com
contact@ad-venta.com	alexandra.tomilin@axalta.com	atcestampaciones@atcestampaciones.com
zentrale@premium-precision.com	u.roesner@atlas-leipzig.de	GDPR@amsafe.com
sales@adwin.co.uk		