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Supply Chain Performance Metrics in the Lean, Agile, Resilient, Green Perspectives: a survey and model

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Abstract

This paper aims to identify adequate metrics to measure supply chain performance in its entirety, following the framework of the lean, agile, resilient, green (LARG) models. A list of 112 metrics referring to the LARG perspectives was derived from an analysis of relevant literature. On the basis of that list, a questionnaire survey was developed, for evaluating the usage of the various metrics in real contexts. Overall, 33 companies located in the Italian territory provided their feedback to the questionnaire, indicating the metrics used inside the company itself and the perceived importance of each metric. Besides the LARG metrics, the questionnaire was also used to analyze the context in which the various companies operate in the current state of the world, having been heavily impacted by both the coronavirus (COVID-19) pandemic and by the Industry 4.0 innovations. The survey asked the selected companies to give opinions about 13 statements regarding the impact of Industry 4.0 and COVID-19 on their supply chain. The research found that 15 out of the 112 metrics are considered to be essential to measure the performance of the supply chain, as well as the correlation between company size and metrics used.

Keywords: LARG; survey; Italy; empirical study.

1. Introduction

Supply chains and their players are increasingly facing various internal and external challenges. Various phenomena have been characterising the markets in the last decades, such as globalization, price volatility, competitiveness, network complexity, or demand customization (Lotfi & Saghiri, 2018). Moreover, the recent epidemic outbreak caused by the COVID-19 pandemics largely disrupted supply chains worldwide; its unpredictable behaviour could lead to inappropriate decision-making, in turn causing severe economic shocks (Jha et al., 2021). Performance measurement systems are recognised as tools that allow managers to monitor the relevant performance indicators of their products, services and internal/supply chain processes, over a given period of time (Gunasekaran et al., 2001, 2004).

In an attempt to combine the various perspectives of supply chain effectiveness and evaluating the relating performance, the concept of LARG (lean, agile, resilient, green) performance measurement systems was introduced (Azevedo, Carvalho, & Cruz-Machado, 2011). The four LARG perspectives are recognised as a suitable response to the changing demand and characteristics of modern markets. The integration of these perspectives in the same framework is of paramount importance also from a strategic point of view. If, on one hand, lean strategies would call for designing products to minimize the waste and increase the added value for the customer, agile and resilient strategies, on the other hand, advocate that a supply chain must be responsive to customer and able to regenerate after a disruption. Greenness, finally, suggests that all the above aspects should be obtained without affecting the environment.

For a proper implementation of the LARG concepts, there is typically the need to measure the capability of supply chain players along the four perspectives, which could be obtained by developing an appropriate set of metrics. Indeed, the main challenge in applying LARG models in real cases is the proper identification of the set of indexes to be used. Although there are numerous performance metrics in literature, it is unlikely that a company will make use of all these indexes, because of various reasons. First, performance metrics typically need to be customized taking into account the specific market field, for being effectively used in a company and capturing its real situation. Second, among the metrics available in literature, any company will select a subset of useful indexes depending on its specific processes. Third, some perspectives of the LARG models have been more debated than others, especially in recent times, resulting in more indexes available. This is, for instance, the case for the resilient perspective, which has been recently emphasized by the COVID-19 pandemics. A fourth aspect is the availability of data useful for computing these indexes and therefore evaluating the company's performance. Industry 4.0 technologies could provide a valuable support to data collection and elaboration to this purpose.

In line with this set of considerations, this paper proposes an empirical study, in the form of a questionnaire survey, focusing on the general theme of performance measurement along with the LARG perspectives. Within this theme, two specific aspects are analyzed. The first one refers to the degree of usage of performance indexes relating to the LARG perspectives; the second one concerns the impact of Industry 4.0 technologies and COVID-19 on the supply chain performance, in terms of improvement, worsening or simply evaluation, again with a particular attention to the key perspectives of the LARG framework. On the basis of the responses received, some key considerations are elaborated concerning the two specific topics mentioned.

The remainder of the paper is organized as follows. The next section details the methodology followed in the study, in terms of questionnaire contents, questionnaire development, sample construction and analyses made. Section 3 proposes the main results of the study against the two topics introduced above. Section 4 concludes by summarizing the study, highlighting the scientific contribution, and, most importantly, developing theories for future research directions.

2. Materials and methods

2.1. Survey contents

The survey proposed in this study includes contents that basically reflects the two topics mentioned in the Introduction section. As far as the first topic is concerned, the performance metrics embodied in the questionnaire survey were derived from an analysis of the scientific literature. The databases used for identifying the pertinent studies were "Scopus", "Web of Science" and "Google Scholar". The following keywords were used in the search: "Supply Chain", "LARG", "Agile Supply Chain", "Green Supply Chain", "Resilient Supply Chain" and "Lean Supply Chain"; it is easy to see that the keywords used basically reflect the LARG perspectives. Moreover, concerning the second topic, the same databases were used to analyze the context with the keywords "COVID-19" and "Industry 4.0".

Using the above search terms, a total of approximately 40 papers focusing on performance measurement metrics within the LARG framework was derived. Further 10 papers, approximately, focused instead on the impact of COVID-19 and Industry 4.0 on the supply chain performance. Looking at the LARG perspectives, 112 metrics were obtained from the literature, divided into 5 macro-categories, and then into sub-categories to make the survey clearer. Macro-categories refer to the supply chain in its entirety and to each of the four LARG perspectives.

2.2. Questionnaire development

The questionnaire survey was prepared using the platform "Google Modules" and consists of three sections.

The first part of the survey is basically focused on defining a profile of the respondent company; as such, relating questions asked the companies to indicate their size and business area. For the former aspect, a multiple-choices question was formulated, including the following options: big company (>249 employees), medium company (between 50 and 249 employees), small company (between 10 and 49 employees) and micro company (<10 employees). For the business field, the companies could select between food, automotive, metallurgic/metal mechanic and pharmaceutical, and in the case the company belonged to a different field they were given the option to directly type it. On the contrary, for privacy reasons, the company names were not asked. Questions of this section were nonetheless used for determining possible relations between the metrics used and company size and/or business field.

The second section of the survey reflects the list of the performance metrics identified from the available literature and organized into the categories mentioned. The first macro-category (relating to the *entire supply chain*) includes 35 metrics and is divided into three sub-categories, focusing on general indicators, economic indicators and time indicators. The second macro-category (*green* perspective) includes 20 metrics, divided into three groups, such as general indicators, economic indicators and use/emissions. The *lean* category has 19 metrics, divided into general indicators, time indicators and economic indicators. The *agile* category consists of 12 metrics in one single group. Finally, the fifth category

(*resilient* perspective) includes 26 metrics, shared among general indicators, time indicators, economic indicators and customers satisfaction. Some of the metrics of the survey could be repeated, as they are supposed to be interpreted in the different perspectives. As an example, the metric "percentage of waste" is repeated in both the lean perspective and the green perspective as they apply to each perspective differently.

The respondents were asked to select the metrics they currently use to measure their supply chain performance, as well as to specify which metrics they considered as particularly relevant, regardless of their use.

Following the findings from the literature, the third section of the survey focuses on the context in which the supply chain operates. This section is divided into two parts, relating to the Industry 4.0 (I4.0) and the COVID-19 pandemics. The part about I4.0 consists of seven statements, which explore the technologies of I4.0 and their usefulness for performance improvement in the supply chain, as shown in Table 1.

Table 1. Statements on Industry 4.0.

Statement	Source
Industry 4.0 has a positive impact on green purchasing	Umar et al., (2021)
Industry 4.0 has a positive impact on green design	*ibidem*
Industry 4.0 has a positive impact on green training	*ibidem*
Industry 4.0 has a positive impact on green manufacturing	*ibidem*
Industry 4.0 has a positive impact on supply chain resilience.	*ibidem*
GSCM practices mediate the relationship between Industry 4.0 and environmental performance	Frederico (2021)
GSCM practices mediate the relationship between Industry 4.0 and economic performance	*ibidem*

The last part of the survey is dedicated to the COVID-19 pandemic and its relationship with the performance of the supply chain. This part has six statements regarding the impact that Industry 4.0 technologies have on supply chain in the COVID-19 context. The statements are shown in Table 2.

Table 2. Statements on COVID-19 pandemic.

Statement	Source
Industry 4.0 technologies impact on reactivity and resilience of supply chain.	Frederico (2021)
Big data analysis improves decision process in supply chain amid the COVID-19 pandemic	*ibidem*
Integration of IoT and cloud computing in supply chain processes contributes to the improvement of supply chain performance	*ibidem*
Integration of artificial intelligence, of robotics and augmented reality in the supply chain improves performance	*ibidem*
Integration of additive manufacturing in the supply chain processes contributes to performance improvement.	*ibidem*
Blockchain technology has a positive impact on traceability and security of supply chain	*ibidem*

For each of the above statements, the respondents were asked to express their degree of agreement, on a linguistic scale with the following options: "strongly agree", "agree", "not really agree", "strongly disagree".

2.3. Sample of companies

For testing purpose, the survey was initially sent to a manager of a company, who was asked to make a preliminary analysis of the questionnaire contents, completeness and clarity. Following the feedback received, some modifications were made to the survey and a final version was delineated. The final version of the survey (in Italian) can be seen at: https://docs.google.com/forms/d/e/1FAIpQLSenZzJmDo9qxQm2vgRaCQCdaJDFksCETBjjbylLx7yS_PIsOA/closedform.

Then, an appropriate sample of companies was built starting from the following sources: personal contacts of the author, contacts shared by the University of Parma, contacts shared by personal contacts of the author, e-mail addresses found on companies' websites and e-mail contacts shared directly by companies' managers. Overall, a list of 151 companies from different business fields and of different size was obtained by gathering those sources of information. The survey was then sent by e-mail to the addresses of selected companies; 33 useful replies (21.8% response rate) were obtained. As in any survey, there were some difficulties in receiving the responses. The main one was that the recipient of the survey was not able to respond and, in that case, was asked to forward the questionnaire to a more appropriate company's representative. However, the authors have no control on this process, and therefore it is not known whether the questionnaire was really forwarded. Another issue sometimes observed was that privacy issues prevented the recipient to respond to surveys sent by external parties.

2.4. Data analysis

With the answers received, the authors tried to highlight correlations between the size and/or the business field of the companies and the metrics used. To this end, the metrics were first examined entirely, looking at the whole set of indexes in each category, and then they were narrowed down to the ones used most frequently. The main goal of this analysis was to identify the most relevant metrics to measure supply chain performance.

Looking instead at the questions relating to the context (COVID-19 & I4.0), the responses were initially elaborated as a whole. Then, to get a more detailed focus, only the "strongly agree" and "agree" answers were considered, with the aim to highlight the elements on which the respondents agree most.

3. Results and discussion

This section of the paper analyses the findings of the

survey.

3.1. Sample overview

For providing an overview of the answers obtained, the responding companies were classified as a function of the business field and size; results are shown in Table 3 and Table 4.

Table 3. Business fields from the sample.

Business field	Answer
Metallurgic/metal mechanic	57.60%
Food	12.10%
Automotive	12.10%
Pharmaceutical	6.10%
Minimarket	3.00%
Defense	3.00%
Optical	3.00%
Personal services	3.00%

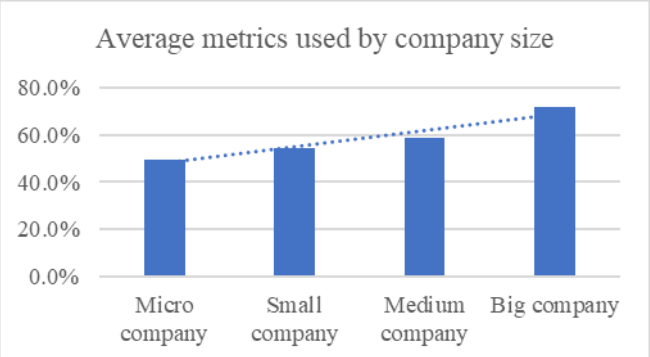
Table 4. Company sizes from the sample.

Company size	Answers
Micro company	12.1%
Small company	12.1%
Medium company	39.4%
Big company	36.4%

The first finding of the survey is that the business field that uses, on average, more metrics compared to the remaining ones is the food field, which averaged 82.4% of the metrics of the survey. This is explained by the fact that the food field is a field with very differentiated products and services and therefore it probably needs to measure more performance metrics than fields with less variation of products.

Looking at the company size, the survey shows that there is a strong correlation (96%) between the company size and metrics used to measure supply chain performance. This is an important finding, and it is explained by the fact that bigger companies must consider more aspects of the supply chain compared to companies of smaller sizes. This correlation is shown in Figure 1.

Figure 1. Correlation between company size and metrics used.



3.2. LARG performance measurement indexes

Examining the performance metrics belonging to each category of the survey, the following outcomes will detail each category with the correspondent performance metrics and the percentage of usage by the respondents of the survey.

Looking at the first macro-category (*entire* supply chain), the metrics are shown in Table 5 and they are divided by the sub category. It is clear that the "quality" metric is the one used the most, followed by the metric "speed of delivery". These metrics are very significant to measure supply chain performance because these are two of the main indicators which are used to select suppliers.

Table 5. Metrics of the supply chain in its entirety.

Metrics	Answers
Quality of infrastructure	60.6%
Risk assessment index	75.8%
Fragility index	33.3%
% of products in transit	27.3%
Quality	97.0%
Effective production over planned production	72.7%
Forecasting accuracy	42.4%
Supplier's delivery performance	87.9%
Products' safety	72.7%
% of storage use	42.4%
% of new clients	39.4%
Partners' satisfaction	72.7%
Employees' satisfaction	54.5%
Number of accidents in the workplace	57.6%
Speed of delivery	90.9%
total order cycle time	51.5%
product development cycle time	48.5%
lead time	87.9%
% effective time of production over potential	45.5%
Impacts of breaks over total hours of production	45.5%
Planned process cycle time	33.3%
Suppliers' lead time	66.7%
Frequency of delivery	63.6%
Effectiveness of master production schedule	36.4%
order entry methods	27.3%
Cost of production	87.9%
Profit per client	57.6%
Daily profits	33.3%
Cost of raw materials and components	81.8%
Unit production cost	72.7%
Cost of using new technologies	51.5%
Variation from budget	57.6%
Liquidity	57.6%
ROI	54.5%
ROS	45.5%

Focusing on the LARG perspectives, the first perspective analyzed in the survey is the *green* perspective and the metrics that belong to it are shown in Table 6. The most used metric for this category is "energy use", which shows that companies consider it important to be aware of their energy consumption. Additionally, regulations that companies have to

follow make it all the more important to be cautious of energy consumption.

Table 6. Metrics of the green perspective.

Metrics	Answer
Green certificates	48.5%
Green competences	45.5%
Actual environmental efficiency	69.7%
Suppliers' green image	42.4%
Functional product eco-efficiency	33.3%
Customer returns	54.5%
Number of green products	27.3%
Percentage of production and office materials recycled	30.3%
Information processing cost	15.2%
Net life cycle cost	36.4%
Recycling revenues	33.3%
Disposal costs	72.7%
% of renewable resource use	48.5%
Energy use	81.8%
Greenhouse gas emissions	51.5%
Hazardous material output	66.7%
% of waste (trash)	60.6%
% of product remanufactured	48.5%
Water use	63.6%
Gas use	60.6%

The second perspective analyzed is the *lean* perspective and the metrics proposed in the survey are shown in Table 7. The metrics of this category that are most used by companies are "quality level" and "delivery lead time". "Quality level" differs from the (simpler) metric "quality" because the former is to be considered as a quantitative metric and the latter can be somehow regarded as a qualitative metric. Indeed, it is important to monitor the "quality level" so that companies can be aware of any changes in their quality and can improve it when needed. The second top-used metric is important by definition in a lean supply chain, as time is an important indicator for the efficiency of a supply chain.

Table 7. Metrics of the lean perspective.

Metrics	Answers
Customer satisfaction	93.9%
Buyer-supplier relationship	66.7%
Quality of delivered goods	93.9%
Accuracy of forecasting techniques	63.6%
Productivity	90.9%
Inventory turnover rate	63.6%
Quality level	97.0%
Stock level	69.7%
Inventory level	66.7%
% of production waste	48.5%
OEE	36.4%
total cycle time	63.6%
Purchase order cycle time	60.6%
Production time/piece	75.8%
Delivery lead time	97.0%
lead time	84.8%
Products cost	87.9%
Total logistics cost	72.7%
Profitability	75.8%

The *agile* perspective is the category that had fewer metrics in the survey; they are shown in Table 8. The metric mostly used from this category is "flexibility", which indicates that companies consider this aspect as important for supply chain agility. Being flexible is crucial for a company considering the constant changes in the supply chain and in the customer behavior.

Table 8. Metrics of the agile perspective.

Metrics	Answers
Competency	78.8%
Responsiveness	78.8%
Decisiveness	63.6%
Alertness	48.5%
quickness	72.7%
Market sensitivity	54.5%
Innovativeness	75.8%
Flexibility	81.8%
Cooperation	69.7%
Information sharing	75.8%
Integration	63.6%
Data accessibility	63.6%

The last category covers the *resilient* perspective and the metrics included in the survey are shown in Table 9. The only metric that is used by 100% of the companies who participated in the survey is the "maximum on-time deliveries", which highlights that on-time deliveries are a key performance factor for every company and that they are crucial for the selection of suppliers.

Table 9. Metrics of the resilient perspective.

Metrics	Answers
Safety stock	85%
Inventory gap	55%
Information sharing	79%
Flexibility of production	85%
Redundancy rate	48%
Risk-sharing rate	36%
Labor productivity	76%
Visibility	48%
Distributed production rate	52%
Supplier assistance in solving technical problems	82%
Minimum recovery time	64%
Maximum on-time deliveries	100%
Delivery time	82%
Loss per unit of time	39%
Stock-out time	58%
Cash flows	79%
Cost of pre-positioning emergency inventory	24%
Cost of implementation of recovery activities	36%
Net earnings	82%
Costumer service level	97%

% of unfulfilled demand	85%
Demand postponement rate	42%
Sale lost ratio	58%
Customer loyalty	73%
Product range	58%
Depth of range	42%

Looking instead at the importance judgement expressed by the respondents, the metrics that were labelled as "very relevant" by at least 15% of the companies are the ones shown in Table 10. We recall that the importance judgement does not take into account the usage of the metrics; in other terms, these metrics have been judged as relevant by the company regardless of their usage in practice. This suggests that they are perceived as key performance factors for supply chains.

The metric that was labelled as "very relevant" by most of the respondent is "green certificates", which highlights how important the environmental factor is for companies and emphasizes its role in the supplier's selection process.

Table 10. Metrics considered very relevant.

Metrics	Answers
Green certificates	18.2%
% of renewable resource use	15.2%
Supplier assistance in solving technical problems	15.2%
Customer loyalty	15.2%

The metric "percentage of renewable resource use" is again perceived as "very relevant" by many companies, but compared to the remaining metrics, it is not so used in practice (only 48.5% of the respondents declares its usage). This indicates that many companies perceive the benefits of considering the use of renewable resources but do not actually make use of these resources, probably because of the costs of renewable energies. Concerning, instead, the metric "supplier assistance in solving technical problems", this is relevant because it is a fundamental issue for selecting the supplier; if the supplier can help solving technical problems, the supply chain will be less subject to interruptions and its processes can continue faster. "Customer loyalty" is an important metric as well, typically used for monitoring which customers return to the company and to check whether customer's loyalty is low or high.

3.3. Industry 4.0 and COVID-19

The statements and answers to the survey about the relationship between the supply chain and Industry 4.0 are shown in Table 11. As can be seen from that table, none of the companies strongly disagreed with any of the statements and it is evident that >50% of the respondents either agree or strongly agree with the statements. The statements that received the greatest number of positive answers (strongly agree and agree) are "Industry 4.0 has a positive impact on supply chain resilience" and "GSCM practices mediate the relationship between Industry 4.0 and environmental performance" with 88% of the respondents agreeing with these statements.

Respondents also agree that Industry 4.0 has had, in general, a positive impact on supply chain performance. This means that Industry 4.0 is crucial to performance measurement and that companies benefit from these new technologies. Additionally, from an environmental point of view, Industry 4.0 has significantly helped improve performance in green supply chain management.

Considering instead the context of COVID-19, the answers to the statements included in the survey are shown in Table 12. As with the statements in Table 11, these statements received >50% consensus by the respondent companies. Only one respondent strongly disagreed with the statements, so it is fair to say that most of the companies believe that the technologies introduced by Industry 4.0 have helped to improve the supply chain performance during the COVID-19 pandemic. According to the companies, the new technologies have also helped to avoid and/or overcome the disruption caused by the pandemic.

Table 11. Statements about supply chain context: Industry 4.0.

Statements	Strongly agree	Agree	Not really agree	Strongly disagree
Industry 4.0 has a positive impact on green purchasing.	36%	39%	24%	0%
Industry 4.0 has a positive impact on green manufacturing.	27%	52%	21%	0%
Industry 4.0 has a positive impact on green design.	18%	58%	24%	0%
Industry 4.0 has a positive impact on green training.	21%	55%	24%	0%
Industry 4.0 has a positive impact on supply chain resilience.	18%	70%	12%	0%
GSCM practices mediate the relationship between Industry 4.0 and environmental performance.	18%	70%	12%	0%
GSCM practices mediate the relationship between Industry 4.0 and economic performance.	27%	58%	15%	0%

Table 12. Statements about supply chain context: COVID-19.

Statements	Strongly	Agree	Not really	Strongly

	agree		agree	disagree
Industry 4.0 technologies impact on reactivity and resilience of supply chain.	33%	48%	18%	0%
Big data analysis improves decision process in supply chain amid the COVID-19 pandemic	33%	58%	9%	0%
Integration of IoT and cloud computing in supply chain processes contributes to the improvement of supply chain performance.	33%	48%	18%	0%
Integration of artificial intelligence, of robotics and augmented reality in the supply chain improves performance.	30%	64%	6%	0%
Integration of additive manufacturing in the supply chain processes contributes to performance improvement.	33%	61%	3%	3%
Blockchain technology has a positive impact on traceability and security of supply chain.	27%	55%	18%	0%

The statements that received the greatest number of positive answers (94% agreed or strongly agreed) are "Integration of additive manufacturing in the supply chain processes contributes to performance improvement" and "Integration of artificial intelligence, of robotics and augmented reality in the supply chain improves performance". This implies that artificial intelligence, robotics, augmented reality and additive manufacturing are the most important technologies from Industry 4.0 to improve the performance of the supply chain.

4. Conclusions

This paper has proposed an empirical assessment of the usage of performance indexes by companies, with a specific focus on the LARG (lean, agile, resilient, green) perspectives of supply chains. A set of 112 available metrics was derived from a detailed analysis of the literature and embodied in a questionnaire survey. These metrics covered aspects related to the entire supply chain, and the specific aspect relating to each of the LARG perspectives. Besides these aspects, a set of 13 statements (again formulated on the basis of the available literature) was added in the survey to evaluate the role of Industry 4.0 technologies and COVID-19 in performance evaluation, improvement or worsening. The survey was addressed to a sample of 151 companies and 33 useful responses were obtained. Respondents were asked to mark the performance indexes they used and to indicate their perceived importance (regardless of the real usage), using a linguistics scale (from "very relevant" to "not relevant at all"). About the statements, respondents were instead asked to express their level of agreement using a linguistic scale (from "strongly agree" to "strongly disagree").

An elaboration of the outcomes obtained showed that all the metrics found in the prior research are actually used by the respondent companies, which indicates that they are all somewhat relevant for supply chain performance. The least used metric was found to be "information processing cost," used by about 15% of the companies only. Since this metric emerged as important from an analysis of the literature, the authors have tried to deepen the reason for the very limited usage. To this end, one of the respondents to the survey who does not use this metric was interviewed and asked to explain the rationale behind that choice. The respondent, member of a medium-sized company working in the metallurgic/metal mechanical field, explained that this cost is usually allocated as an overhead cost and is not considered on its own. However, the respondent indicated that a larger company may consider the cost by itself. This is confirmed by the fact that 60% of the companies that use this metric are larger companies.

Looking instead at the most used indexes, some metrics appeared as particularly important, either because they were used by >90% of the respondents or because they were labelled as "very relevant" by >15% of the respondents. By gathering these outcomes, out of the original set of 112 metrics, 15 metrics were found to be particularly important for performance measurement (see Table 13).

Table 13. Most relevant metrics found in the research.

Metrics
Quality
Quality level
Quality of delivered goods
Productivity
Customer satisfaction
Customer service level
Customer loyalty
Maximum on-time deliveries
Speed of delivery
Energy use
Delivery time
Green certificates
% of renewable resource use
Supplier assistance in solving technical problems
Flexibility

The role of Industry 4.0 and COVID-19 is relevant as well. Respondents in general agreed that Industry 4.0 had a positive impact on supply chain performance, thus suggesting the crucial role of new technologies as enablers for performance measurement. Respondents also perceive that Industry 4.0 has significantly helped improve performance in green supply chain management, and that, at the same time, these new technologies have also helped to avoid and/or overcome the disruption caused by the COVID-19

pandemic.

From the purely scientific point of view, LARG models are not new in literature, as they were introduced at least one decade ago. However, it is easy to observe that they have started being reproposed in the recent times, probably because the COVID-19 disturbance recalled just above has highlighted that resilience, in particular, is crucial for supply chain success. Also, the relationships between COVID-19, Industry 4.0 and performance measurement are a very recent topic, still poorly explored in the literature, especially with regard to the LARG perspectives. In this respect, the key scientific contributions of the paper consist in:

1. the identification of a set of LARG indexes which are perceived as particularly important by companies in the evaluation of their performance; and
2. an exploration of the impact (at various level) of Industry 4.0 and COVID-19 on supply chain performance.

On the other hand, some limitations of this research have to be mentioned. The main one is the fact that the sample size of the survey, although satisfactory for the present study, is not sufficiently large to provide results specific to the industry field. Indeed, there is not enough diversity in the business fields in which the respondent companies operate, and some fields are underrepresented. Unfortunately, this does not allow for deriving exhaustive considerations regarding the relationship between business fields and metrics used; elaborating on this relationship is left for future studies.

For further development to this study, it should be encouraged to first repeat the survey on a sample of at least 200 companies - at least 50 companies of different sizes as well as more diversity within the business fields. Additionally, repeating the survey after some time (following a longitudinal perspective), to analyze the differences between the companies' approach to performance measurement after the pandemic, as well as the potential emergence of new technologies, would be impactful for practical purposes. Results of such a longitudinal study would be beneficial for academic, strategic, and economic purposes. For example, studying the development in the usage of performance metrics could show the most relevant improvements in supply chain management, highlighting how companies have (possibly) changed their approach to the LARG perspectives and how supply chain performance management develops over a variety of circumstances. A longitudinal study would also be useful for elaborating on the role of Industry 4.0 technologies, but more likely COVID-19, on supply chain performance, and to check whether the approach of companies to the LARG perspectives will change in time. To be more specific, it is reasonable to expect that resilience will become the perspective on which companies will deserve particular attention in the future, for ensuring their competitiveness and efficiency, as both the COVID-19 pandemics (in 2020-2021) and the war (at present) have clearly shown that external unpredictable disruptions could always be observed in real supply chains (Rinaldi et al., 2022). As a closing aspect, the relationship between Industry 4.0, COVID-19 and performance measurement seems promising. Re-evaluating those relationships in some years, again following a longitudinal perspective, would be another interesting research direction in the future.

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