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Sustainable Lean & Green 4.0 production: a bibliometric analysis

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As a consequence of the effects of climate change that all countries around the world are currently experiencing, which put at risk the inventory of natural resources for future generations, has made mankind, especially industrialists, think about the innovation that must necessarily be made in the production process. This has led the scientific community to explore how Industry 4.0, or the fourth industrial revolution, can contribute to Lean and Green clean production practices, generating an innovative strategy that leads companies down the path of business sustainability. The objective of this paper was to explore by conducting a bibliometric analysis on the research trends that arise around Industry 4.0 (4IR); Lean and Green (4IRE) and Business Sustainability (BS). For this purpose, scientific software and the prisma method were used to analyze 68 articles from the Scopus(Sco) and Web of science (WoS) databases. The findings support the evolution that is directing the literature towards the contribution that this set of technologies can bring to Lean and Green to improve the triple bottom line.

Keywords—Lean and Green; Industry 4.0; fourth industrial revolution; Bibliometric analysis; Project Management.

I. INTRODUCTION

Nowadays, the companies with the objective of staying on the road to competitiveness must simultaneously focus on reducing waste, assuming complexity as a challenge or increasing value, being this possible through the implementation of the paradigms of greater application among entrepreneurs such as the fourth industrial revolution (4IRE) and Lean and Green (L&G) [1]. In this order of ideas, the 4IRE has presented benefits and firepower for industrialists designing strategies with the purpose of taking advantage of this set of technologies to enhance sustainability in companies[2].

The evolution of these technologies in the last three decades resulted in the 4IRE, also called Industry 4.0, this paradigm can work in association with manufacturing and supply chain processes, achieving the automation of production, with minimal human intervention [3], [4].

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On the other hand, the concept of Lean Manufacturing was born from Toyota's production system and became known in the scientific community at the end of 1980, catalogued as a new manufacturing process compared to the traditional ones by identifying industrial waste and using 50% of the company's resources [5], [6]. Green manufacturing are production techniques that minimize ecological impacts and green waste by implementing green practices with the intention of conserving and protecting the ecosystem and environmental resources [7].

The concept of BS relates the environmental, social and economic pillars, generating a triple bottom line model developed by Elkington & Rowlands [8] in which the competitive advantage of the company is found at the intersection of these three axes[9]-[10].

However, despite the importance of these paradigms, the relationship between 4IRE and sustainability addressed by several authors is neither clear nor understandable, which becomes an obstacle for companies seeking to address these paradigms as a whole[11], [12].

Therefore, the need arises to understand how 4IRE technologies can be combined with L&G cleaner production practices, posing the following research questions:

1. What are the research trends that specifically relate 4IRE to L&G BS?

2. Which are the countries and authors leading the research on these paradigms?

3. How can the key words of the authors be used to explore possible non-empirical relationships between 4IRE and L&G and corporate sustainability?

This work is divided as described below:

Firstly, in the introduction, the importance and challenges that industrialists currently face in the implementation of L&G technologies were discussed, and each research paradigm was defined. In addition, the problem of the lack of understanding of the relationship between 4IRE and L&G was mentioned, and

research questions were posed. Section two presents the different bibliometrics and literature reviews that have contributed to the research problem. Section three presents the methodology used to carry out the research. Fourth, the results of the research are presented. Finally, the research is concluded, and future lines of research are presented.

II LITERATURE REVIEW

There are different bibliometric studies that have made significant contributions to the 4IRE together with L&G.

In the first place and in alphabetical order we find the paper of Alves[13].According to the empirical experience of the researchers, Lean supports the transformation from 4IRE to Industry 5.0. However, this study only addressed the 4IRE paradigms, Lean in relation to the economic/operational and environmental pillars.

Amjad et al. [14] , researched 4IRE combined with L&G and resilient and agile practices to the extent that adopting these types of strategies provides improved economic/operational and environmental performance by decreasing waste, generating faster and more efficient processes and improving response to disruptions.

Following in the same line of research Amjad et al.[15] designed a framework for integrating L&G with agile and resilient practices supported by IN4, with the purpose of achieving fast, productive, environmentally friendly processes while decreasing waste and uncertainty.

Ciliberto et al. [16] studied the relationship between L&G and 4RI, where the combination of technologies and practices improves quality and productivity, making processes simpler in the company.

Dahmani et al.[17] proposed a conceptual framework for the simultaneous implementation of L&G and 4RI, with the objective of producing and designing pollution-free products, achieving customer and societal welfare.

Despeisse et al. [18] conducted a systematic review of the literature (SRL) in which their findings determined the importance of integrating sustainable development objectives with industrial objectives and proposed a framework to guide future research on the specific environmental problems encountered in manufacturing.

Ding et al.[19] concluded that 4IRE allows linking Lean and agile practices, covering the trade-offs between competing objectives.

Florescu & Barabas.[20], [21] reported that the connection between specific technologies, such as digital twin and simulation with Lean together with flexible manufacturing, allows reconfiguration and adaptability to improve production processes.

Pei et al. [21], [22] characterized the areas related to L&G, where they highlight as a future line of research the relationship between additive manufacturing and Internet of Things (IoT) as a support to the green manufacturing process.

Rosin et al.[22] identified that Lean practices such as Jit and Jidoka can be supported by 4IR technologies, however their effectiveness decreases for waste elimination and collaborative work.

Finally, Sinha & Matharu. [23] concluded that the existing works are concentrated in countries of Asian origin, at the beginning the research were being conducted by developed countries, currently the studies are also focused on emerging economies, on the other hand, there is an inclination of the research in relating Lean with 4IR and business sustainability.

III METODOLOGY

Bibliometric studies are effective methods that present the current status of research topics by applying statistical and mathematical tools [24], [25].

To capture the scientific information, a search equation was designed to relate the research topics 4IRE, L&G and BS (Fig. 1) to increase the capture spectrum, keywords and synonyms were used, as well as Boolean depth operators such as the asterisk sign and accuracy operators such as quotation marks, applied in the scientific databases SCO) and (WoS), limiting the search to the title, abstract and keywords of only articles classified in the quartiles 1-2 (Q1, Q2).

Fig. 1 Design of the search equation by research pillars

Note. The authors.

For this purpose, the PRISMA 2020 (Fig. 2) method of information flow diagram was used, which allows the inclusion of significant works and the exclusion of those that do not meet the research objectives[26], it also provides researchers with assistance in improving and structuring SLRs and meta-analyses [27]- [28].

For the visualization of the information, the Vantage Point technological tool and the open-source software Vos Viewer and Biblioshiny in R were used, the latter allowing the loading of the 57 SCO documents and the 40 WoS documents to identify 29 duplicates by means of the mergel function (Fig. 3) for a result of 68 articles (SCOWOS).

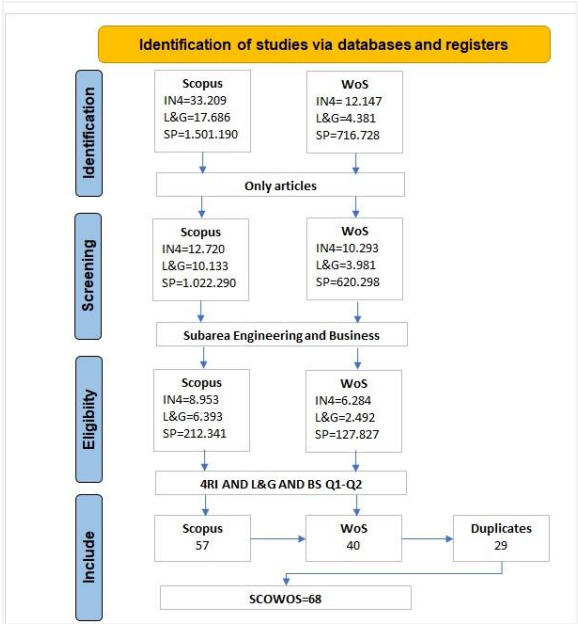

Fig. 2 PRISMA method.

Note. adapted from http://www.prisma-statement.org/PRISMAStatement/

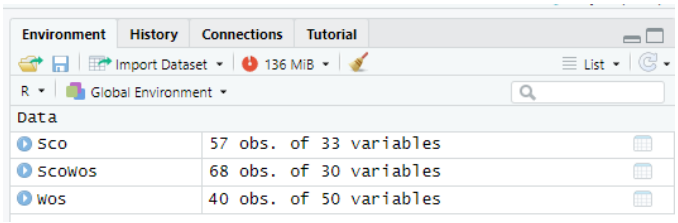

Fig. 3 R Studio interface

IV. RESULTS

For the presentation of the results, the questions posed in the introduction were used as a guideline for their presentation.

1. What are the research trends that specifically relate 4IRE to L&G BS?

Figure 4 shows the historical trend of publications over time, the graphical analysis shows an upward trend, with a maximum value of 24 articles in 2022, an increase of 9% over the previous year, with a record of two publications in the first half of 2023.

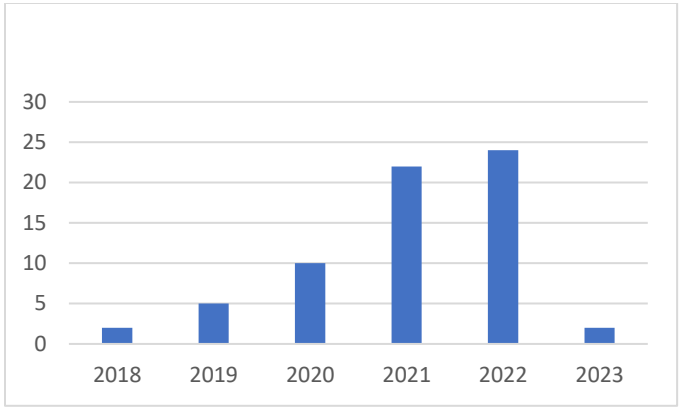

Fig. 4. Historical research trend

Note. Note. Authors' elaboration in in R

Figure 5, presents the thematic map in research that shows the evolution of scientific topics, in this order of ideas 4IRE together with L&G are at the border of going from a niche topic to a driving topic, likewise the integration between 4IRE, Lean manufacturing and sustainability, are at the border of basic topics to driving topics.

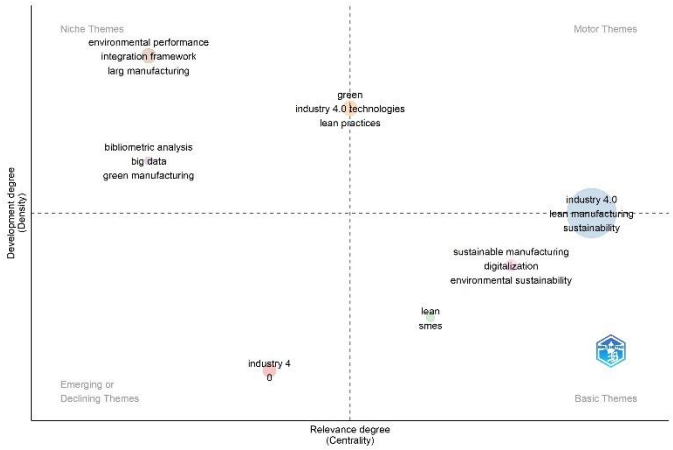

Fig. 5. Thematic evolution

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2. Which are the countries and authors leading the research on these paradigms?

With respect to the geographical distribution of the documents, Figure 6 taking as a classification the 5 most important countries and according to the number of publications in parentheses, and in their respective hierarchical order, we find India as the leader in research with 18 documents, followed by China (13), Pakistan in third place, and finally Spain and the United Kingdom (UK) with 8 articles, respectively.

Fig. 6. Geographical map of the research

Note. Authors' elaboration in Vantage Point

According to the distribution of geographically related publications and years, Figure 7 shows India, the United States and Germany as research precursors; however, only India and the UK present documents at the beginning of the year 2023.

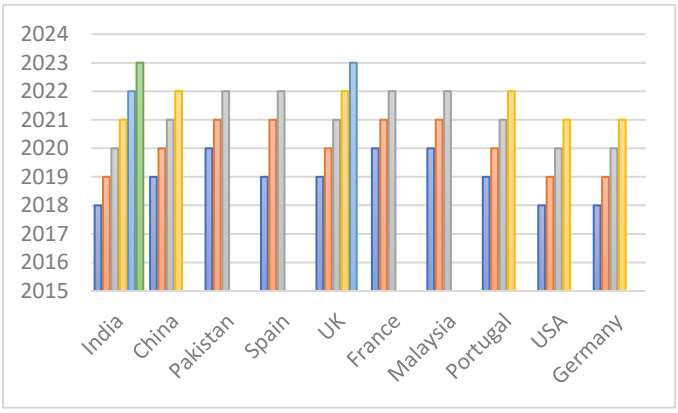

Fig. 7. Relationship between countries and years

Note. Authors' elaboration in Vantage Point

According to the results presented in the cluster analysis (Fig 8), India (red circle) leads the global research partnership, sharing work with countries such as: Malaysia, Czech Republic, Singapore, China, Egypt, Saudi Arabia, South Africa, Morocco, France, Australia, Ethiopia and Pakistan.

On the other hand, in bibliometric studies, papers with a higher number of citations and great theoretical and methodological innovation have a greater academic impact and their topics and methodology participate in important research[29], in this order of ideas and taking as ranking the top 5 authors and cited papers according to the number of records, initially we find Yadav et al.[30] with 231, S. Kamble et al. [31]with 226; in third place, Ghobakhloo & Fathi. [32] with 249, then Rosin et al. [22] with 142, finally, Raut et al. [33] with 129 (Figure 9).

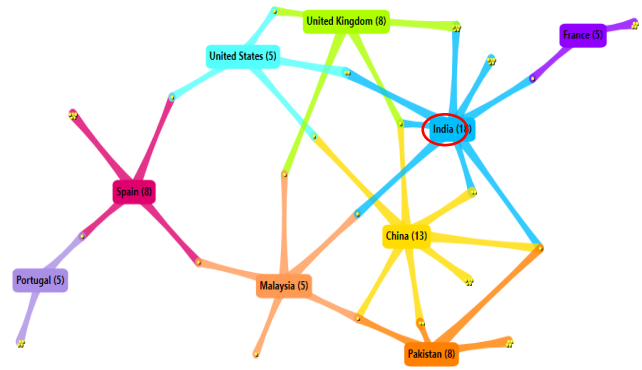

Fig. 8. Research cluster.

Note. Authors' elaboration in Vantage Point

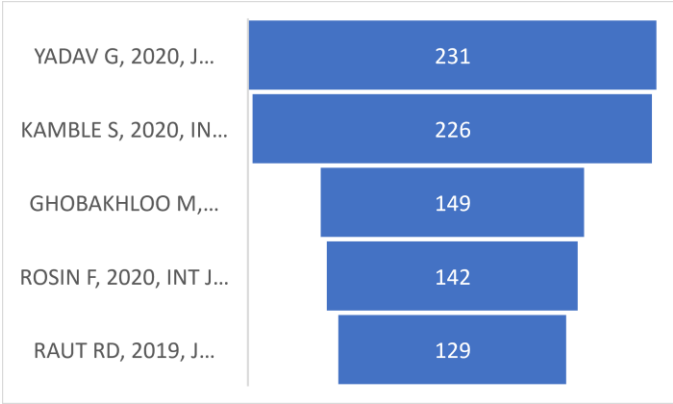

Fig. 9. Most cited authors

Note. Authors' elaboration in R

In this order of ideas, the authors carry out research networks with the objective of contributing to the topics, according to the analysis of the association between researchers, 4 research networks were identified. The authors studied above: Khan M, RafiqueM and Amjad belong to network number one; network number two is formed by Yadav G. BagS; Jakhar Chattopadahyaya S and Li C work in association in network number three, which is the strongest network linking eight researchers. Finally, S. Kamble and Belhadi form partnership (Figure 10).

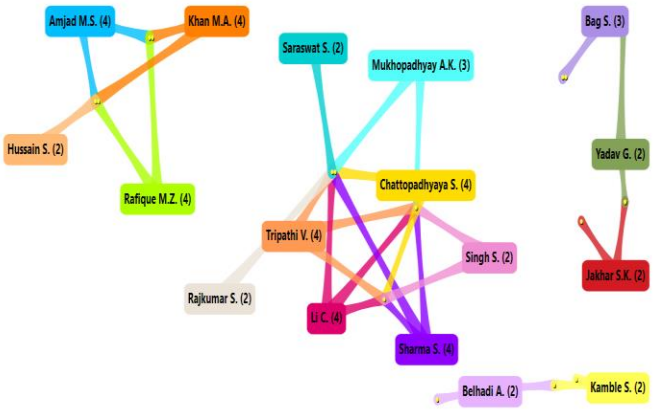

Fig. 10. Research social networks
Note. Authors' elaboration in Vantage Point

3. How can the key words of the authors be used to explore possible non-empirical relationships between 4IRE and L&G and corporate sustainability?

Figure 11 presents the keyword analysis of the authors represented in the cloud diagram, where the size of the word represents the importance in the subject, according to the records presented in parentheses in their respective order are Industry 4.0 (51), Lean manufacturing (34), Sustainability (14), Green practices (11), finally, sustainable manufacturing (8).

Fig. 11. Authors' keyword cloud

Note. Authors' elaboration in Vantage Point

Figure 12 presents the co-occurrence analysis, where the size of the node represents the importance, and the proximity between words possible relationship between them being the most representative according to their records in parentheses 4RI (223), Technologies (183) Lean (147), manufacturing companies (135), Green manufacturing (111). In terms of their relationship, it is possible to observe greater closeness between 4IRE, Lean and sustainability. The density graph shows a limited relationship between L&G and Business performance and 4IRE (Figure 13).

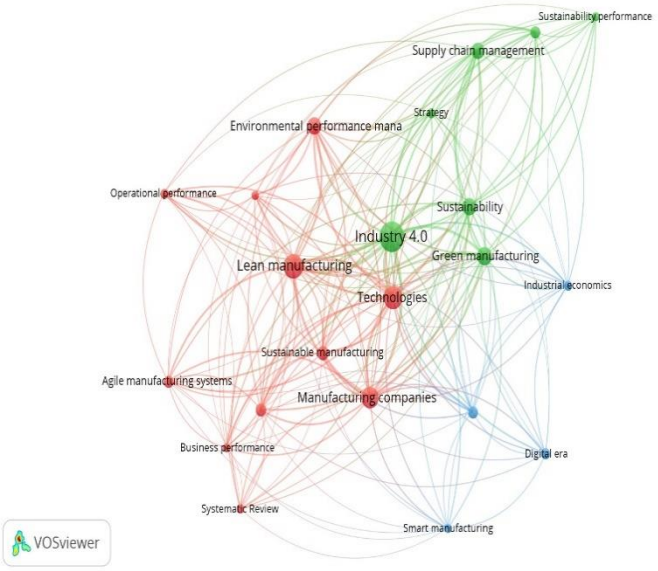

Fig. 12. Co-occurrence analysis

Note. Authors' elaboration in VOSviewer

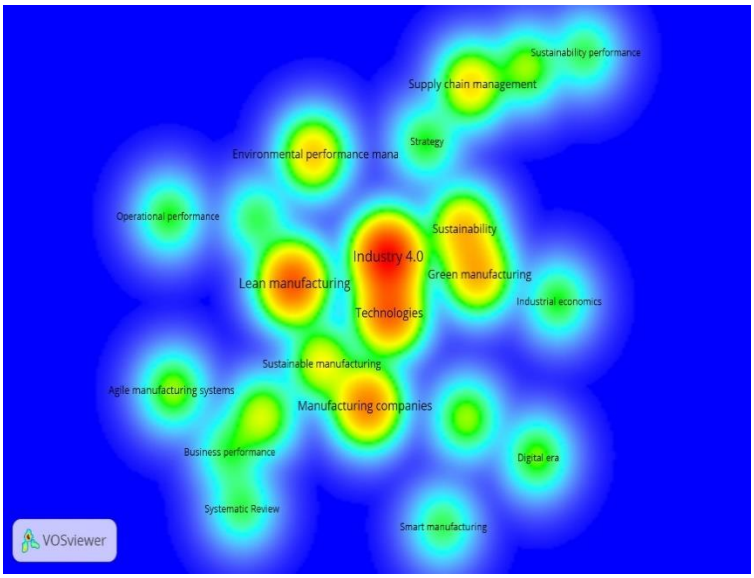

Fig. 13. Linking between keywords

Note. Authors' elaboration in VOSviewer

Figure 14, shows the relationship between keywords over time, it can be seen that the first studies addressed the topics of 4IRE with Lean, in the year 2018, In the year 2019 begins to explore the topics related to green practices, with sustainability, performance and L&G.

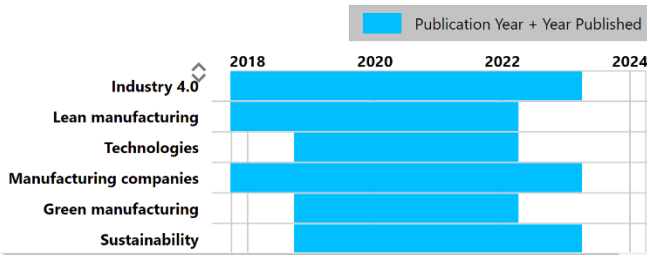

Fig. 14. Linking between keywords and years

Note. Authors' elaboration in Vantage Point

Figure15 presents the relationship between time with the co-occurrence of the key words, it can be analyzed that in the year 2018 works were initiated that related the 4RI with Lean manufacturing; and green manufacturing with sustainable development, in the year 2019 the studies begin to focus on Lean manufacturing with Sustainable development; from the year 2020 the integration between L&G is evidenced. Currently, there is little research that addresses the 4IRE, L&G with corporate sustainability.

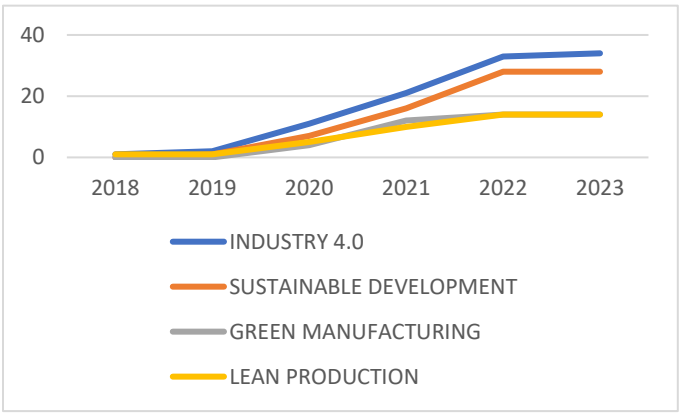

Fig. 15. Linking between keywords; years and Co-occurrence

Note. Note. Authors' elaboration in R

V. CONCLUSIONS

The main objective of this study was to present the research trends that revolve around the new 4IR production paradigms, L&G and their relationship with business sustainability. To achieve the above, a bibliometric study was carried out to show graphically and quantitatively the research direction of the topics, three research questions were posed, and scientific computer tools were used to perform data mining, regarding the question:

1.What are the research trends that specifically relate 4IRE to L&G BS?

According to the graphical analysis of figure 4, there is an upward trend in the publication of papers in the last year, also figure 5 presents the evolution of the research topics of 4IRE, along with L&G 4IRE and Lean manufacturing with sustainability are in the gaps between niche and basic topics.

2. Which are the countries and authors that lead the research on these paradigms?

The findings presented show India as the country that leads the research at world level, being the central axis of the largest research cluster. The most important authors are Yadav et al.[30] with 231, S. Kamble et al. [31]with 226; in third place, Ghobakhloo & Fathi. [32] with 249, then Rosin et al. [22]with 142, finally, Raut et al. [33] with 129 (Figure 9).

3. How can the key words of the authors be used to explore possible non-pirational relationships between 4IRE and L&G and corporate sustainability?

The keyword cloud figure presents 4IRE as the most used by the authors, followed by Lean manufacturing, sustainability and green practices. However, the smaller keywords present research topics that have been little explored and can generate future research work, among which we find L&G industry 5.0 Big data, Value Street mapping. On the other hand, the density figure presents more relationship between 4RI and Lean manufacturing, however the same figure presents L&G as a topic isolated from the 4IRE and sustainable development. This is an important aspect for future research because it is a little explored topic, which can be focused on studies with methods that allow to prove the possible empirical relationship that exists between the 4IRE, the practices of clean production L&G as a whole and with an impact on business sustainability. This presents an encouraging outlook for decision makers who want to maximize their utility in balance with the environment and society in the generation of a new production model that incorporates technologies together with L&G to achieve this purpose.

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