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Quantitative Methods In Industry 4.0 And Telework Research: A Systematic Review In Support Of The Un Sustainable Development Goals

Abstract
This study aims to map and analyze the quantitative research methods employed in scientific studies addressing telework and Industry 4.0 within the framework of the Sustainable Development Goals (SDGs). A systematic literature review was conducted, analyzing 20 peer-reviewed articles retrieved from the Scopus, Web of Science, and ScienceDirect databases. Eligibility criteria included focus on remote work in the context of Industry 4.0, open access, English language, and journals with an impact factor above 3. The findings reveal that 60% of the studies used quantitative approaches, with discriminant analysis being the most frequent statistical technique (41.7%). Structural Equation Modeling (SEM), Confirmatory Factor Analysis (CFA), Analysis of Variance (ANOVA), and descriptive statistics were each employed in 33.3% of the studies. Questionnaires were the primary data collection tool (75% among quantitative studies), with the 5-point Likert scale used in 42% of the sample. SPSS was the most commonly used software (58%). All studies utilized graphical representations, predominantly diagrams (75%). This paper contributes by highlighting methodological trends in research on telework and digital transformation, offering insights for environmentally focused policy frameworks and sustainable organizational practices in alignment with SDGs 8 and 9.

Keywords: *Quantitative methods; Telework; Industry 4.0; Sustainable Development Goals; Remote work; Environmental policy.*

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I. INTRODUCTION

The Fourth Industrial Revolution (Industry 4.0) has brought transformative changes to production systems, labor dynamics, and technological infrastructures. Among its most significant outcomes is the accelerated adoption of telework, especially intensified during the COVID-19 pandemic, which redefined organizational structures and environmental dynamics worldwide. The abrupt shift to remote work reduced commuting emissions, reconfigured energy consumption patterns, and introduced new challenges related to digital infrastructure, ergonomics, and worker health. These transformations intersect with several United Nations Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation, and Infrastructure).

In 2011, Brazil formally recognized telework in Article 6 of the Consolidation of Labor Laws (CLT), anticipating a modality that would later be reinforced by the technological advancements of the Fourth Industrial Revolution (Industry 4.0) and widely adopted during the COVID-19 pandemic. These events profoundly reshaped the way individuals interact and work. Measures such as lockdowns and social distancing were implemented to contain the spread of COVID-19 (Nundy et al., 2021), accelerating the diffusion of innovations and the integration of Industry 4.0 principles. Activities that once required physical presence transitioned to virtual platforms, pushing traditional work environments toward remote operations. Organizations had to rapidly adapt to ensure survival during social isolation.According to political, business, and cultural leaders affiliated with the World Economic Forum, these changes are fundamentally altering how humanity interacts, experiences, and works. From steam-powered mechanization during the First Industrial Revolution, to mass production through electricity in the Second, to automation enabled by electronics and information technology in the Third, we are now witnessing a fusion of technologies that blur the boundaries between the physical and the digital (Schwab, 2016).

The technological transformation initiated by Industry 4.0 (I4.0) is expanding into households, leisure activities, and work routines, promoting a physical-virtual integration that enhances operational efficiency through robotics, automation, artificial intelligence, big data, and the Internet of Things (IoT) (IEDI, 2019). This evolution, propelled by Information and Communication Technologies (ICTs), has redefined work relations and the provision of services.However, the rapid shift to telework has introduced risks to workers' health due to inadequate control over working conditions. The World Health Organization (WHO) and the International

Labour Organization (ILO) have emphasized the importance of protective measures to mitigate both the benefits and risks of telework, including long working hours, poor ergonomics in home environments, and the psychosocial effects of isolation such as loneliness and irritability (ILO/WHO, 2021).

In 2015, the United Nations introduced a comprehensive global action plan encompassing economic, social, and environmental dimensions through 17 Sustainable Development Goals (SDGs) and 169 associated targets (ONU, 2015). Among these, SDG 8—Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all — and SDG 9 — Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation — are particularly relevant to this study, as they address the evolving nature of work and innovation driven by Industry 4.0.

Knowledge production and scientific dissemination are essential for advancing academic careers and enriching the scientific community. Publishing in high-impact journals remains the most prominent method of sharing discoveries globally. However, the growing demand for scholarly publication presents a challenge, especially in top-tier journals (Serra et al., 2008). High-quality research requires a solid theoretical and methodological foundation and alignment between the research design and methodological approach (Fiates et al., 2014; Gouvêa et al., 2013).

Choosing appropriate statistical techniques is a critical component of quantitative research design, as it supports the analytical robustness of the study (Ferreira & Falaster, 2016). Academic research is often critiqued on epistemological and methodological grounds (Prearo et al., 2009). Thus, researchers must continually develop competencies, refine concepts and procedures, and overcome limitations to improve the quality of academic research (Fiates et al., 2014).

Articles submitted to business and administrative journals are most frequently rejected due to weaknesses in methodology, literature review, conceptual development, and discussion (Falaster et al., 2016). As Creswell (2010) points out, the structure of a sound quantitative research report should include an introduction, literature review, methodology, results, and discussion.

Once the research method is defined, the choice of statistical techniques and their assumptions must be carefully considered to ensure the validity and inferential accuracy of the findings (Lana et al., 2018). Bibliographic reviews remain a valid mechanism to explore conceptual knowledge, whether as standalone studies or as components of larger theses or dissertations (S. V. Soares et al., 2018).This study aims to address the following research question: **How are quantitative methods being applied in studies examining the impacts of Industry 4.0 on the promotion of telework within the SDG framework?** To answer this, **the main objective is to map the landscape of quantitative research methods used in this domain, thereby informing future empirical investigations.**

The justification for this research lies in both its relevance and feasibility. Relevance is supported by the ongoing scholarly attention to this subject (Castro, 2006), as evidenced by previous studies that reinforce its importance (Agostineto et al., 2020; Bido et al., 2018; Borges et al., 2020; Dallabona et al., 2009, 2010; Damázio et al., 2020; Garcia et al., 2019; Hosser et al., 2018; Koerich et al., 2021; Prearo et al., 2009, 2011, 2012; G. F. da Silva et al., 2021; Smania et al., 2019; T. C. Soares et al., 2019). Feasibility is ensured by access to reliable academic databases and analytical tools necessary to complete the study within the proposed timeframe.

This article is structured in five sections: Section 1 introduces the context, research problem, and justification; Section 2 presents the literature review; Section 3 describes the methodological procedures; Section 4 discusses the results; and Section 5 provides the conclusions and recommendations.

II. LITERATURE REVIEW

This section presents an overview of previous studies on health, digital labor transformation, and the statistical techniques applied in quantitative research, particularly within the context of telework and Industry 4.0. The aim is to identify patterns and methodological tendencies that inform future research and align with the SDGs.

Creswell (2010) describes quantitative research as a process to test objective theories by examining relationships among variables, measured numerically and analyzed using statistical procedures. Methodological studies that introduce new or revised analytical tools contribute significantly to the academic community by enabling reproducibility, comparative assessments, and refinement of best practices (APA7, 2020).

Systematizing methodological patterns enhances decision-making regarding statistical techniques and supports the critical evaluation of both strengths and weaknesses found in the literature. Silva et al. (2010), for example, analyzed 299 papers presented at three academic conferences between 2007 and 2009 and observed a rise in the use of quantitative methods from 46% to 62% over the period. The most frequently employed techniques were statistical inference, regression analysis, and descriptive statistics.

Santos et al. (2021), in their bibliographic review on quantitative methods in financial education, found that descriptive statistics were used in 26.9% of the studies, multiple regression in 23.1%, and ANOVA in

11.5%. Questionnaires were the dominant instrument in 12 of the 13 analyzed articles, with 30.8% using a 5-point Likert scale. SPSS was the most cited software.Damázio et al. (2020) reviewed 11 studies on health information systems published between 2010 and 2019. Frequently used techniques included descriptive statistics, hypothesis testing, and multiple regression. SEM, logistic regression, and CFA also appeared in several cases. Questionnaires were the main data collection tool in all studies, while 36.36% employed the Likert scale, and 27.27% used Cronbach's Alpha for reliability. SAS was referenced in two papers.Buhr et al. (2021), in a review of 17 studies, found that descriptive statistics were used in 47% of the papers, SEM in 23%, non-parametric hypothesis testing in 18%, and factor analysis in 12%. They concluded that the incorporation of quantitative methods into analyses of impact, perception, and awareness contributes to more robust and relevant findings.

Fuchs and Martins (2022), analyzing carbon footprint assessments in higher education institutions, presented tables detailing titles, authors, publication venues, and methodologies used. They emphasized the importance of instrument design and the use of visual aids in data presentation. Similarly, Pazetto et al. (2021) categorized studies by methodological type (qualitative, quantitative, or mixed), graphical tools, number of hypotheses tested, and statistical approaches.Soares et al. (2018) highlight the significance of bibliographic reviews as foundational components in dissertations and scientific articles, particularly for synthesizing fragmented knowledge and identifying methodological gaps.

These studies collectively reinforce the increasing prevalence and sophistication of quantitative techniques in sustainability and digital labor research, while also identifying underexplored opportunities to integrate environmental and systemic variables into empirical assessments.

III. MATERIALS AND METHODS

This study adopted a systematic literature review approach to investigate the application of quantitative methods in studies involving telework and Industry 4.0 within the context of the Sustainable Development Goals (SDGs). The process began with a comprehensive search for academic articles conducted on June 17, 2022, across three major databases widely recognized for their scientific relevance: ScienceDirect, Scopus, and Web of Science.

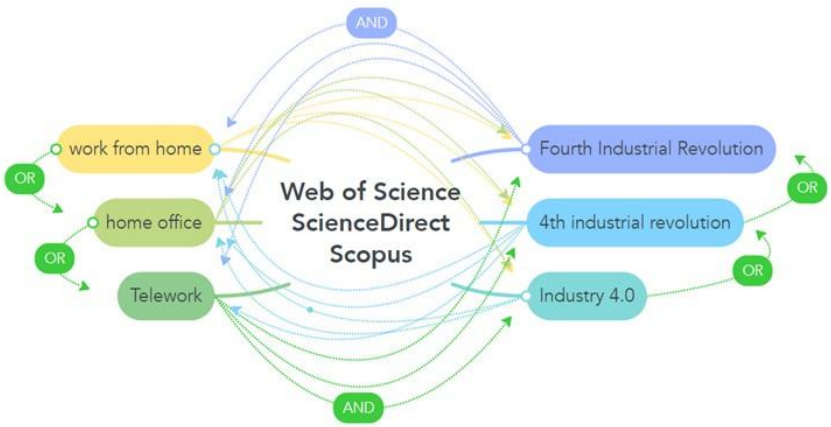
The search strategy employed combinations of terms such as "Fourth Industrial Revolution," "4th Industrial Revolution," "Industry 4.0," "Work from home," "home office," and "Telework," using Boolean operators to refine the results and ensure a broad yet focused coverage of the subject.

To ensure rigor and alignment with the research objectives, only articles that met specific eligibility criteria were considered. These included peer-reviewed studies written in English, available in open access, and published in journals with an impact factor greater than 3, as indexed by the Journal Citation Reports (JCR) or SCImago Journal Rank (SJR). Studies that did not explicitly address the intersection of Industry 4.0 and remote work or that failed to meet quality and accessibility standards were excluded. Non-article publications, such as books, book chapters, conference proceedings, and technical reports, were also disregarded.

The initial search retrieved 400 documents: 143 from ScienceDirect, 250 from Scopus, and 7 from Web of Science. After removing duplicates and applying the defined eligibility criteria, 144 articles remained. These were screened based on their titles, abstracts, and keywords. A full-text reading of potentially relevant studies was then conducted, leading to the selection of 20 articles for final analysis.

Figure 1 presents the PRISMA-style flowchart detailing each stage of the selection process, from initial identification to final inclusion.

Figure 1 – Databases and Search Strategy.



Source: Autor (2025).

The eligibility criteria (inclusion and exclusion) used to select the articles are described in **Table 1**.

Table 1. Inclusion and Exclusion Criteria

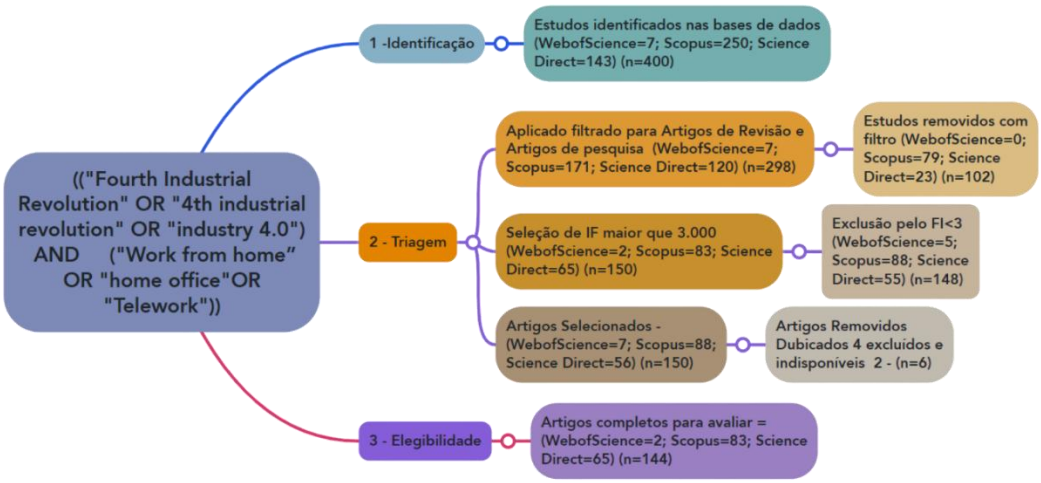
Inclusion and Exclusion Criteria		
Criterion	Inclusion	Exclusion
Focus	Articles addressing Industry 4.0 and remote work	Articles unrelated to these topics
Type of Study	Research or review articles	Books, book chapters, conference papers, reports
Language & Access	Full-text available in English	Inaccessible full texts or not in English
Journal Quality	Peer-reviewed, impact factor > 3 (JCR or SJR)	Journals with impact factor < 3 or no peer review
Scope	Research on administrative sectors and telework	Studies focusing solely on infrastructure or unrelated technologies

Source: Autor (2025).

3.3 Article Selection Process

The initial search retrieved 400 documents: 143 from ScienceDirect, 250 from Scopus, and 7 from Web of Science. After removing duplicates and applying the eligibility criteria, 144 articles remained. Titles, abstracts, and keywords were screened, resulting in a final sample of **20 articles** for full-text review and analysis.

Figure 2 - Article Selection Flowchart.



Source: Autor (2025).

3.4 Data Extraction and Analytical Tools

To process the selected studies, the following software tools were used: VOSviewer - for bibliometric mapping and clustering, Nvivo - for qualitative categorization and content analysis, Microsoft Excel - for tabulation, descriptive statistics, and visual representation of results.

The extracted data included publication year, journal name, impact factor, number of citations, type of research method (qualitative, quantitative, or mixed), statistical techniques used, instruments for data collection, scale types (e.g., Likert), software employed, and types of graphical representations.

All steps were conducted to ensure reproducibility, transparency, and alignment with systematic review standards recommended for environmental and interdisciplinary research contexts.

IV. RESULTS

This section presents the results of the systematic literature review based on the final sample of 20 selected articles. The findings are organized into seven analytical categories: type of methodological approach, statistical techniques used, data collection instruments, types of measurement scales, software employed, graphical representation formats, and bibliometric indicators.

The articles analyzed are presented in Table 2, showing the article numbering in the scope (No.), the method used (Method), the titles of the articles (Title), the indication of the authors of the works (References),

the journals in which they were published (Journal), the year of publication (Year) and the number of citations of each article (Cit.). The citations reflect research carried out on the Google Scholar platform on August 26, 2022.

Table 2 –Final sample of articles.

Nº	Method	Título	Reference	Year	Periodical	Cit.
1	Mixed	Current research and future perspectives on human factors and ergonomics in Industry 4.0	(Kadir et al., 2019)	2019	Computers and Industrial Engineering	150
2	Qualitative	Village 4.0: Digitalization of village with smart internet of things technologies	(Malik et al., 2022)	2022	Computers and Industrial Engineering	12
3	**Quantitative**	Job quality and work—life balance of teleworkers	(Rodríguez-Modroño & López-Igual, 2021)	2021	International Journal of Environmental Research and Public Health	47
4	**Quantitative**	Not all remote workers are similar: Technology acceptance, remote work beliefs, and wellbeing of remote workers during the second wave of the covid-19 pandemic	(Donati et al., 2021)	2021	International Journal of Environmental Research and Public Health	14
5	**Quantitative**	Technostress of chilean teachers in the context of the covid-19 pandemic and teleworking	(Estrada-Muñoz et al., 2021)	2021	International Journal of Environmental Research and Public Health	28
6	**Quantitative**	Impact of COVID-19 outbreak on employee performance - Moderating role of industry 4.0 base technologies	(Narayanamurthy et al., 2021)	2021	International Journal of Production Economics	88
7	Qualitative	Impact of COVID-19 pandemic on socio-economic, energy-environment and transport sector globally and sustainable development goal (SDG)	(Nundy et al., 2021)	2021	Journal of Cleaner Production	72
8	Qualitative	Gig Work and the Discourse of Autonomy: Fictitious Freedom in Japan's Digital Economy	(Shibata, 2020)	2020	NEW POLITICAL ECONOMY	48
9	**Quantitative**	COVID-19 oriented HRM strategies influence on job and organizational performance through job-related attitudes	(Bieńkowska et al., 2022)	2022	PLoS ONE	1
10	Qualitative	Modelling long-term COVID-19 impacts on the U.S. workforce of 2029	(Shutters, 2021)	2021	PLoS ONE	3
11	**Quantitative**	Covid-19 and beyond: Employee perceptions of the efficiency of teleworking and its cybersecurity implications	(Mihailović et al., 2021)	2021	Sustainability	10
12	Qualitative	Delineating the implications of dispersing teams and teleworking in an agile uk construction sector	(Burton et al., 2021)	2021	Sustainability	4
13	Qualitative	Digitization in the Design and Construction Industry-Remote Work in the Context of Sustainability: A Study from Poland	(Orzeł & Wolniak, 2022)	2022	Sustainability	7
14	**Quantitative**	Implementing remote working policy in corporate offices in Thailand: Strategic facility management perspective	(Tanpipat et al., 2021)	2021	Sustainability	13
15	**Quantitative**	Mapping industry 4.0 enabling technologies into united nations sustainability development goals	(Mabkhot et al., 2021)	2021	Sustainability	33
16	**Quantitative**	Positive and negative impacts of covid-19 in digital transformation	(Subramaniam et al., 2021)	2021	Sustainability	7
17	**Quantitative**	Telecommuting during COVID 19: A Moderated-Mediation Approach Linking Job Resources to Job Satisfaction	(Jamal et al., 2021)	2021	Sustainability	6
18	Qualitative	Telework, hybrid work and the united nation's sustainable development goals: Towards policy coherence	(Moglia et al., 2021)	2021	Sustainability	9

19	**Quantitative**	Wellbeing costs of technology use during Covid-19 remote working: An investigation using the Italian translation of the technostress creators scale	(Molino et al., 2020)	2020	Sustainability	239
20	**Quantitative**	Adequacy of telework spaces in homes during the lockdown in Madrid, according to socioeconomic factors and home features	(Cuerdo-Vilches et al., 2021)	2021	Sustainable Cities and Society	33

Source: Autor (2022).

4.1 Methodological Approach

Among the 20 articles analyzed, 60% employed quantitative approaches, 35% were qualitative, and 5% adopted a mixed-methods design. This distribution underscores the prominence of quantitative research in addressing the relationship between telework and Industry 4.0 within the Sustainable Development Goals (SDGs) context, as can be seen in **table 3**.

Table 3: Absolute and relative frequency of the methods used.

Methods Employed	*f*	Relative Frequency	%
Qualitative Method	12	0,6	60%
Quantitative Method	7	0,35	35%
Mixed Method	1	0,05	5%
Total	**20**	**1**	**100%**

Source: Autor (2025).

4.2 Statistical Techniques

The most frequently used statistical technique was discriminant analysis, present in 41.66% of the articles using quantitative methods. Techniques such as Structural Equation Modeling (SEM), Confirmatory Factor Analysis (CFA), Analysis of Variance (ANOVA), and descriptive statistics were each employed in 33.33% of the studies. Other statistical methods identified include correlation analysis, regression models, and cluster analysis, although with lower frequency.

The categorization was carried out in search of statistical techniques raised in statistics books, the occurrences shown in **table 4**.

Table 4 – Distribution of Statistical Techniques Used.

Descrição das técnica estatística	**Occurrences**	**%**
Analysis of variance (ANOVA)	4	33,3%
Cluster Analysis	2	16,7%
Confirmatory factor analysis (CFA)	4	33,3%
Descriptive statistics	4	33,3%
Discriminant analysis	5	41,7%
Exploratory factor analysis (EFA)	2	16,7%
Logistic regression analysis	2	16,7%
Multidimensional scaling	1	8,3%
Ordinary Least Square (OLS) hierarchical linear regression models	2	16,7%
Principle component analysis	1	8,3%
Structural equation modeling (SEM)	4	33,3%

Source: Autor (2025).

4.3 Data Collection Instruments

The use of questionnaires as a data collection tool was observed in 55% of the total sample and in 75% of the studies using quantitative approaches. This finding is consistent with trends in empirical social science research, particularly in studies addressing perceptions and attitudes toward remote work and technological adoption.

Table 4: Use of questionnaire in the total sample and in articles with quantitative methods.

	Sample	*f*	Relative Frequency	%
Total articles	20	11	0,55	55%
Quantitative Method	12	9	0,75	75%

Source: Autor (2025).

4.4 Types of Measurement Scales

The Likert scale is one of the most common techniques used in opinion research, which consists of multiple indicators measuring the intensity of a feeling (Bryman, 2020), and according to Hair et al., (2009), the more points used on the Likert scale, the more accurate the information obtained by the researcher will be. In the portfolio of quantitative articles, the Likert measurement scale accounted for 58% of the research, with the 5-point scale being the most used at 42%, as shown in **Table 5**.

Table 5: Types of Scales Used in Quantitative Studies.

Scale	*f*	Relative Frequency	%
Not specified	5	0,4166666	42%
5-point Likert	5	0,4166666	42%
6-point Likert	1	0,0833333	8%
7-point Likert	1	0,0833333	8%
Total	12	1	100%

Source: Autor (2025).

4.5 Statistical Software

The most commonly used software was the Statistical Package for the Social Sciences (SPSS), employed in 33% of the articles. Other software included SAS, AMOS, and SmartPLS, each supporting advanced modeling and analysis techniques such as SEM and multivariate regression.

Table 6: Frequency of Software Tools Used in Data Analysis.

Softwares Used	*f*	Relative Frequency	%
Statistical Package for the Social Sciences (SPSS)	4	0,333333	33%
AMOS (módulo adicional do SPSS)	3	0,25	25%
R.Studio	1	0,083333	8%
CAWI	1	0,083333	8%
SmartPLS 3	1	0,083333	8%
SurveyMonkey®	1	0,083333	8%
Mplus 7	1	0,083333	8%
Total	12	1	100%

Source: Autor (2025).

4.6 Graphical Representations

All 20 articles in the sample used some form of graphical representation to support the presentation of their results. The most commonly used format was the diagram, found in 75% of the studies, followed by bar charts, tables, and flowcharts. These visuals enhanced comprehension of complex models and relationships.

Table 7: Occurrences of the use of graphical representation in studies with quantitative methods.

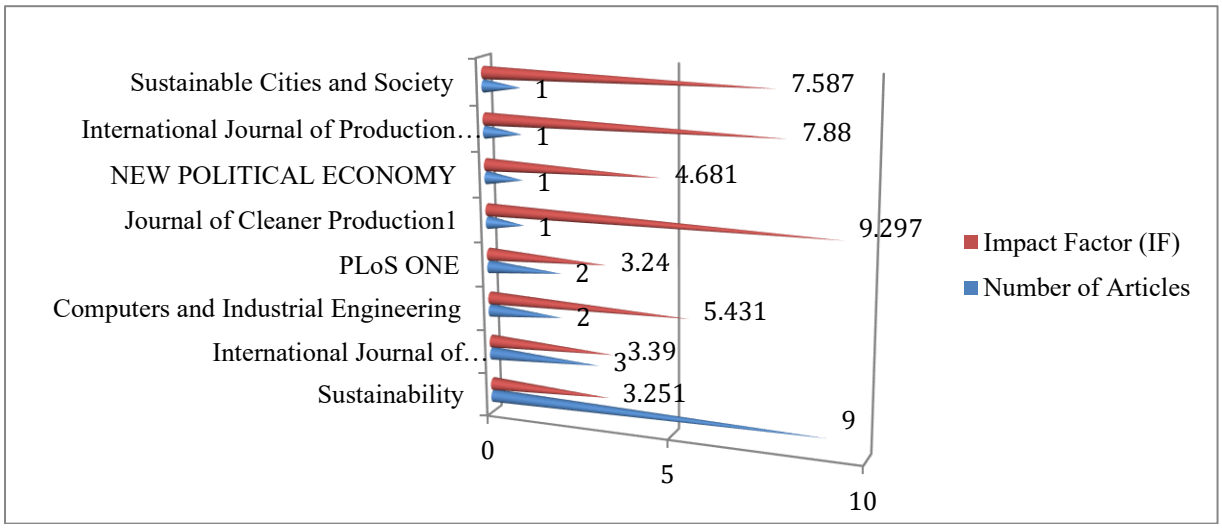
Using graphical representation	f	Frequência Relativa	%
Boxplot type graph	1	0,083333	8%
Histogram type graph	1	0,083333	8%
Diagram type graph	9	0,75	75%
Pie type graph	1	0,083333	8%
Total	12	1	100%

Source: Autor (2025).

4.7 Bibliometric Indicators

The articles reviewed were published in journals indexed in Scopus, Web of Science, or ScienceDirect, all with an impact factor greater than 3 at the time of analysis. The number of citations varied considerably across the sample, ranging from 2 to 357 citations, indicating both emerging and consolidated relevance in the scientific community.

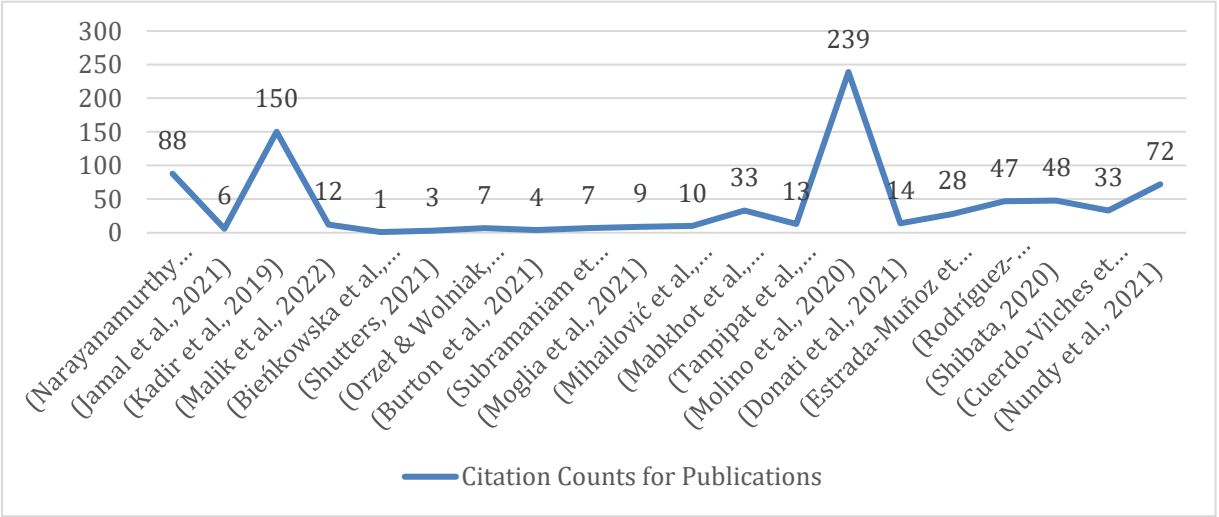
Figure 3 - Correlation between Journals, impact factor and number of articles.



Source: Autor (2022).

From the correlation between journals and number of articles, it can be concluded that the journal with the most publications is Sustainability (9), followed by the International Journal of Environmental Research and Public Health with 3 publications. Three articles found stood out in the number of citations, as can be seen in **Figure 4**.

Figure 4 - Citations by work.



Source: Autor (2022).

The most cited documents, according to the Google Scholar platform on August 26, 2022, were from Narayanamurthy et al. (2021) with 88 citations, from Kadir et al. (2019) with 150 citations, and from Molino et al. (2020) with 239 citations dealing with Industry 4.0 or remote work aligned with the SDGs.

V. CONCLUSIONS

This study provided a comprehensive overview of the quantitative research methods employed in scientific investigations addressing the impacts of Industry 4.0 on telework within the framework of the Sustainable Development Goals (SDGs). The systematic review of 20 articles revealed a clear prevalence of quantitative approaches (60%), with a strong emphasis on statistical rigor and empirical validation.

Discriminant analysis stood out as the most frequently used statistical technique (41.66%), followed by Structural Equation Modeling (SEM), Confirmatory Factor Analysis (CFA), Analysis of Variance (ANOVA), and descriptive statistics (each used in 33.33% of the sample). Data collection was primarily carried out through questionnaires, especially those using 5-point Likert scales, which were present in 42% of the quantitative studies. The most frequently used analytical tool was SPSS (58%), demonstrating a preference for accessible

and widely adopted software solutions. All studies included graphical representations, with diagrams being the most common.

These findings suggest a growing methodological consolidation in the study of digital labor transformations. However, the environmental and systemic implications of telework—such as its impact on energy consumption, transportation, digital infrastructure, and sustainability—remain underexplored in the existing literature. Addressing these gaps may contribute to more comprehensive, interdisciplinary assessments of telework and Industry 4.0 within the SDG agenda.

This research also reinforces the importance of aligning research questions, methodological choices, and analytical tools to ensure robust scientific contributions. As highlighted by Serra et al. (2008), Fiates et al. (2014), and Ferreira & Falaster (2016), methodological consistency is fundamental for high-quality research output, particularly in high-impact publication environments. Additionally, the review echoes Prearo et al. (2009, 2011, 2012) in highlighting recurring epistemological and methodological challenges in academic work.

Future studies should consider integrating environmental indicators, sustainability metrics, and broader societal impacts into analyses of telework and Industry 4.0 adoption. Interdisciplinary approaches and mixed-methods designs may offer deeper insight into the complex interactions between technological innovation, labor practices, and sustainable development.

This work contributes to the theoretical and methodological foundations for future research and serves as a practical guide for scholars aiming to design environmentally relevant, statistically sound studies aligned with global sustainability goals.

Strengthening the integration of environmental impact indicators into digital work research can help shape resilient and sustainable work environments in the post-pandemic world.

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