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# Indicators for the facility layout design in MSMEs in the textile sector with a resilient approach

*Indicadores para el diseño de distribución de planta en MiPymes del sector Textil con un enfoque resiliente*

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**Palabras claves:**
problema de distribución de instalaciones, resiliencia, revisión literaria, MiPymes textiles, indicadores.

**Resumen**

**Introducción.** La capacidad de respuesta y adaptación a los riesgos y problemas de una organización es fundamental para el éxito empresarial. Cualquier tipo de debilidad provoca un uso ineficiente de los recursos. Por el contrario, unas instalaciones flexibles pueden garantizar la continuidad de las operaciones ante eventos disruptivos, los cuales perjudican en gran medida a la empresa de no ser controlados, sin embargo, la flexibilidad no se consigue sólo con la optimización de las instalaciones, ya que los enfoques resilientes pueden potenciarla. **Objetivo.** Sintetizar las variables e indicadores con mayor uso en tres diferentes ámbitos, la resiliencia empresarial, la industria textil y el problema de disposición de instalaciones (FLP). **Metodología.** La investigación es de carácter bibliográfico-documental. Se desarrolló una revisión sistemática de la literatura, haciendo uso de la metodología Fink, considerando 99 estudios publicados entre el año 2010 y 2021. El análisis de los documentos se lo realizó mediante el software Atlas.ti, posteriormente se usó un análisis 4W (cuándo, quién, qué y dónde), y finalmente se dieron respuesta a 3 preguntas de investigación planteadas mediante la estrategia PICO. **Resultados.** Los resultados indican que, existe una escasez de estudios sobre FLP resilientes, sin embargo, es notable que el interés científico en relación con la resiliencia ha aumentado en los últimos seis años, específicamente en los métodos y enfoques de evaluación para identificar los factores e indicadores de resiliencia en la industria a través de modelos matemáticos difusos. **Conclusiones.** Los estudios sobre resiliencia aplicada al FLP no son desarrollados en gran medida a nivel mundial, en el contexto ecuatoriano la resiliencia no ha sido profundizada. Finalmente se resalta la importancia de los indicadores para un modelo preciso y se propone una serie de indicadores para el análisis del comportamiento del diseño de instalaciones con un enfoque resiliente basado en factores FLP.

**Keywords:**
Facility layout problem, Resilience, Literature review, Textile

**Abstract**

**Introduction.** The capacity to respond and adapt to the risks and problems in an organization is critical for business success. Any type of weakness causes inefficient use of resources. On the contrary, flexible facilities can ensure the continuity of operations in the face of disruptive events, which significantly harm the

SMEs,
Indicators.

company if they are not controlled. However, flexibility is not achieved only with the optimization of facilities, as resilient approaches can enhance it. **Objective.** To synthesize the variables and indicators with greater use in three different areas, business resilience, the textile industry, and the facility layout problem (FLP) in the textile industry. **Methodology.** The research is of a bibliographic-documentary nature. A systematic literature review was conducted, using the Fink methodology, considering 99 studies published between 2010 and 2021. The documents were analyzed using the Atlas.ti software; subsequently, a 4W (when, who, what, and where) analysis was used; finally, answers were given to three research questions posed through the PICO strategy. **Results.** The findings indicate that, there is a scarcity of studies about resilient FLPs, however, it is notable that the scientific interest regarding resilience has increased in the last six years, specifically in assessment methods and approaches to identify resilience factors and indicators in the industry through fuzzy mathematical models. **Conclusions.** Studies about resilience applied to FLP are not developed to a great extent worldwide, in the Ecuadorian context resilience has not been explored in depth. Eventually, the importance of indicators for an accurate model is highlighted and a series of indicators for the analysis of the behavior of facility layout with a resilient approach based on FLP factors is proposed.

## Introduction

The need for companies to adapt to an uncertain future represents a challenge, primarily due to the pandemic caused by Covid-19 (Moosavi & Hosseini, 2021). This has generated abrupt changes, resulting in a challenging competitive environment in the areas of price, quality, time and innovation. As a result, organizations focus their attention on achieving the appropriate levels in the aforementioned areas. Unfortunately, companies' strategies have been obsolete or inefficient (Carvajal et al., 2018). This is most evident in small and medium-sized enterprises (SMEs), whose response to the unpredictable nature of the sanitary crisis has been affected by their limited resources (Moosavi & Hosseini, 2021; Ugail et al., 2021). In addition, these types of organizations are one of the main integrators of economic growth, creating job opportunities and helping them to become contributors to large companies such as suppliers of goods and services. SMEs represent over 70 % of world production, so that a considerable drop in their production would represent a major

impact on the economy, making the development and implementation of change strategies essential for them to remain in a highly competitive environment (Ates & Bititci, 2011).

Because of the limited innovation and implementation of new methodological tools, Ecuador has experienced a great impact on the industrial sector, as processes have not been able to be managed properly, generating greater difficulty for organizations to remain active (Villalba et al., 2018). At the national level, the textile industry is one of the most important, being considered as the second productive axis of the country, however, the textile sector and other sectors such as footwear present adaptability problems to this type of situation due to the highly dynamic nature of their processes. For this reason, it is of utmost importance that organizations use different methodologies or tools that provide an optimal solution to the problems and risks generated in these industries (Ramos et al., 2018; Zhao & Kim, 2021).

One of these necessary tools for companies is the facility layout since through this tool, it is possible to optimally design the physical space, following a series of criteria under certain restrictions, such as shape, size, orientation, or availability (Hosseini-Nasab et al., 2018). Moreover, flexibility in the industries is another key point to improve their performance and provide adequate responses to different adversities. In this sense, the facility layout problem (FLP) fits somewhat into these flexibility requirements (Flores et al., 2021). However, plant designs do not always react adequately under unfavorable circumstances, generating instabilities and failures in activities. Thus, adapting to critical events with positive results has become an intrinsic necessity (Tayal & Singh, 2019). In situations like this, resilience plays a crucial role since its application allows organizations to anticipate their responses to perturbations and react before, during, and after a problem (Thoma et al., 2016). Several authors have studied the concept of resilience from different perspectives. However, this study concerns resilience engineering, defined as the capacity of an organization to adapt to critical events or threats, i.e., constantly anticipating risks before their consequences affect the company (Flores, 2021; Shirali et al., 2013).

FLP and Resilience can face several strategic challenges; unfortunately, the research that refers to the interaction of both subjects is scarce (Navazi et al., 2021). Therefore, the relevance of resilience studies focuses on analyzing methods for its measurement, considering a series of variables and indicators. The different studies on the subject support this statement. For example, Bevilacqua et al. (2020) study the supply chain through fuzzy cognitive maps to analyze the domino effect of resilience inhibitors. In the same line Macuzić et al. (2016), propose a two-step fuzzy mathematical model to classify resilience factors in the process industry. In both cases, it is emphasized that resilience factors allow better management of organizations.

FLP focuses its interest on the optimum use of physical space, considering factors such as material flow, equipment utilization, process times, and, in general, the minimization of costs related to production (Perez, 2016). Nevertheless, FLP studies generally ignore certain elements such as top management, learning culture, communication, or teamwork, causing the design and monitoring of a plant layout to leave aside a series of features necessary to overcome possible disruptions (Azadeh et al., 2014b). This is evidenced in the proposal of Diego-Mas et al. (2009), which exposes geometric restrictions. They use a two-phase genetic algorithm to solve facility design problems, considering only FLP dependent indicators, such as the material handling, falling back on the one-dimensional use of measuring the efficiency of a cost-based plant layout model. On the contrary, an important factor in the study of resilience and FLP is the focus of the proposed indicators for monitoring and evaluating the designs.

Using indicators other than the traditional employed in facility layout designs allows better integration of the flexibility mentioned above. For example, Azadeh and Moradi (2014) present a fuzzy simulation algorithm for facility design. In this study, safety and ergonomic factors are considered metrics and restrictions in searching for the optimal model. The authors also used indicators such as average queue waiting time, average system time, and average machine utilization, in addition to FLP-dependent indicators. Therefore, integrating indicators for plant layout design with a resilient approach requires an analysis of the elements and variables used in the three dimensions, i.e., resilience, textile industry, and plant layout design. However, combining all aspects of each dimension in a single conceptual framework of indicators is a highly challenging task (Raman et al., 2009). Unfortunately, the literature has not explored the relationship between resilience and FLP (Flores et al., 2021; Raman et al., 2009).

The purpose of this article consists of an analysis of the resilience factors and variables used in the industry, followed by a synthesis of the most relevant indicators in the textile sector, pointing out its variables and elements. Finally, the relationship between resilience, textile sector indicators, and FLP is studied to obtain a list of indicators applicable to plant layout design with a resilient approach. This research contributes to the literature by introducing the indicators mentioned and guiding companies and researchers in understanding the current lines of research on resilience in the industry and indicators for FLP in the textile sector. The rest of the article is structured as follows. Section 2 describes the methodology used for the systematic literature search. Section 3 is constituted by the investigation results through the descriptive analysis of the information and a concise discussion. Finally, section 4 presents the main conclusions.

## Methodology

The present research work uses the Fink methodology, which consists of seven steps to select relevant information systematically (Fink, 2019, pp. 3–5). In this manner, it is

ensured that the research encompasses the resilience factors and indicators applied in designing the plant layout of MSMEs in the textile sector.

The first step of the Fink method refers to selecting the research questions, for which the PICO strategy was used (Santos et al., 2007), determining the Population, Intervention, Comparison, and Outcomes related to the research. Thus, three questions were obtained: a) What variables or indicators are considered in a resilient model in the textile industry? b) What variables or indicators are used in the textile industry? c) What variables or indicators can be used in a resilient approach for a plant layout design in SMEs in the textile sector?

As for Step 2, the definition of database sources, Scopus and Web of Science, were used for academic articles. Due to the need to integrate studies in which textile industry indicators and FLP indicators are applied, LA Reference and RRAAE repositories were used for theses. For Step 3, selection of search terms, 12-character strings were selected, which respond to the research questions. These strings were: “Resilience” AND “Industry”, (“Industry” AND “Textile” AND “Indicators”) OR (“Indicator” OR “Indicators”) AND “Textile”, “Industry” AND “Resilience” AND “Indicators”, “Distribution problems” AND “Indicators” AND “Industry”, “Resilience” AND “Industry” AND “Textile”, “Resilience” AND “Indicators” AND “Facility layout problems”, “Resilience” AND “Facility layout problems”, “Indicators” AND “Facility layout problems”, “Resilient facility location”, “Standard” AND ("Facility Layout" OR "Plant Design" OR "Plant Layout") AND Textile", "Standard" AND ("Facility Layout" OR "Plant Design" OR "Plant Layout"), ("Facility Layout" OR "Plant Design" OR "Plant Layout") AND ("Textile" OR "Confection").

Applying practical and methodological selection criteria from Steps 4 and 5 facilitates the searches to provide relevant results following the research topic. In this manner, the literature review guarantees that the articles and theses collected are relevant and current. Therefore, the following criteria were considered for their inclusion: 1) theoretical or applied articles and theses written in Spanish and English; 2) scientific journals articles; 3) articles and theses published between 2010 and 2021; 4) subject areas: Engineering, Management, Production, Mathematics, Decision Sciences, Economics, and Econometrics. In addition, the following exclusion criteria were used: 1) irrelevant articles, 2) duplicate articles, and 3) articles with comments from academic publications.

The documents that satisfied the exclusion criteria answered the following questions: Has the research design internal and external validity? Is reliability and validity present in the databases used? Are the analytical methods adequate to the characteristics and quality of the research data? The methodological quality of the documents found decreased if they did not answer one or more questions. The review of the documentation corresponding to

Step 6 was carried out qualitatively using the Atlas.ti software, in which 53 codes were established to highlight and classify the information.

Finally, the results were synthesized in Step 7. The number of documents obtained after the review and application of the search methodology is summarized in Table 1. As can be seen, there are 99 research studies, of which 59 correspond to articles and 40 to theses. In addition, 26 studies have been identified that addressed issues related to textile industry indicators, 27 to FLP, and 46 referring to resilience in the industry.

**Table 1**

*Application of practical and methodological selection criteria*

| Description | Articles | | Theses | | Total of documents | Excluded documents |
|---|---|---|---|---|---|---|
| | Scopus | WOS | LAR | RRAAE | | |
| No exclusion criteria | 1874 | 927 | 619 | 853 | 4273 | |
| Documents obtained after applying exclusion criteria | 1683 | 875 | 510 | 727 | 3795 | 478 |
| Documents after the title reading | 63 | 90 | 16 | 42 | 211 | 3584 |
| Documents after reading the summary and conclusions | 44 | 26 | 14 | 35 | 119 | 92 |
| Documents after reading the full text | 38 | 21 | 8 | 32 | 99 | 20 |

**Developed by:** The authors

## Results and Discussion

The 99 selected research documents analysis is reported and discussed in two sections: a meta-analysis and descriptive analysis.

*Meta-analysis*

A 4W analysis (When, Who, what, and where) was developed to better detail the results. The starting point is the "When" field, for which a temporal distribution is used, as detailed in Figure 1. The number of studies published in the different years analyzed is observed in this figure.

Notably, 2014 and 2020 reflect the most significant number of research studies carried out, with 15 and 13 studies, respectively. In addition, an increase in publications from 2014 to 2020 can be observed since the average number of published documents is 10.7, with a rise of 6 studies compared to the time interval from 2010 to 2013 (4 documents). Since the data collection period was carried out during 2021, this year is not considered in this analysis to avoid misinterpretation of the results.

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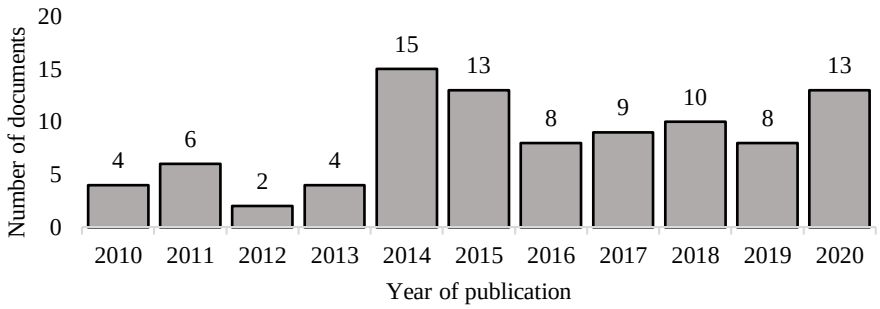
**Figure 1**

*Time distribution of sample documents.*




**Developed by:** The authors (based on systematic literature review)

It is pertinent to mention that, at the highest peak of the sample, in 2014, only 33.3 % of the 15 published studies talk about resilience, while the remaining 66.7 % focused on textile sector indicators and plant layout design indicators. Of the latter, most of the indicators mentioned in the studies are related to business management, lead times, failures, productivity, and environment (Azadeh et al., 2014a; Miniguano, 2014). Although in the second peak, corresponding to the year 2020, there is a decrease of two investigations compared to the previous year analyzed, the studies on resilience in the industry amounted to 53.84 %. Despite this, it represents an increase of only two more investigations on resilience in 2014. Regarding the studies on indicators of the textile sector and FLP in 2020, the approach is similar to that of 2014. It can be noted that the perspective of the indicators studied in the textile sector for the facility layout design resides in the financial and productive scope. Therefore, these studies emphasize production costs, fulfillment of safety regulations, and environmental factors to a lesser extent (Quispe et al., 2020).

If the documents are analyzed in detail, there is a clear difference in terms of the focus and publication trend of the theses and articles. Regarding the year of publication of the last ones, figure 2 shows a clear increasing trend, starting in 2014, with 2020 being the year with the highest number of publications of the articles; presenting 1 study about FLP, 2 focused on indicators in the textile industry and 7 about resilience. The studies related to the latter topic remain centered on resilience measurement methodologies, resilience factors in the industry, and decision-making for resilient supply chains (Piprani et al., 2020).

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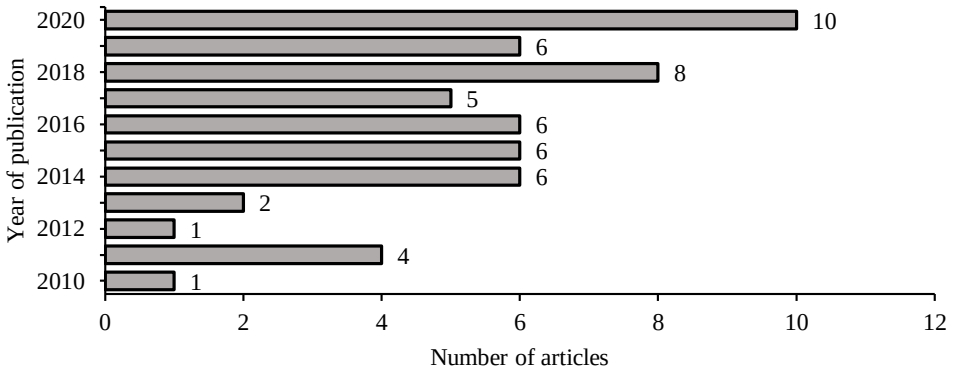
**Figure 2**

*Time distribution of sample articles*



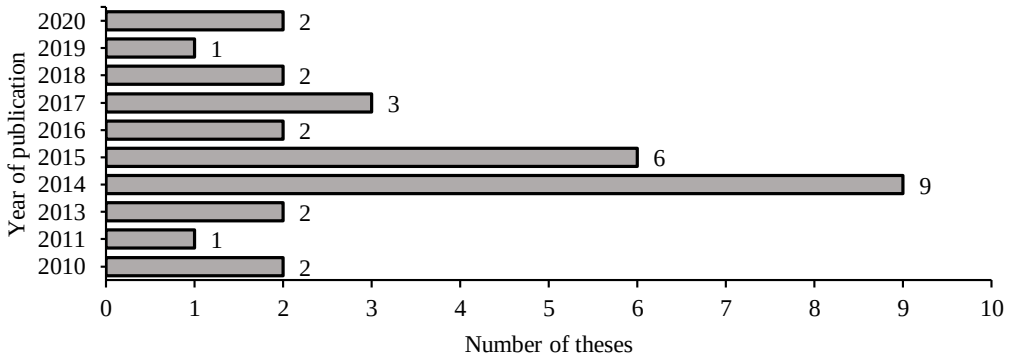

**Developed by:** The authors (based on systematic literature review)

The part of the sample corresponding to theses presents only two studies focusing on resilience applied to the industry, published in 2012 and 2017, which represents 5 % (2 studies) of the analyzed theses. In contrast, FLP and indicators in the textile industry represent 55 % (22 studies) and 40 % (16 studies) of the total samples of this type of documents. In addition, the years with the highest publication of these topics are: 2014 for FLP and 2015 for studies related to indicators of the textile sector.

As shown in Figure 3, the highest peak of the entire thesis sample occurs in 2014, with 2 studies referring to textile industry indicators and 7 to FLP. The common focus of the last mentioned topic resides in the application of facility distribution models in which the indicators are a fundamental part of the study, in addition to compliance with regulations related to occupational safety, employee comfort and the reduction of production costs (De la Cruz, 2014; López, 2014).

**Figure 3**

*Time distribution of sample theses*

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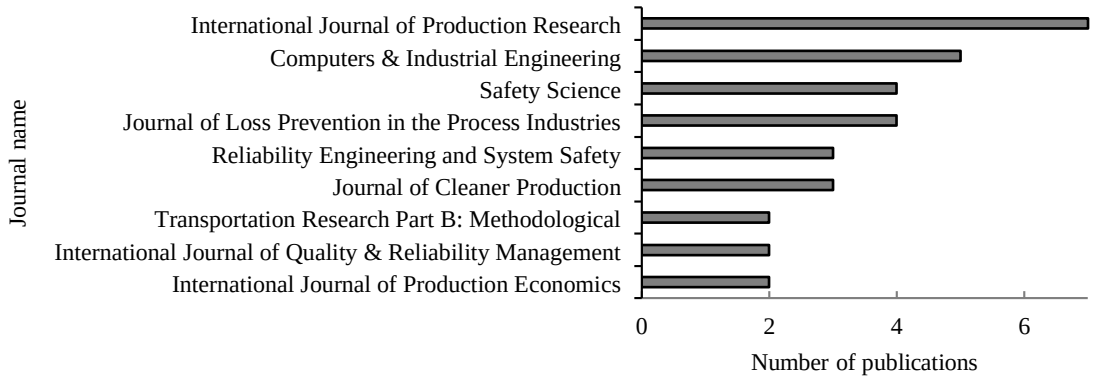
Continuing with the 4W analysis, for practical purposes, it is necessary to carry out the "Who" and "What" aspect separately in terms of theses and articles. Regarding to the "Who" aspect, the 59 papers in the sample were considered. Figure 4 shows the journals with the highest number of publications, considering the three thematic areas, which include: textile industry indicators, FLP or Resilience.

**Figure 4**

*Articles per journal*




**Developed by:** The authors (based on systematic literature review)

With the aforementioned, it is possible to continue with the "What" aspect, i.e., to know what is developed in the studies, as far as articles are concerned. Obtaining that, of the 59 articles, 6.7 % correspond to FLP studies, 16.94 % to textile industry indicators, and 76.36 % to resilience. The four journals with the most publications related to the topics of study are the International Journal of Production Research with seven publications, Computers & Industrial Engineering with five publications, and the Journal of Loss Prevention in the Process Industries and the Safety Science with four publications each. In the journals mentioned, the focuses of the publications, almost entirely, are on resilience, emphasizing the detection of disruptive events (Burnard & Bhamra, 2011), the study of competitive strategies, and the construction of methodological frameworks for business resilience building (Acquaah et al., 2011).

Similarly, for the " Who" aspect referred to the theses, the universities in which the studies were published, and their respective thematic areas are analyzed, thus, it is possible to answer the "What" field. Of the total number of theses analyzed, 22 studies (55 %) concern FLP, 16 studies (40 %) indicators in the textile field and only 2 studies (5 %) resilience. As for the Technical University of Ambato, which has the largest number of theses (35% of the theses), the studies mainly deal with FLP and indicators in the textile sector, highlighting the focus of the latter on indicators in the area of production for decision making (Gordon, 2015; Yépez, 2017).

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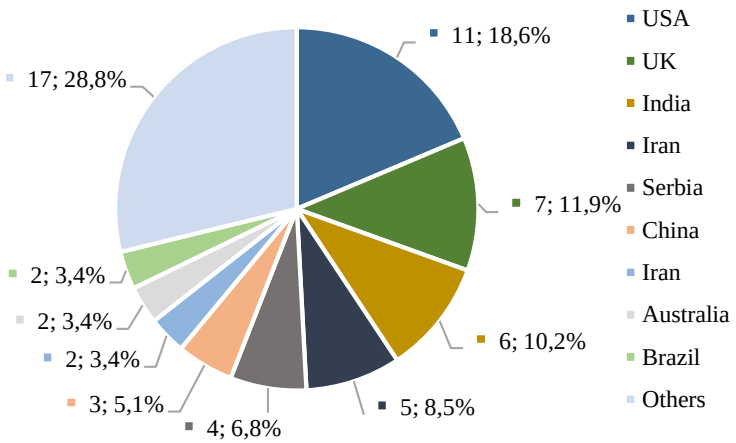
The final step in the 4W analysis analyzes the geographic origin of the sample; thus, the "Where" field is answered. As for the articles, the results indicate that studies have been conducted in 25 countries detailed in figure 5. Furthermore, the findings reveal those four countries with the highest number of publications account for more than 50 % of the sample, i.e., 31 out of the 59: the USA with eleven, Iran and UK with seven, and India with six. The studies developed in the United States, speak almost entirely about resilience, presenting an increase from the year 2018, such researches present a common approach, which is the measurement and implementation of resilience to face risks, through decision-making models, considering resilient factors. Most studies denote three main characteristics, which are: the assessment of resilience, the association of resilience to a system and the future benefits (MacKenzie & Hu, 2019). Similarly, several studies propose systemic methods to improve risk management and safety through resilience analysis frameworks. As mentioned, the studies analyzed present similarities, since all of them consider technical and social factors as key points to manage an organization, and also establish basic aspects such as: early detection, error tolerant design, plasticity, recoverability and several basic resilience metrics, thus obtaining key tools for the early detection of risks (Jain et al., 2018). As for the UK and Iran, since 2013 there has been an increase in their publications. The main topic of these studies is resilience with a total of 9 studies together and 3 on FLP in the textile industry. The trend in these countries in terms of resilience is repeated with the United States, as they propose methodologies for improvement, as well as conceptual frameworks for measuring resilience (Mehrjerdi & Shafiee, 2021). The FLP studies propose methodologies for optimization in plant layout design, as well as algorithms for plant selection (Vitayasak et al., 2017).

**Figure 5**

*Distribution of sample papers by country*

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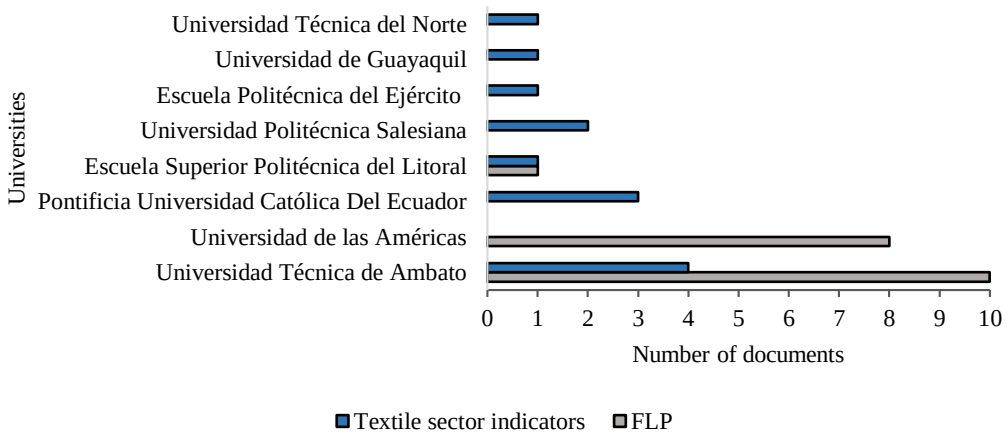
Regarding the research corresponding to theses, since a Latin American database (LA Reference) and an Ecuadorian repository (RRAAE) were used, most of the studies analyzed were developed in countries related to these sources of information, so that Ecuador predominates with 32 studies, followed by Spain with five studies; thus, 92.5% of the theses sample is represented by the countries mentioned above. Analyzing the Ecuadorian context in more depth, it is worth mentioning that in the country there are no studies on resilience applied to FLP, but there is a clear tendency to analyze, propose and apply the distribution of facilities, as well as management models based on key performance indicators, as shown in figure 6, which shows the thematic areas of the universities in the sample belonging to Ecuador in terms of theses. In addition, as mentioned in the "Who" field referring to theses, the Technical University of Ambato tops the list with the highest number of publications, however, it is notable that the tendency of the country's universities resides only in the two topics shown, leaving resilience aside.

**Figure 6**

*Distribution of theses per university*




**Developed by:** The authors (based on systematic literature review)

*Descriptive Analysis*

This section focuses on answering the three research questions obtained through the PICO strategy, detailed in the methodology. The first question corresponds to the *variables or indicators to be considered in a resilient industry model*. To this end, 46 studies comprised of articles and theses have been analyzed. These studies describe evaluation methods and strategies to identify resilience factors and indicators in the industry. For example, Aleksić et al. (2013) propose a method to assess organizational resilience through a fuzzy mathematical model, proposing internal, external, and resilience factors for subsequent evaluation. This resilient measurement facilitates learning and

improvement of various aspects since it is possible to report externally and demonstrate a certain level of performance, efficiently controlling and monitoring processes. Therefore, according to the authors, a high resilience potential with minimized costs allows increasing the effectiveness of the processes. In the same manner, Burnard and Bhamra (2011) approach the detection of disruptive events and the response actions of an organization. For this, they propose a conceptual framework of resilient organizational response. The factors described facilitate decision-making in the face of problematic and turbulent environmental conditions by adjusting to the immediate risk and preparing for future uncertainty. Finally, Pournader et al. (2016) employ a multi-method approach using data envelopment analysis models and fuzzy set theory to create an analytical model to assess resilience to supply chain (SC) risks. The information described ensures the identification and appropriate mitigation of SC trouble sources.

It should be emphasized that, for the most part, the studies mention that there is no single set of resilience elements and factors in the industry. Conversely, these should be used according to the organization; thus, the quantification of resilience is adequate since they contribute significantly to the competitiveness of SMEs. Therefore, any weakness in the factors would cause inefficient and inadequate use of resources, leading to frustration and waste (Gunasekaran et al., 2011). Nevertheless, through all this research about resilience, it is possible to synthesize the information, obtaining as a result, a set of indicators in which most of the authors agree, as shown in table 2.

**Table 2**

*Industry resilience indicators and variables*

| Indicator | Variables |
|---|---|
| Adaptive capacity | - Access to information<br>- Communications and relationships<br>- Information and knowledge<br>- Innovation<br>- Leadership<br>- Decentralized decision making |
| Planning | - Planning strategies<br>- Proactive posture<br>- Recovery priorities<br>- External resources |
| Key vulnerability management | - Severity of occupational accidents<br>- Frequency of occupational accidents<br>- Participation in drills<br>- Process safety<br>- Unplanned shutdowns per year<br>- Accident learning |

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**Table 2**

*Industry resilience indicators and variables (continuación)*

| Indicator | Variables |
|---|---|
| Just culture | - Understanding and perception of errors<br>- Awareness<br>- Fault tolerances |
| Information flow efficiency | - Management communication<br>- Control capacity |
| Managerial Efficiency/ Top Management Commitment | - Rules and procedures<br>- Violations of regulations<br>- Work pressure and stress<br>- Self-organization<br>- Information culture<br>- Teamwork |
| System safety efficiency | - Safety Policies<br>- Safety equipment<br>- Safety and physical problems |

**Developed by:** The authors (based on systematic literature review)

To answer the second research question, which corresponds to: *What indicators are used in the textile industry?* It is necessary to know the different perspectives of the indicators to have a clear understanding of the trend in the industrial sector under study. In most investigations, indicators are applied or analyzed in the production and management areas since they are of interest to know the state of the main operations of the companies. The importance of indicators lies in the ease of obtaining a global vision of the company and, thus, knowing the most critical parameters and the causes of the existing problems, for example, Montava et al. (2010), propose a series of indicators for management in the textile industry from different perspectives.

The authors highlight financial, quality, and innovation perspectives, presenting indicators that consider the consequences of business management strategies and critical success factors, to a lesser extent, the indicators related to the environment focus their attention on water consumption, global warming, or resource use. As the study developed by Reyes et al. (2020), in which a method for selecting life cycle assessment indicators in the textile industry in France is presented. This method is adapted as an environmental learning engine since the approach mentioned is one of the most difficult to implement in the textile sector due to the nature of its processes. Therefore, the importance of this type of indicator lies in calculating the environmental impact of various textile products.

Most of the indicators analyzed refer to the activities of the production area or top management administration, considering factors such as quality or the environment. However, the supply chain and logistic indicators are left aside in most cases. Table 3

summarizes the indicators and variables obtained through synthesizing the studies compiled about the textile industry.

**Table 3**

*Textile industry indicators and variables*

| Perspective | Indicator | Variable |
|---|---|---|
| Financial | - Financial position | - Liquidity |
| | | - Solvency |
| | | - Cash flow |
| | - Operating efficiency ratios | - Inventory turnover |
| | - Profitability ratios | - Gross margin percentage |
| Commercial | - Customer indicators | - Distribution costs |
| | | - Billing |
| | | - Non-payments |
| | - Commercial network | - Achievement of budgeted sales |
| Human resources | - Staff satisfaction | - Absenteeism |
| | | - Occupational accidents |
| | | - Occupational accident costs |
| Innovation | - Innovation indicators | - New article benefits |
| | | - Innovation efficiency |
| | | - R&D&I projects |
| Production systems | - Quality and service of the manufactured product | - Cost of non-quality |
| | | - Returns |
| | | - Failed delivery deadlines |
| | | - Percentage of defects and waste |
| | | - Ordering services |
| | - Environmental efficiency | - Cleaner production knowledge |
| | | - Compliance with environmental standards |
| | | - Resource management |
| | | - Solid waste management |
| | - Time | - Lead time for customer service |
| | | - Lead time for incoming orders |
| | | - Supplier response time |
| | | - Average transit time |
| | | - Operational times |

**Developed by:** The authors (based on systematic literature review)

Completing the descriptive analysis, the present study answers the third research question, which refers to "*What are the variables or indicators that can be used in a plant layout design in MSMEs in the textile sector with a resilient approach*?" Initially, through the analysis of the 99 studies compiled, it can be said that no research has been found in which these two areas interact. Thus, the benefits of resilience in plant layout design have not yet been thoroughly studied. This means that information is not yet at the fingertips of organizations. However, the constant need to adapt to new, highly competitive markets generates circumstances in which companies must effectively know the current situation

of their processes, operations, and performance in general. In this manner, MSMEs can understand the areas and variables generating problems, and thus their responses are quick and appropriate.

Most of the FLP studies in the textile sector include indicators that consider elements such as the materials flow, transport time, travel distances, or the use of machines. As Quispe et al. (2020) mention, these indicators are related to the low production efficiency since they cause unproductive times and unexpected production stops. Nonetheless, these criteria are not the only ones to consider since other indicators are important to ensure optimal plant layout design and monitoring. For instance, Azadeh et al. (2015) propose a multivariate fuzzy approach to find the appropriate strategy for the distribution of facilities with ambiguity. In addition, the authors use operational, qualitative, and dependent indicators such as distance, adjacency, and shape ratio (Lin & Sharp, 1999). In this manner, the efficiency and accuracy of the models are greater, obtaining a correct arrangement of the work areas and machinery, thus achieving an economic reduction and at the same time a safer and fairer distribution for employees (Vitayasak et al., 2017).

It is necessary to propose a series of indicators for the plant layout design to have a resilient approach and respond to the FLP principles. For this, seven factors synthesize the information present in a facility layout design. These factors are material, equipment, waiting, services, facilities, change, and finally, the human element (Quispe et al., 2020). The indicators are detailed in table 4.

**Table 4**

*Proposed indicators and variables for resilient plant layout design*

| Factor | Indicator | Variable |
|---|---|---|
| Material | - Material Handling Cost | - Traveled distance between activities |
| | - Material movement time | - Duration of travel between activities |
| | - Material volume moved | - Volume of material between activities |
| | - Time spent to move material | - Loading/ Unloading time |
| Equipment | - Average time between failures | - Overall operation time in the period |
| | | - Overall number of failures |
| | - Meantime to failure | - Stoppage times |
| | | - Frequency of failures |
| | - Overall Equipment Effectiveness | - Availability |
| | | - Efficiency |
| Waiting | - Time | - Average waiting time between queues |
| | | - Lead time for order entry |
| | | - Average transit time |
| | - WIP | - Average queue length |

**Table 4**

*Proposed indicators and variables for resilient plant layout design (continuación)*

| Factor | Indicator | Variable |
|---|---|---|
| Service | - System safety efficiency | - Emergency equipment design |
| | | - Safety routes |
| | | - Safety and physical problems |
| Building/Facilities | - Adjacency | - Index of proximity between activities |
| | | - Perimeter of contact between activities |
| | - Space sufficiency and utilization | - Space utilization efficiency |
| | | - Productive area utilization |
| Change | - Facilities layout flexibility | - Expansion flexibility |
| | | - Volume flexibility |
| | - Building expansion | - Available outdoor area |
| | | - Current area |
| Human Resource | - Staff satisfaction | - Absenteeism |
| | | - Occupational accidents |
| | - Training and development | - Cost of training provided |
| | | - Operators with degrees or specific training |
| | - Fair culture | - Understanding and perception of errors |

**Developed by:** The authors (based on systematic literature review)

## Conclusions

- Through the literature review, 99 research studies were identified, of which 59 articles and 40 theses were analyzed systematically, reproducible, and critically. The most common indicators and variables in terms of business resilience, FLP, and the textile industry were determined from the information obtained.
- The analysis of studies about resilience, indicators in the textile industry, and FLP in the textile industry denotes a rising trend in research development on the topics mentioned above. Indeed, in the period 2015-2021, there was a rate of published research of 9.71, higher than the period between 2010 and 2014, which was 6.2. In both periods, research on this topic focused on resilience measurement methodologies, resilience factors in the industry, and decision-making predominated.
- Resilience research is superior to the other two topics analyzed in the study as it represents 46.46 % of the total sample of 99 research studies. In the Ecuadorian context, it is notable that resilience has been poorly explored, since the studies that passed the methodological and exclusion criteria only refer to FLP and indicators in the textile industry. In the international context, studies on the subject in question focus almost entirely on the evaluation and classification of resilience factors in the industry; no study has analyzed the interaction between FLP and resilience. Furthermore, several authors emphasize that the use of indicators other

than those traditionally used in the design of facilities could allow a better integration of resilience in organizations.

- As for the studies related to indicators in the textile industry, most of them consider aspects such as commercial, material or financial, however, several key elements such as labor or resilience are left aside. In addition, the indicators analyzed apply mainly to the production area and top management. Regarding FLP in the textile industry evidenced the use of indicators that evaluate the material flow, transit times, distance traveled, machine utilization, or the geometry of the building. Finally, a series of indicators have been proposed for the facility layout design, considering a resilient approach. These indicators respond to the FLP principles based on seven main factors: material, machinery, waiting, service, facilities, change, and human resources.
- Despite certain limitations of this type of research, it is expected that the work will serve as a key tool for future studies in which the interaction between FLP and resilience is studied. For instance, one of the research limitations lies in obtaining the sample since it depends on the search terms and the database used. The subjectivity of the study is another limitation. The approach of the indicators for the plant layout design with a resilient attitude depends mainly on judgment, experience, and the number of researchers involved. Nevertheless, the systematic literature review provides a broad overview of the current trends of the aspects analyzed despite these issues.

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