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ORIGINAL ARTICLE

Pull processes in health care: a systematic literature review

(PT-BR) - Processos puxados em saúde: uma revisão sistemática da literatura

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Abstract: The lean production paradigm was first adopted by the automobile industry and has been progressively adapted and adopted by several other sectors. Health services are, in general, co-created by users. This poses a logical challenge when applying one of the principles of the lean production paradigm: the establishment of pulled processes. This article investigates how pull processes have been adapted for lean production in healthcare (lean healthcare). A bibliometric analysis of 267 articles on lean healthcare research, published between 2004 and 2021, is presented in this article. A qualitative review of 233 articles is also presented. Most articles presented in this study were published after 2012, and publications and citations are primarily from the US, Brazil, and the UK. 39 articles pertain to an application of the concept, but most of the articles refer to pulling intermediate products, which are not subject to the aforementioned logical challenge. Only 8 articles effectively discuss the pulling of the flow of users. The main conclusion is that pulling has a distinct objective when applied to health care: the goal is not exactly the elimination of queues (the equivalents of intermediate stocks) but the elimination of idleness in downstream resources with limited capacity.

Keywords: Lean production; Lean healthcare; Pulled process; *Kanban*; Literature review; Bibliometrics.

Resumo: O paradigma da produção enxuta (lean production) surge na indústria automobilística, mas é progressivamente adaptado e adotado por outros setores. Serviços de saúde são, em geral, cocriados pelo usuário, o que impõe uma dificuldade lógica na aplicação de um dos princípios desse paradigma: o estabelecimento de processos puxados. Este artigo investiga como processos puxados têm sido aplicados nas adaptações da produção enxuta para o setor de saúde (lean healthcare). Foi realizada uma análise bibliométrica de 267 documentos publicados entre 2004 e 2021 e também uma revisão qualitativa dos 233 documentos cujos

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textos completos foram localizados. A quantidade de documentos cresce a partir de 2012, com concentração de publicações e citações nos EUA, Brasil e Reino Unido. São 39 os textos que apresentam uma aplicação do conceito, mas a maior parte trata de puxar o fluxo de produtos intermediários, não sujeitos ao desafio lógico em questão. Apenas oito textos tratam efetivamente de puxar o fluxo de usuários. A principal conclusão é que puxar processos aparenta ter um objetivo distinto quando aplicado no fluxo de usuários em saúde: o objetivo seria menos a eliminação de filas (equivalentes a estoques intermediários), mas sobretudo a eliminação de ociosidade em recursos de capacidade limitada a jusante.

Palavras-chave: Produção enxuta aplicada à saúde; Processo puxado; Kanban; Revisão da literatura; Bibliometria.

1 Introduction

In the Toyota Production System, the paradigm of “lean thinking” was incorporated to eliminate the various types of waste in the production processes (Womack & Jones, 2013). Womack & Jones (2013) define five principles for lean production: (i) the specification of what is perceived as value by the customer; (ii) the identification of the value stream, i.e., the sequence of activities responsible for adding the specified value (and also the activities that do not add value); (iii) the organization of production activities to keep the flow of materials active even between different departments; (iv) the establishment of a pull production, which will be described in detail in later sections; and (v) continuous improvement.

The establishment of pull production is related to one of the main principles of the practical operationalization of lean production. Pull production refers to a change in the way information is exchanged about when and how tasks should be performed at each position. Therefore, lean production is a paradigm of production planning and control (PCP) and can be treated as an alternative to existing pushed production paradigms, for example, the PCP method proposed by MRP II (manufacturing resources planning).

The programming logic of MRP II first estimates the final product sales to be conducted over the programming time horizon. Subsequently, the final product sales are transformed into purchase or production orders of each component, considering a set of parameters. This production paradigm tends to be lenient with inventories used as buffers for any unforeseen events in the production process, preventing production line activities from being interrupted (Slack et al., 2009).

Inventories, however, are considered waste in the lean production paradigm. Lean manufacturing is a partial solution to this problem. In lean manufacturing, the production lines are organized as a pull process. Two underlying steps, the output of the upstream step and the input of the downstream step, in a production line are connected by the intermediate product flowing between them. Ideally, in pull production, the upstream step produces the intermediate product not because a centralized system has issued a production order but because the immediate downstream step has signaled that it will need the product to start its activities. Ideally, the starting point of production as a whole is the arrival of a customer order. However, in lean manufacturing, all production is carried out only when necessary, and therefore, this paradigm is known as just in time. Furthermore, information about what to produce and when to start the production is transmitted along the value stream, in the opposite direction from the goods, instead of being calculated in a centralized system and transmitted from there to all stages (Slack et al., 2009).

In pull processes, communication about what is to be produced is not carried out by a centralized planner. Instead, visual signals are used by a process step to signal the upstream step that production needs to be triggered. This signaling is called *kanban* and can take different formats (Shingo, 1996). For example, small batches of intermediate products can be arranged in different boxes. Once they are used, the box is returned empty, signaling that it must be replenished. *Kanban* can even be cards, essentially replicating the traditional production order format, but with the crucial difference that they are passed from step to step and not from the end of the production line to the beginning.

Although lean production was first adopted by the automotive sector, the principles and tools of lean production have been applied in other sectors, including healthcare. For example, Womack et al. (2005) reported some possible applications, which require adaptation of the lean production concepts, including pull processes (Lima et al., 2021; Augusto & Tortorella, 2019; Hallam & Contreras, 2018; Al-Balushi et al., 2014). Womack et al. (2005) refer to pulled processes as patients' “expressed needs.”

However, some challenges to the adoption of lean processes persist, for example, in the *stricto sensu* adoption of the logic of pull processes in a health unit. Services such as healthcare are co-created by the customer; in this case, the user of the health unit. Ideally, in pull operation, the arrival of an order triggers the activity of the last production line position, which, upon performing its tasks, signals the previous production line position that it should be activated, and so on. However, a process that is co-created by the customers depends on the passage of the customer through the chain. A specific position can only be activated if the customer has already passed through the previous positions. Therefore, co-created services would always work as push processes in terms of the communication between the posts. In this type of sector, the implementation of the pull logic is restricted to intermediate materials.

Therefore, to address the aforementioned restrictions, we performed a comprehensive analysis of when and how the concept of the pull process has been applied in the adaptations of lean production for the healthcare sector (lean healthcare).

We conducted a bibliometric study and literature review, whose methods are presented in section 2. Section 3 presents the bibliometric study on 267 articles published between 2004 and 2021. In section 4, the results of the systematic literature review (SLR) on 233 articles and the resulting discussions are presented. Finally, section 5 concludes the article.

2 Method for selection and analysis of articles

In this section, the initial survey of the articles and the selection filters applied are detailed. General characteristics of the sample texts used in the review are also identified.

The literature review is usually an initial step in research, which allows the researcher to map the previous developments and existing knowledge of an area of study (Mian et al., 2005). In contrast, a systematic review incorporates systematic, rigorous, explicit, and responsible methods through three main activities: mapping of the research, systematic critical appraisal, and synthesization of the findings (Gough et al., 2012).

Similar to qualitative structured literature reviews, bibliometric research introduces a measure of objectivity in the evaluation of scientific literature, with the potential to increase rigor and mitigate researcher bias through a systematic, transparent and reproducible review process (Zupic & Čater, 2015). Bibliometrics has two main procedures: performance analysis, which aims to evaluate the activities of the authors,

universities, departments, and researchers; and the scientific map, which is used to represent the cognitive structure of a field of research (Cobo et al., 2011).

The first step of the literature search is selecting the database according to the research protocol (Thomé et al., 2016). The most common databases used for literature search are *Web of Science*, by Thomson Reuters, and *Scopus*, by Elsevier (Chadegani et al., 2013). The samples used in this review were obtained from searches in *Scopus* and *Web of Science* conducted in May 2021. The initial search revealed that the spellings “lean healthcare” and “lean health care” were commonly used in the existing literature. Thus, the searches were performed with the keyword set to “lean healthcare” and “lean health care.” The use of the term lean healthcare helps in restricting the search to results that are related to the theme; approximately 1% of the results were identified as false positives. In the *Scopus* database, the terms were searched in title, abstract, and keywords, and in the *Web of Science*, the terms were searched in Topic, which performs the search in title, abstract, author's keywords, and KeyWords Plus.

Figure 1 presents the flowchart of the selection process of the articles used in this research, adapted from the PRISMA protocol (protocol for selecting report items for systematic reviews and meta-analyses), as suggested by Moher et al. (2015).

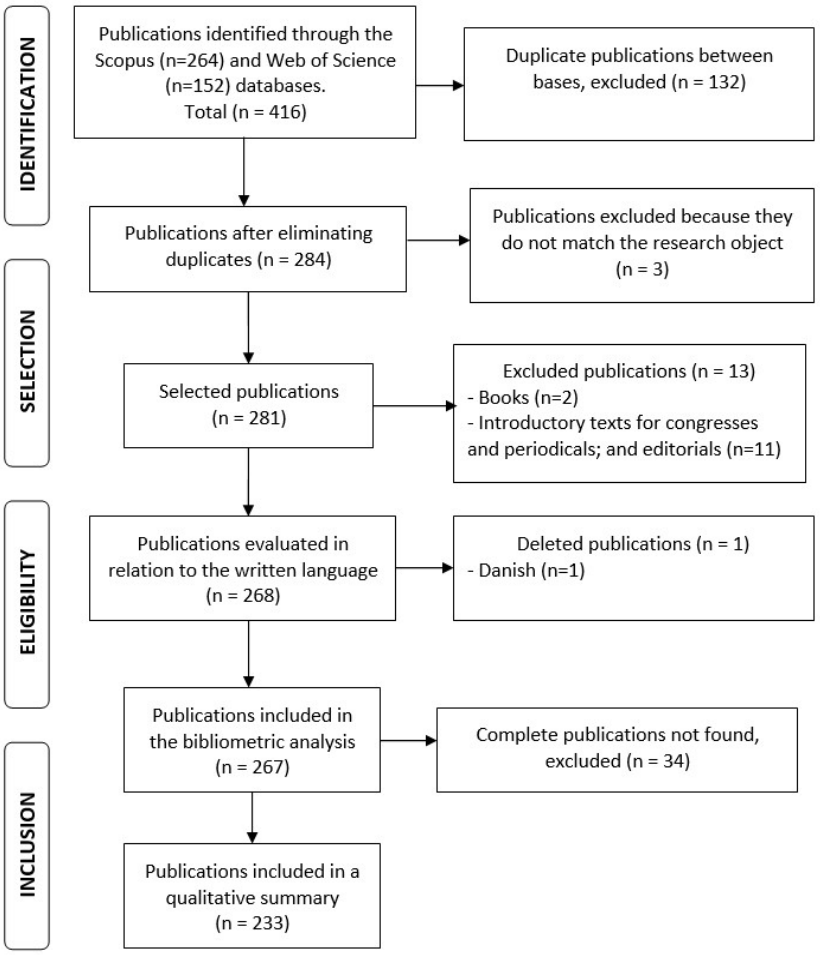

Figure 1. Flowchart of the document selection process used in this research adapted from the PRISMA protocol. Source: The authors (2021).

The search in *Scopus* and *Web of Science* returned 264 and 152 entries, respectively, of which 132 were in both databases, resulting in an initial total of 284 articles. An initial filter that involved a title and abstract analysis was applied, and 3 articles were excluded because they were not relevant to the research. During the analysis of the type of document, 2 complete books and 11 introductory articles of congresses, periodicals, and editorials were also excluded, thereby leaving 268 articles. Subsequently, only the English, Spanish, French, and German articles were maintained, and 1 article in Danish was excluded. After these selection processes, 267 articles were kept, and their metadata was used in the bibliometric analysis presented in section 3. Of these, 233 were complete articles and were effectively used for the literature review and qualitative synthesis, both presented in section 4.

In addition to the 233 articles from the database searches, 3 other texts were included in the final stage of the qualitative analysis of the literature review by snowball sampling, in which a search for other relevant works was conducted based on the references of the articles selected for analysis (Greenhalgh & Peacock, 2005).

3 Bibliometric analysis

Bibliometrics provide more objective analyses, using tools that describe the current state of various domains of human activity related to science, which is essential not only for research but also for the formulation of policies and practices (Aria & Cuccurullo, 2017). Bibliometrics enable the quantitative evaluation of information about selected publications and thus present the evolution of research in a given field of knowledge.

The bibliometric analysis was performed in the R language (Oliveira et al., 2018), using the *bibliometrix* library, which was developed to perform scientific mapping analysis (Aria & Cuccurullo, 2017). Similarly, the packages *countrycode, tidyverse, dplyr, and googleVis* were also used. All packages are freely available for RStudio, an integrated development environment for the R language.

This article summarizes quantitative data, such as the evolution of publications over the years, the list of the most productive authors, the most cited articles, and the journals that published the most types of articles, from the sample of 267 articles analyzed. It also presents analyses of the places of publications and frequency of citations per country.

The chronological distribution of publications is shown in Figure 2. In the number of articles published between 2004 and 2021, there was a significant increase in 2012 and peaks in 2015 and 2020. Between 2015 and 2021, 185 articles were published, corresponding to 69.3% of the total number of articles published.

Of the 267 publications in the sample, 174 (65.2%) articles were published in periodicals, 71 (26.6%) were published in congresses. However, apart from articles, there are 14 book chapters, 3 letters, 2 notes, 1 editorial, 1 meeting abstract, and 1 short survey in the sample. Regarding the language of the publications, 258 (96.6%) are in English, 5 publications were written in Spanish, 2 are in German, and 2 were originally written in Portuguese.

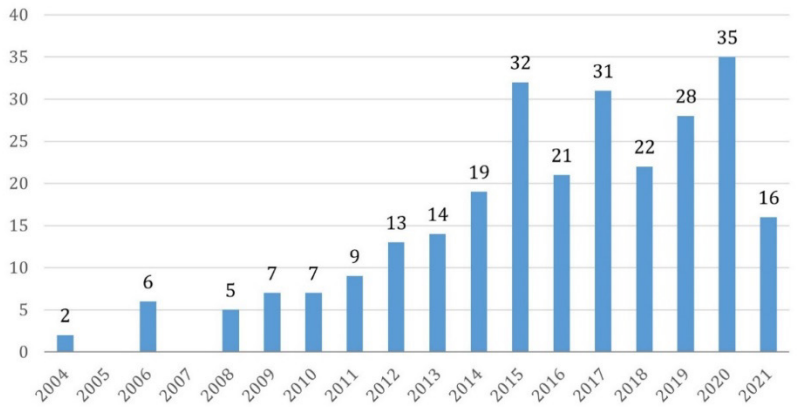

Figure 2. Chronological distribution of publications.
Source: *Scopus*. Processing by the authors (2021).

Among the 267 publications, 41 (15.4%) have a single author and 39 have multiple authors, which accounts for 5.5% of the total of 714 authors in the sample. Table 1 presents the relationship among the most productive authors, the number of citations, and the h index of the authors, which relates the number of publications with the number of citations (Hirsch, 2005). The table shows that there are 39 authors with more than 3 published papers. Tortorella GL, associated with the Federal University of Santa Catarina, is the author with the most publications, and Kim C, a researcher at the University of Washington, has the most citations. Godinho F M, associated with the Universidade Federal de São Carlos, has the highest h index of 24, which implies that 24 articles by this author received at least 24 citations, according to the publications indexed in *Scopus*.

Table 1. Authors with the most publications.

Author	Publications	Freq.	Citations	h index	Author	Publications	Freq.	Citations	h index
Tortorella GL	Augusto & Tortorella (2019), Borges et al. (2020), Fogliatto et al. (2019), Tlapa et al. (2020), Tortorella et al. (2015, 2017, 2019, 2020a, 2020b), Zepeda-Lugo et al. (2020)	10	84	20	Dinis-Carvalho J	Barretiri et al. (2021), Castanheira-Pinto et al. (2021), Lima et al. (2021)	3	0	11
Godinho F M	Bertani et al. (2019), Costa & Godinho (2016), Costa et al. (2017), Godinho et al. (2015), Henrique et al. (2016, 2021)	6	200	24	Gonçalves BS	Barretiri et al. (2021), Castanheira-Pinto et al. (2021), Lima et al. (2021)	3	0	2
Lima R	Barretiri et al. (2021), Castanheira-Pinto et al. (2021), Lima et al. (2021), Souza et al. (2019, 2020a, 2020b),	6	3	15	Guercini J	Barnabè et al. (2017, 2018, 2019)	3	17	3
White M	White et al. (2014a, 2014b, 2014c, 2017a, 2017b), White & Waldron (2014)	6	84	7	Guizzi G	Chiocca et al. (2012), Romano et al. (2013, 2015)	3	30	12
Butterworth T	White et al. (2014a, 2014b, 2014c, 2017a, 2017b)	5	75	15	Habidin N	Habidin (2017), Habidin et al. (2014, 2015)	3	33	11

Table 1. Continued...

Author	Publications	Freq.	Citations	h index	Author	Publications	Freq.	Citations	h index
Souza T	Lima et al. (2021), Souza et al. (2019, 2020a, 2020b), Vaccaro et al. (2015)	5	4	3	Jobin M	Dorval & Jobin (2019, 2021), Fournier & Jobin (2018)	3	7	5
Wells JSG	White et al. (2014a, 2014b, 2014c, 2017a, 2017b)	5	75	14	Kim C	Kim et al. (2005, 2006), Platchek & Kim (2012)	3	260	14
Anuar A	Anuar et al. (2018, 2019a, 2019b), Anuar & Sadek (2018)	4	5	3	Limon-Romero J	Tlapa et al. (2020), Zepeda-Lugo et al. (2018, 2020)	3	16	6
Anzanello MJ	Fogliatto et al. (2019, 2020), Tortorella et al. (2015, 2017)	4	50	17	Marodin G	Henrique et al. (2021), Tortorella et al. (2015, 2017)	3	41	17
Fogliatto FS	Fogliatto et al. (2019, 2020), Tortorella et al. (2015, 2017),	4	50	20	Reis A	Conceição et al. (2020), Reis et al. (2020), Santos et al. (2020)	3	4	3
Morrissette M	Morrissette (2009a, 2009b), Morrissette & Cassidy (2009a, 2009b)	4	2	1	Romano E	Chiocca et al. (2012), Romano et al. (2013, 2015)	3	30	12
Poksinska B	Drotz & Poksinska (2014), Poksinska (2016), Pokinska et al. (2017), Rotter et al. (2019)	4	148	14	Saad R	Anuar et al. (2018, 2019a, 2019b),	3	4	3
Rentes AF	Bertani et al. (2019), Costa et al. (2017), Godinho et al. (2015), Henrique et al. (2016)	4	104	6	Sadek D	Anuar et al. (2019a, 2019b), Anuar & Sadek (2018)	3	1	1
Sobek DK	Ghosh & Sobek (2006), Sobek & Jimmerson (2006), Sobek & Lang (2010), Sobek (2011)	4	26	15	Sarantopoulos A	Lot et al. (2018), Sarantopoulos et al. (2017), Siqueira et al. (2019)	3	13	1
Báez-López Y	Tlapa et al. (2020), Zepeda-Lugo et al. (2018, 2020)	3	16	6	Silva M	Coelho et al. (2013), Pinto et al. (2013), Silva et al. (2013)	3	28	11
Barnabè F	Barnabè et al. (2017, 2018, 2019)	3	17	6	Tlapa D	Tlapa et al. (2020), Zepeda-Lugo et al. (2018, 2020)	3	16	8
Bertani T	Bertani et al. (2019), Costa et al. (2017), Godinho et al. (2015)	3	51	2	Verbano C	Crema & Verbano (2017), Verbano et al. (2017, 2019).	3	10	17
Calado R	Coelho et al. (2013), Pinto et al. (2013), Silva et al. (2013)	3	28	4	Yusoff R	Anuar et al. (2018, 2019a, 2019b)	3	4	9
Chiocca D	Chiocca et al. (2012), Romano et al. (2013, 2015)	3	30	4	Zepeda-Lugo C	Tlapa et al. (2020), Zepeda-Lugo et al. (2018, 2020)	3	16	2
Demirli K	Alkaabi et al. (2019, 2021), Yu et al. (2015)	3	3	17					

Source: *Scopus*. Processing by the authors (2021).

Table 2 presents the list of the 10 most cited papers, listing the authors, the title, the year of publication, the journal in which the article was published, the number of citations,

and the citation rate per year. Citation rate per year is the ratio between the number of citations and the total number of years between the date of publication and 2021.

Table 2. Most cited publications.

Author(s)	Title	Periodical	Citations	Citations per year
Souza (2009)	Trends and approaches in lean healthcare	Leadership In Health Services	350	26,92
Kim et al. (2006)	Lean health care: what can hospitals learn from a world-class automaker?	Journal of Hospital Medicine (Online)	249	15,56
Waring & Bishop (2010)	Lean healthcare: rhetoric, ritual and resistance	Social Science and Medicine	226	18,83
D'Andreamatteo et al. (2015)	Lean in healthcare: a comprehensive review	Health Policy	222	31,71
Dahlgaard et al. (2011)	Quality and lean health care: a system for assessing and improving the health of healthcare organizations	Total Quality Management and Business Excellence	166	15,09
Souza & Pidd (2011)	Exploring the barriers to lean health care implementation	Public Money and Management	126	11,45
Al-Balushi et al. (2014)	Readiness factors for lean implementation in healthcare settings - a literature review	Journal of Health, Organisation and Management	109	13,62
Costa & Godinho (2016)	Lean healthcare: review, classification and analysis of literature	Production Planning and Control	95	15,83
Drotz & Poksinska (2014)	Lean in healthcare from employees' perspectives	Journal of Health, Organisation and Management	95	11,88
McCann et al. (2015)	Casting the lean spell: the promotion, dilution and erosion of lean management in the NHS	Human Relations	62	8,86

Source: *Scopus*. Authors' processing (2021).

The most cited article, Trends, and approaches in lean healthcare (Souza, 2009), has an average citation rate of 26.92 citations per year between 2009 and 2021. D'Andreamatteo et al. (2015) are the authors with the highest average rate of citations per year: 31.71. The only periodical that appears more than once in this ranking is the *Journal of Health, Organisation and Management*, with 2 publications. When the data in Table 1 are compared with data in Table 2, it is observed that, of the most productive authors, only Godinho F M, Kim C, and Poksinska B appear in the list of the most cited documents.

The 18 countries with more than two publications are presented in Table 3. For this classification, the address of the institution to which the first author is affiliated was considered. This table also shows the total number of citations and the average number of citations per document.

Table 3. Publications and citations by country (first author).

Country	Total Publications	Total Citations	Average of Citations per Publication
United States	50	580	11,60
Brazil	50	364	7,28
United Kingdom	23	868	37,74
Italy	21	334	15,90
Canada	14	91	6,50
Spain	11	40	3,64
Malaysia	9	39	4,33
Portugal	9	11	1,22
Sweden	7	316	45,14
India	6	53	8,83
Ireland	6	82	13,67
Mexico	5	19	3,80
Czech Republic	5	2	0,40
Morocco	4	9	2,25
United Arab Emirates	3	13	4,33
Oman	3	111	37,00
Peru	3	0	0,00
Turkey	3	23	7,67

Source: *Scopus*. Processing by the authors (2021).

The total number of publications from these 18 countries is 232 (86.9%). Another 24 countries are present in the sample, with at most 2 publications. Furthermore, 7 publications, accounting for 2.6% of the sample, did not have their authors' affiliation address registered, according to data exported from *Scopus*. These publications have 25 citations in total; therefore, their exclusion does not significantly impact the results. The United States and Brazil are the countries with the most significant number of publications. Sweden has the highest average number of citations per document, despite having only 7 publications.

In addition, Table 4 also shows the dispersion of scientific production by country, considering all the authors of a given publication. If a publication has more than one author affiliated with institutions from the same country, that country is counted only once. Table 4 shows the 12 countries with 6 or more publications. The concentration of publications in the United States shows that the country is at the forefront of research on the subject. The United States, Brazil, the United Kingdom, Italy, and Canada are the five most productive countries. The sum of the contribution of researchers from these five countries is equivalent to 58.4% of the total sample, thus demonstrating the centralization of academic production.

Table 4. Publications by country (all authors).

Country	Total Publications	Cumulative %
United States	60	18,8%
Brazil	57	36,6%
United Kingdom	30	45,9%
Italy	21	52,5%
Canada	19	58,4%
Spain	13	62,5%
Sweden	10	65,6%
Malaysia	9	68,4%
Portugal	9	71,3%
India	6	73,1%
Ireland	6	75,0%
Czech Republic	6	76,9%

Source: *Scopus*. Processing by the authors (2021).

In Table 3, which lists only the countries of the first authors, 42 countries were identified. In contrast, in Table 4, which considers all authors, 47 countries were identified. Saudi Arabia, the UK, Poland, Puerto Rico, and Senegal are the countries observed only in Table 4.

Table 5 presents the rankings of the 12 countries with more than 4 publications. The total number of citations and some metrics of the journals are also listed. The impact factor, *Journal Citation Reports* (JCR), is calculated based on the journals indexed by the *Web of Science*. The 2019 JCR is obtained by summing the number of citations made to the articles published by a journal in 2017 and 2018 and dividing by the sum of articles published by that journal in the same period. Similarly, the journals indexed by *Scopus* present the *CiteScore* 2020, which is obtained by dividing the number of citations made in 2020 to articles published by a journal in 2017, 2018, 2019, and 2020 by the total number of articles published by that journal in the same period. The *SCImago Journal Rank* (SJR) was developed by SCImago and is based on journals indexed by *Scopus*. In SJR, in addition to the number of citations, the journal's prestige is also considered, based on an algorithm similar to that of *Google PageRank*. Table 5 also presents the h index of the journals based on the number of articles and citations indexed in *Scopus*.

Table 5. Publications by journals.

Source	Publications	Total Citations	JCR 2019	CiteScore 2020	SJR 2020	h index 2020
Journal of Health Organization and Management	8	277	1,054	2,30	0,490	3
International Journal of Environmental Research and Public Health	5	13	2,849	3,40	0,747	46
International Journal of Supply Chain Management	5	6	-	1,00	0,585	5

Table 5. Continued...

Source	Publications	Total Citations	JCR 2019	CiteScore 2020	SJR 2020	h index 2020
Advances in Intelligent Systems and Computing	5	2	-	0,90	0,184	21
Production Planning and Control	4	174	3,605	8,20	1,331	13
International Journal of Health Care Quality Assurance	4	63	-	2,10	0,408	2
IFAC Proceedings Volumes (IFAC-PapersOnline)	4	37	-	2,10	0,308	4
BMC Health Services Research	4	22	1,987	3,50	1,098	9
Production	4	11	-	2,20	0,336	3
International Journal of Lean Six Sigma	4	8	2,511	5,20	0,578	6
Brazilian Journal of Operations & Production Management	4	0	-	-	-	-
Society for Health Systems Conference and Expo	4	0	-	-	-	-

Source: *Scopus*. Processing by the authors (2021).

The *Journal of Health Organization and Management* stands out with the most significant number of publications. Only the *Journal of Health Organization and Management* and 4 other sources listed in Table 5 have JCR 2019, indicating that a considerable portion of the sample does not appear on the list of journals with the most significant impact in the scientific field, as they are not indexed by the *Web of Science*.

4 Qualitative literature review

This section presents the qualitative literature review of the 233 articles filtered. The filtered articles considered for the review had full-text access. Section 4.1 presents the analysis dimensions of the articles and general figures concerning these analyses. Sections 4.2 to 4.6 present the results and discussions of the review.

4.1 Dimensions of analysis and overall review figures

The 233 articles filtered were categorized into four dimensions: (i) whether pull processes are mentioned in the article; (ii) type of the article (theoretical, empirical, or review); (iii) whether the nature of the reference to pull processes is theoretical; (iv) whether the nature of the reference to pull processes is empirical. These dimensions of analysis are detailed below, thereby presenting the general numbers of the categorizations.

To identify whether an article mentions pull processes, the English texts in the article were searched for two terms: "*pull*" and "*kanban*." The first term is self-explanatory, and the second term refers to a way to operationalize a pull process. When these two terms were located in the text, the excerpt was analyzed to verify if it effectively referred to pull processes, as the term "*pull*" can be used in other

contexts. For texts in other languages, the same method was used; however, the German texts were searched for the term “pull,” and the French and Spanish texts were searched for words beginning with “*tir-*.” Of the total of 233 articles, only about half mention pull processes: 109, or 46.8%. 124 (53.2%) articles make no mention of pull processes. The following analyses were conducted to assess how these 109 articles describe the use of the concept of pull processes.

The articles were categorized as empirical, theoretical, or literature reviews in the second dimension of the analysis. Every article that included some fieldwork was categorized as empirical, even if a systematic review was present in the article. For the other articles, if they had some degree of systematicity in the texts cited in the theoretical references, they were categorized as literature reviews; otherwise, they were categorized as theoretical works.

We identified 156 articles with some empirical bias in the application of some method or the report of some implementation via a case study, survey, or other methods. These articles are the majority, corresponding to 67.0% of the 233 articles reviewed. The remainder consists of 40 (17.2%) articles that include reviews with some degree of systematicity and 37 (15.9%) articles that have a more theoretical character.

The third dimension of the analysis focuses on how the articles frame the concept of pull processes when the term pull or *Kanban* is present in their theoretical framework. Note that the theoretical framework here refers to the entire text in the case of theoretical and review papers. Four possible frameworks were considered: Principle (PRI); Method (MTD); Literature - case (LTC); Literature - discussion (LTD).

The framing “Principle” (PRI) refers to the mention of pull processes as one of the five principles of the lean production paradigm, as established by Womack & Jones (2013). Alternatively, the terms may be mentioned for methods of implementing this paradigm in practice. For example, the term *kanban* may be mentioned as a tool for implementing a pull process. In some articles, the term pull may describe the part of the mapping by the Value Stream Mapping (VSM) method that involves defining whether the flow is pulled or pushed. In such cases, the “Method” (MTD) framework is considered. Furthermore, the terms may be used to describe existing literature, either a specific case or a broader discussion. For example, the authors may mention some study that implements pull processes in the health sector. This example is framed as “Literature - case” (LTC). The authors may also, for example, state that there has been little discussion in the existing literature about the application of *kanban* as a lean healthcare tool. This example would be framed as “Literature - discussion” (LTD).

All 233 texts in the review have theoretical references, but only 92 of them, or 39.5%, mention pulled processes or *kanban* in this part of the document. Still, most of them do not mention specific applications of the concepts. Table 6 presents, for the 92 texts in question, the framing of mentions.

It can be observed that most of the mentions of the terms in the theoretical framework are not linked to any practical application. 27 articles mention pull processes only as one of the five principles of lean production established by Womack & Jones (2013) (“Only PRI,” in Table 6). Besides these, 23 articles mention applying the concept, but without providing cases (“Only MTD,” in Table 6). However, there are 11 articles that do both (“PRI + MTD,” in Table 6). In other words, 61 (66.3%) of the 92 articles that mention the concepts in their theoretical framework do so without providing sufficient details.

Table 6. Number of articles according to the nature of the mention of pull processes in the theoretical framework.

Framing of the mention in the theoretical framework						
Framework	**Qty.**	**%**	**Section**	**Sub-framework**	**Qty.**	**%**
No discussion or case	61	66,3%	-	PRI only	27	29,3%
				MTD only	23	25,0%
				PRI + MTD	11	12,0%
Discussion of the literature	13	14,1%	4.2	LTD only	7	7,6%
				PRI + LTD	4	4,3%
				PRI + MTD + LTD	2	2,2%
Case of literature	13	14,1%	4.3	LTC only	8	8,7%
				PRI + LTC	1	1,1%
				MTD + LTC	2	2,2%
				PRI + MTD + LTC	2	2,2%
Discussion and case of the literature	5	5,4%	4.2 e 4.3	LTD + LTC	2	2,2%
				PRI + LTD + LTC	2	2,2%
				MTD + LTD + LTC	1	1,1%

Source: The authors (2021)

Among the 92 articles that mention the concept in their theoretical framework, excluding the aforementioned 61 articles, there are 31 articles that include references to discussions or case studies found in the literature. They are divided as follows:

- 13 articles present some discussions found in the literature on the concepts. Whether there has been prior mention of the concepts within the principles or implementation method framework will be discussed in section 4.2;
- 13 articles present some case studies found in the literature. Whether there has been prior mention of the concepts as a principle or method will be discussed in section 4.3;
- 5 articles do both. These articles will be discussed in sections 4.2 and 4.3.

The fourth dimension of the analysis focuses on the empirical works that mention pull processes, specifically when pull processes are mentioned in the empirical part of the article and not in the theoretical framework.

Although the 156 empirical articles are the majority, only 39 (25.0%) articles mention pull processes in their empirical parts. Of the 39, 10 articles do not deal with applications of the logic of pull processes or the *kanban* tool: 5 articles mention pull processes in the context of diagnosis or evaluation; 2 deal with teaching methods of the lean production paradigm; and 3 pertain to generic discussions. These articles are discussed in section 4.4.

There are only 29 empirical studies that effectively include some application or attempt to apply the logic of pulled processes or the *kanban* tool, although often treated superficially. These articles are discussed in section 4.5.

Regarding the reading level (Adler & Van Doren, 2014) used in the review, it is important to highlight that the review method, as described above, does not involve an analytical reading of the articles. Instead, the articles were read in an inspectional manner to assess their type (theoretical, empirical, or literature review). Following this, the body of the text was searched for the terms pull and *kanban*. However, this method involves a risk that the concept of pull processes may appear in some articles, but the articles might not be detected because they do not make references to the terms *pull* or *kanban*. However, this risk is relatively inconsequential.

Summarizing the conclusions of this first analysis, it can be said that most articles that mention the terms pull and *kanban* do so in a superficial way. Of the 233 articles in the review, only 92 mention pull processes in their theoretical framework, and 61 of these do not advance the issue in any practical application. Of the 156 articles with some empirical section, only 39 mention pull processes in their field study, 29 of which involved some practical application of the concept.

The following sections detail the discussions based on the review. To recapitulate, section 4.2 presents the articles that include generic discussions about applying pull processes in the health context in their theoretical references. Section 4.3 presents the articles that mention applications of pull processes based on articles from third parties. Section 4.4 presents the articles that mention pull processes in their empirical part, but without effectively applying the concept to a flow. Section 4.5 presents the articles that mention pull processes, effectively applied in a case, in their empirical part. Finally, section 4.6 presents comments on those articles that apply the logic of pull processes to the flow of users in a health facility: 7 articles, cited in sections 4.3 and 4.5, and a review text that was not covered in previous sections.

4.2 General discussions about pull processes in lean healthcare

The first group of articles discusses pull processes outside an applied context, presenting more generic issues. Some authors mention that the principles of lean production as established by Womack & Jones (2013) are not often observed in the literature, especially the fourth principle, which refers to the establishment of pull processes (Augusto & Tortorella, 2019; Régis et al., 2019; Hallam & Contreras, 2018; Schonberger, 2018; Mutingi et al., 2017; Ljungblom, 2014). For example, in a systematic review of 107 articles, Costa & Godinho (2016) found that only 5 articles reported the use of the tools in question. Rocha & Vasconcelos (2021) found the use of the tools was mentioned in 3 of the 15 articles they reviewed, while Lima et al. (2021) presented a quantitative review of the frequency of the use of different tools, in which it was observed that *kanban* is used relatively less. Hallam & Contreras (2018) proposed that this could be an indicator that the health sector is still in the early stages of adopting the lean production paradigm.

However, Van Rossum et al. (2016) and Borges et al. (2020) present a divergent view. Rossum et al. claim that a “lean toolbox,” including *kanban*, is frequently used, but they do not provide a quantitative evaluation of this claim. Furthermore, consulting the original article (Kaplan et al., 2014), cited by Rossum et al., makes it clear that a quantitative evaluation was not performed. Borges et al. claim that *kanban* is frequently used by referencing four literature articles.

The lean healthcare literature mentions that the concept of the pull process is adapted for use in healthcare (Lima et al., 2021; Augusto & Tortorella, 2019; Hallam & Contreras, 2018; Al-Balushi et al., 2014). Lima et al. (2021) commented on how lean tools have been adopted in a manufacturing context but require adaptation in healthcare. This adaptation may be simpler for more familiar flows, such as materials, but specific tools may be needed for flows such as those of patients.

The definition of a pull process, in the case of patients, is a point of discussion. For example, Augusto & Tortorella (2019) cite various literature and propose that, in the health context, pull production refers to the flow of patients and the balance between demand and capacity. Even Womack et al. (2005, p. 2) provide a different definition of pull processes in the healthcare context that involve responding to the real needs of

patients: “To maximize value and eliminate waste, leaders in health care, as in other organizations, must (...) [make] value flow from beginning to end based on the pull - the expressed needs - of the customer/patient.” This redefinition of the concept of the pull process sometimes appears in the literature. Note that in the same article, the authors provide a glossary of terms of lean production, in which they define pull processes in the traditional way (Womack et al., 2005). According to Schonberger (2018), even the application of pull processes using the logic of adapting production to the actual demands of patients will lose traction eventually. Furthermore, Castren (2016) comments that applying this logic in private healthcare may be problematic, citing literature to point out that the goal of cost reduction can lead to the worsening of patient’s well-being.

Other articles provide more practical discussions or comments about the implementation of pull processes. For example, Romano et al. (2015) propose that the flow of medicines and products, in general, can be organized via *kanban*, while Souza & Pidd (2011) comment that certain terms, including pull, have specific meanings in the context of lean production. Henrique et al. (2021) recall that lean goes beyond the pull processes and that its deployment depends on implementing a culture of continuous improvement. Furthermore, Alnajem et al. (2019) mention that the implementation of pull processes requires qualified suppliers.

4.3 Mentions of pull process applications in the theoretical framework

Of the 233 articles included in the review, 14 articles, in their theoretical framework, mention some specific cases of application of pull processes that they found in the literature (Rocha & Vasconcelos, 2021; Borges et al., 2020; Gayer et al., 2020; Tortorella et al., 2019; Alnajem et al., 2019; Regattieri et al., 2018; Régis et al., 2018; Torabi et al., 2018; Schonberger, 2018; Mehdi & Al-Bahrani, 2017; Gomes et al., 2016, 2017; Narayanamurthy & Gurumurthy, 2016; Costa & Godinho, 2016; Van Rossum et al., 2016; Vidal-Carreras Pilar et al., 2016; Reijula & Tommelein, 2012; Sobek II & Lang, 2010; Souza, 2009). References were made to 32 third-party texts that are not included in the review of this work.

In 3 of these 32 references, the concepts are not applied but instead discussed in the context of an assessment tool. 14 of the 32 references are directed at actual applications but without specifying what would be pulled. Another 12 references refer to the relationship of the operation with its inventories (with only 3 articles specifying that it is the inventory of materials and medications). In contrast, one of the referenced texts deals with applying the pull logic to the purchase of cardiovascular stents.

Therefore, there are 29 references out of the 32 in which the application of the logic of pull processes to the main flow of a health operation – the user – is not addressed. This is done only in the remaining 3 references (Burgess & Radnor, 2013, cited by Alnajem et al., 2019; Fillingham, 2007, cited by Torabi et al., 2018; and Pinto, 2010, cited by Mehdi & Al-Bahrani, 2017). These references will be discussed later, in section 4.6, which focuses on pull processes applied to the user flow.

4.4 Mentions of pull processes in a field study, but without an actual application

Among the 39 empirical texts that mention *kanban* or pull processes, 10 do not apply the concepts in a process. For example, 5 of these articles discuss the terms within a diagnostic or evaluation logic (Tortorella et al., 2019; Anuar & Sadek, 2018; Anuar et al., 2018; Sarantopoulos et al., 2017; Van Rossum et al., 2016).

Tortorella et al. (2019) proposed and implemented a method to evaluate lean production practices in units implementing lean healthcare. Part of the method involved prioritizing several lean production tools, and, in the case studied by the authors, it was concluded that *kanban* would be the practice that would cause the most significant impact.

Sarantopoulos et al. (2017) introduced an adaptation of lean production to the health context of the EPLIT questionnaire (Employee Perception to assess Lean Implementation Tool), which assesses how many employees of an organization grasp the concepts of lean production.

The tool built by Anuar & Sadek (2018) consists of a list of statements concerning operational and sociotechnical aspects of a process that operates within the lean production logic and can be used as a reference list to assess how much a given operation effectively uses this paradigm. Something similar was applied by Van Rossum et al. (2016) in their field study, but with the primary objective of investigating the role of leadership in overcoming the gap between decision and implementation of lean healthcare.

Besides these, 5 other articles mention the concepts in other disconnected contexts. Murman et al. (2013, 2014) wrote two similar articles that propose a method for teaching the principles and applications of lean production, including classes and some simulations, in the form of games. Both articles present the same proposal, principles, and simulated practices.

Calero et al. (2019) state as research objective the diagnosis and implementation of lean production tools, especially the rapid tool change (TRF) and the implementation of pull processes, to reduce the queue waiting time in a Peruvian clinic. However, the empirical part of the text contains only the TRF implementation, although it concludes that the waiting period was reduced by 30%.

O'Neill (2015) presents a case study in which he argues that the adoption of lean production principles by a healthcare facility led to work intensification. In contrast, Ljungblom (2014) investigates the extent to which the code of ethics for nurses incorporates lean production principles, concluding that pull processes, in particular, are not represented in that document.

4.5 Application of pull processes in the revised texts

Among the empirical works, 29 articles mention pull processes in their empirical part. Of these, 19 (65.5%) articles refer to pulling some intermediate product from the processes of the health unit under study. Some articles specify the type of product that should be pulled, such as medicines (Régis et al., 2018; Regattieri et al., 2018; Costa et al., 2017; Verbano et al., 2017; Eiro & Torres-Junior, 2015; Abouzahra & Tan, 2014), sterile products (Fogliatto et al., 2019; Tortorella et al., 2017; Costa et al., 2017; Godinho et al., 2015), vaccines (Chiocca et al., 2012), or clean sheets (McCann et al., 2015). Other articles mention the application of pull processes to materials in general, without a specific definition of the material in question (Borges et al., 2020; Régis et al., 2019; Briš et al., 2017; Cardoso et al., 2017; Costa et al., 2017; Pineda Dávila & Tinoco-

González, 2015; Jeffries et al., 2015; Centobelli et al., 2014; Hagan, 2011). In a few cases, the articles mention applying pull processes to purchases of medicines and other materials (Costa et al., 2017; Cardoso et al., 2017).

In addition to these, Haddad et al. (2016) implicitly define the pull of "staff resources" as the pull of human resources against the demand of users. Furthermore, five other articles (Anuar et al., 2019a; Castren, 2016; Mutingi et al., 2017; Centauri et al., 2018; Kinder & Burgoyne, 2013) mention the application of the concept of pull processes in a very superficial way, not specifying what would be pulled.

Note that some of the articles found in the literature may refer to the same case study when analyzing the diagnoses, proposals, and authors. For example, Tortorella et al. (2017) and Fogliatto et al. (2019), Godinho et al. (2015) and Costa et al. (2017), and Régis et al. (2019) and Régis et al. (2018). However, as a complete characterization of the cases treated might be absent in the articles, it is impossible to state this with certainty.

As in the case of mentions of pull processes in the theoretical framework, the mentions in the empirical part also represent a small minority of articles that deal with the application of pull processes on the main flow, that is, the users: only 4 articles do so (Lindsay & Kumar, 2015; Yu et al., 2015; Poole & Mazur, 2010; Lot et al., 2018). Among these 4 articles, 3 articles are similar and are detailed in section 4.3, and 1 review text that comments on the subject without mentioning a specific reference is detailed in section 4.6.

4.6 Application of pull processes to user flows

As mentioned in the previous sections, 8 articles contribute to the application of the logic of pull processes to the user flow. 3 of these 8 articles (Alnajem et al., 2019; Torabi et al., 2018; Mehdi & Al Bahrani, 2017) mention applications proposed by other articles, namely, Burgess & Radnor (2013), Fillingham (2007), and Pinto (2010). These 3 articles, along with the 4 articles selected for the review, apply the concepts in their empirical part (Lindsay & Kumar, 2015; Yu et al., 2015; Poole & Mazur, 2010; Lot et al., 2018). The review text by Reijula & Tommelein (2012) comments on the topic without referring to a specific text. These 8 texts will be detailed in this section.

Lot et al. (2018) propose the use of *kanban* not as a way to coordinate the flow of users but as a form of visual management of these flows, similar to the adoption of the tool in project management contexts. All the other 7 articles present the concept of pulling users to a particular service post when the post becomes available.

Fillingham (2007) defends the idea that users should be moved in a health unit production line only when the downstream activity is available to receive them. Reijula & Tommelein (2012) follow the same line of thought, highlighting that *kanban* systems can call users when a downstream value-adding activity is available, thereby minimizing queues. Torabi et al. (2018), when citing Fillingham (2007), mention this logic in the context of bed occupancy.

Burgess & Radnor (2013) illustrate the possibility of applying pull processes in the interaction between an operating room and a ward team. According to the authors, a push process would occur if the operating team takes the initiative to search for an available ward bed. The authors argue that this could have negative outcomes owing to difficulties in communicating with the ward team or the unavailability of beds. However, if the process was organized in a pulled manner, the ward team can be contacted as soon as a bed is available.

Lindsay & Kumar (2015) mention a case in which users are pulled instead of pushed to the correct beds, although they discuss the proposal in a very superficial way. Poole & Mazur (2010, p. 487) also present a similar application, but with a slightly more precise description: “the pull system was based on a fundamental change in the daily routine to pull patients to the beds right away if a bed was open. Therefore, the patient steps to 1) register; 2) go to the waiting room; 3) go to triage, 4) go back to the waiting room; and finally, 5) go to a bed were consolidated into a one-step process at the bed site with physician assistance”.

Yu et al. (2015) propose that, at a theoretical level, different healthcare units should implement pull processes in different arrangements for the flow of users. For example, for clinics, the authors propose a process in which users are pulled from the queues to each internal service station. For emergencies, because of uncertainty in demand, the process would have to be triggered in a pulled way (by the customer's arrival), but the flow would have to be traversed in a pushed way. The authors proposed this and a few other measures for an oncology clinic, even though implementation was not part of the scope of the study.

Pinto (2010) conducted a case study with proposals for changes in user flows at an oncology hospital. The logic of pull processes was implemented in the process stages in which users wait at the reception for an initial assessment and for the examination room to be vacant. At the process stage, in which users await approved procedures, a *kanban* was created to signal those without pending approvals, and they were transferred directly to the chemotherapy area. These proposals are not extensively detailed, but they seem to suggest that the principle of pulled processes and keeping the flows active should be implemented simultaneously.

In the above cases, users are pulled from pre-existing queues just before the focal post in question. Pull processes seem to be more about preventing the focal point from becoming idle rather than avoiding the emergence of stocks/queues at the interface between the posts. Considering that the 6 cases refer to beds and chemotherapy chairs, this interpretation seems to make sense. A more in-depth study is necessary for each case, but it would not be surprising if these were the bottleneck posts of the operations. This means that any idleness in these posts would lead to lower service capacity in operation as a whole, and efforts should be made to avoid such idle posts when queues are waiting.

5 Conclusion

The lean production paradigm is a solution to the problem of waste in production processes (Womack & Jones, 2013). One of the principles adopted for this is the creation of pull processes. In pull processes, ideally, a workstation is only activated on demand of the workstation immediately ahead, avoiding production ahead of time and preventing the formation of excess intermediate stocks understood as a form of waste. However, service sectors typically have the consumer as a co-producer. Therefore, there is a need for the physical presence of the user. For example, in a healthcare system, various logical challenges need to be overcome: how to produce against the demand of a downstream workstation when the production process depends on the presence of the user, who is “delivered” by the upstream workstation? This article conducted a bibliometric analysis and a systematic review of the lean healthcare literature to answer this question.

The 267 articles indexed by *Scopus* and *Web of Science* and published between 2004 and 2021 were analyzed. During the analysis, an increase in the number of

publications was observed from 2012 onwards, with peaks in 2015 and 2020. In the period from 2015 to 2021, 69.3% of the analyzed articles were published.

Regarding authorship, there was no prominent author in terms of the number of publications, citations, and h-index. When investigating the authors' affiliation, it was observed that the publications and citations are concentrated in institutions from North America, South America, and Western Europe, primarily the United States, Brazil, the United Kingdom, Canada, and Italy.

The Journal of Health Organization and Management stands out with the most significant number of publications. At the same time, the article trends and approaches in lean healthcare (Souza, 2009), published in Leadership in Health Services, is the article with the highest number of citations.

We located the full text of 233 of these articles, used in the qualitative literature review, to understand how the principle of pull processes is incorporated by applying the lean production paradigm in the health sector. However, the establishment of pull processes is one of the five lean production principles; a little less than half of the 233 reviewed articles mention pull processes. A closer analysis of these articles reveals that most of them mention pull processes as one of the pillars of lean production but do not elaborate on applying this concept in the health sector.

Among the 29 articles that effectively present empirical applications of the principle, 16 refer to the pulling of intermediate products, such as medicines, vaccines, sterilized products. In these cases, the logical challenge that motivates the research is not presented. One of the articles mentions pulling of human resources, but 3 other articles do not specify what is being pulled. There are only 4 articles that specifically mention the pulling of the main flow (users) in the health sector. 3 other articles were added that were not part of the review but are cited by the review articles concerning the pulling of users; a review text that comments on the issue, without reference to any specific text, was also considered

The main conceptual contribution of this review comes from the analysis of the 8 articles that deal with the pulling of user flow. In the articles, situations are described in which there is a queue, and the user is pulled from this queue for service as soon as a piece of equipment (in these cases, beds and chemotherapy chairs) becomes available.

This suggests that the aforementioned logical challenge persists, but the principle of pull processes can be applied in the healthcare sector to eliminate a different type of waste. In the production of goods, the focus is on the reduction or elimination of intermediate inventories. The review indicates that the objective, in the health context, is not the reduction of the formation of excess intermediate inventories or queues in the service sector but the reduction of the idleness rate of a piece of equipment, which is the bottleneck of the production process. Therefore, the waste that is sought to be reduced or eliminated here is the idleness of a workstation that limits the capacity of the production process.

Future studies may expand the scope of the review based on other keywords and other databases of scientific articles. Another interesting path would be to approach the topic, not through a literature review but case studies focused on pull processes in healthcare. Analysis of a healthcare production process in which users are pulled may help in understanding how such an initiative is organized and its intended purpose. This type of study can also aid in determining how the pull process is applied in health units of various degrees of complexity, complementing the results of this review, which focuses only on highly complex processes.

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