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Functionalities of Advanced Planning and Scheduling Systems in Supply Chain Planning: A Systematic Literature Review

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Abstract: ***Supply chains are increasingly required to exhibit resilience, responsiveness, and flexibility to deliver high-quality products and services under conditions of persistent complexity and variability. Advanced Planning and Scheduling (APS) systems have emerged as essential tools for effective supply chain planning. This study aims to identify the functionalities of APS systems documented in the literature that support supply chain planning processes. Following the PRISMA-P protocol, a systematic literature review was conducted across ScienceDirect, Scopus, and Web of Science, with predefined inclusion criteria applied during article screening. The findings reveal a concentration of studies focusing on supply planning functionalities, which are discussed in greater depth. This thematic emphasis highlights the need for future research to explore other APS functionalities and their applicability across diverse industrial contexts, thereby broadening the practical and theoretical understanding of APS systems.***

Keywords: Advanced Planning and Scheduling (APS), Supply chain planning, Resilience, Flexibility, Responsiveness, Literature review, PRISMA-P.

1. INTRODUCTION

With intense global competition pressure, supply chains have faced numerous challenges, including the need for rapid responses to market demands, reduction of lead time, decrease in inventory levels, flexibility to fulfill orders according to demand, and real-time information updates. The global advancement of interconnected activities and processes in supply chains requires an integrated, flexible, and agile planning process that facilitates decision-making and the identification of bottlenecks along the chain (Wang et al., 2021).

Supply chain planning is primarily characterized by the ability to anticipate critical points/bottlenecks at the strategic, tactical, and operational levels. New technologies facilitate the identification and implementation of decisions when alerts are generated in planning, enabling the application of planned flexibility (Sengupta; Dreyer; Jonsson, 2024).

Information technology enables an integrated approach, that is, a systemic view, especially in supply chain management. Its effective use can represent the difference between an organization's success and failure (Assis et al., 2023).

Advanced planning systems primarily aim to understand and solve complex supply chain planning problems, considering aspects such as constraints, business variables, demand, capacity, and finite resources. These systems are supported by advanced mathematical logic, with the goal of finding optimal cost-based solutions (Wolfshorndl; Vivaldini; Junior, 2020).

APS systems can bring various benefits to companies through functionalities such as transparency, integration, visibility, and process synchronization, which directly contribute to supply chain planning (Jonsson; Rudberg; Holmberg, 2013).

These systems have a wide range of functionalities focused on production planning, which is their main objective. They integrate planning with resource allocation and use specialized optimization methods and procedures. This specialization is possible due to sophisticated mathematical algorithms, which allow predicting demand, scheduling production processes, and defining the most appropriate production mix, also considering costs, with an emphasis on constraint-based planning (Fachini; Esposto; Camargo, 2018).

The central question of this research is: "What functionalities of APS systems are present in the literature to assist

in the supply chain planning process?"

This study aims to identify the main functionalities presented in the literature on APS systems.

The specific objectives of this study are: a) To conduct research in bibliographic databases prominent in the study area; b) To apply the previously determined inclusion and exclusion parameters for the research; and finally c) To identify the functionalities of an APS system.

This research is structured into five sections. Section two presents concepts on supply chain planning and APS systems. Section three describes the research method applied in this study. Section four presents the results analysis, and finally, section five describes the final considerations.

2. THEORETICAL FRAMEWORK

This chapter aims to provide an understanding of the topic presented in this research; it explores concepts related to supply chain planning management and APS systems.

2.1 Supply Chain Planning

Supply chain planning plays a crucial role in integration, synchronization, collaboration, and innovation within the supply chain. Integrated planning between the links and/or stages of the supply chain has a significant impact on the agility and flexibility of the supply chain, and this occurs through integrated and real-time information, encompassing demand and supply planning activities to minimize discrepancies in the plan and thus create and capture value (Kang; Kang; Du, 2022).

Preparing supply chains to face future situations by identifying bottlenecks and evaluating alternatives for each exception in supply chain planning. Encompassing the definition and evaluation in purchasing, demand, production, capacity, and distribution processes, applying quantification, sizing, and optimization methods with a view to the planning time horizon, i.e., long-term, medium-term, and short-term (Xu; Pero, 2023).

APS offer advanced functionalities that assist in supply chain planning. As these functions have improved over time, these systems provide sophisticated algorithms and can utilize large volumes of data simultaneously. Additionally, they offer the ability to generate optimistic and pessimistic scenario simulations, optimizing production and demand plans (Kunatha; Winkler, 2019).

Given the complexity and high number of decisions involved in constant supply chains, mathematical models are frequently employed, mainly demand forecasting and production optimization models. The decisions made over the planning horizon are crucial. From long-term (strategic) planning, establishing the prerequisites for production processes and for supply chain management as a whole in the company, to medium-term (tactical) planning—at this stage, variables such as seasonality and its implications for production and demand are considered—and finally to short-term (operational) planning, focused on detailed operations, each occurring over distinct time horizons and acting in a synchronized manner (Leite; Junior, 2023).

3. METHODOLOGY

This study is characterized as research with exploratory and descriptive approaches regarding its objectives (Prodanov; Freitas, 2013), adopting a qualitative approach.

The methodology used was a literature review, following the guidelines of the PRISMA-P (Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols) protocol.

Systematic literature review is an efficient tool to test hypotheses, synthesize the results of available scientific publications, and evaluate the consistency of previous studies. It is a method that involves the identification, evaluation, and synthesis of the evidence found (Petticrew, 2001).

The systematic review must be comprehensive, follow a clear methodology, with precise detailing of the applied procedures, and be replicable in other research (Okoli, 2015).

The PRISMA-P protocol guides the stages and structure of systematic reviews, which include the identification, selection, and critical evaluation of scientific research, as well as meta-analysis, which refers to the statistical techniques applied in the analysis of the studies included in the review. A systematic review protocol is fundamental, bringing benefits both during and after its execution (Moher et al., 2015).

The databases used were Web of Science, ScienceDirect, and Scopus, selected due to the need to gather the maximum number of relevant scientific publications for this research. These databases are widely recognized in the scientific community as they cover studies of global scope, with representative indexing and an extensive period of available articles.

The inclusion criteria were: language (Spanish, English, and Portuguese), articles with available access, and, regarding the analysis period, publications from 2013 to 2023 were considered. After applying these criteria, the results of the scientific publications are presented in Table 1.

Table 1: Search string applied

Database	Search string	Number of Articles
SCIENCE DIRECT	(("APS" OR "advanced planning system" OR "advanced planning scheduling") AND ("supply chain planning" OR "integrated planning"))	68
SCOPUS	TITLE-ABS-KEY (("APS" OR "advanced planning system" OR "advanced planning scheduling") AND ("supply chain planning" OR "integrated planning"))	16
WEB OF SCIENCE	TS= (("APS" OR "advanced planning system" OR "advanced planning scheduling") AND ("supply chain planning" OR "integrated planning"))	15

The steps performed and the results obtained, in accordance with the PRISMA-P protocol, are described in Figure 1.

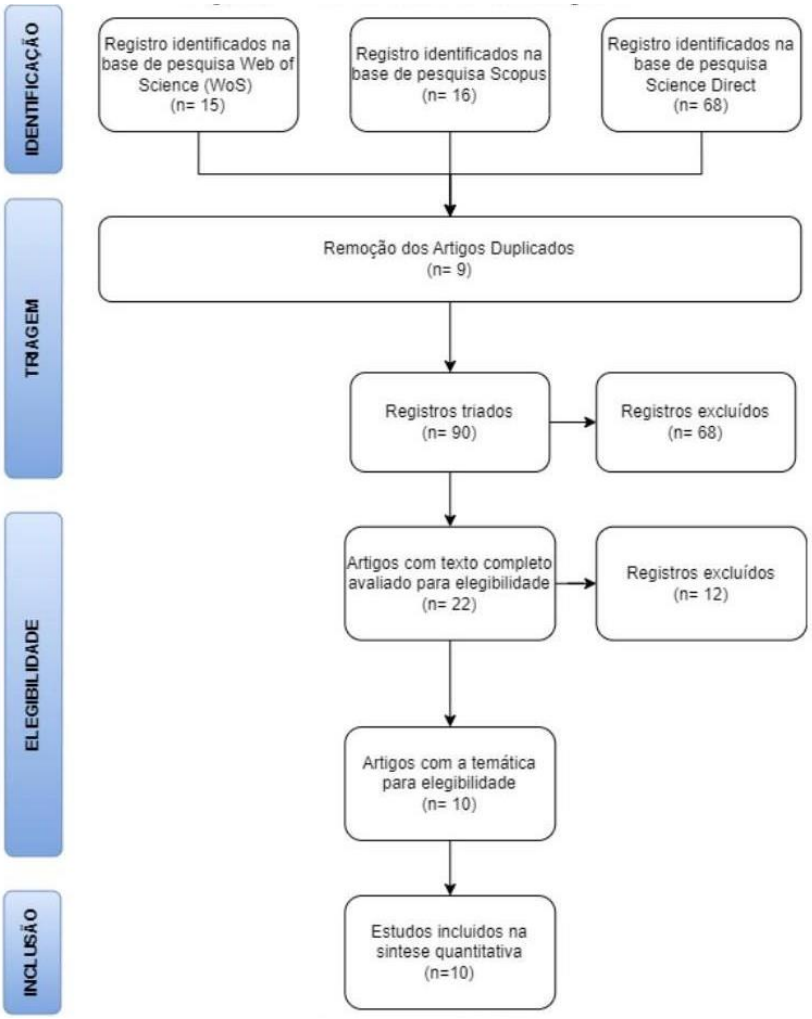


Figure 1: Research Procedure

The integration and removal of duplicates among the resulting articles were performed using an R script, version 2024.04.0. In the identification stage, 99 articles were selected. The script was used to integrate the database files, and after integration, 9 duplicate articles were removed, leaving 90 articles for abstract reading and verification of relevance to the topic.

In the eligibility stage, 22 articles were evaluated to determine if they presented elements relevant to the objective of this study. Each article was read in full, and studies outside the scope were discarded. As a result, 10 scientific publications were selected for the development of the results section.

4 RESULTS AND DISCUSSIONS

The results were presented through graphs, word clouds, and tables. For the analysis, the software VOSviewer, version 1.6.19, Bibliometrix, and the electronic spreadsheet software Microsoft Excel were used.

Table 2 presents the details of the publications selected for use in this research.

Table 2: Article selected for the research

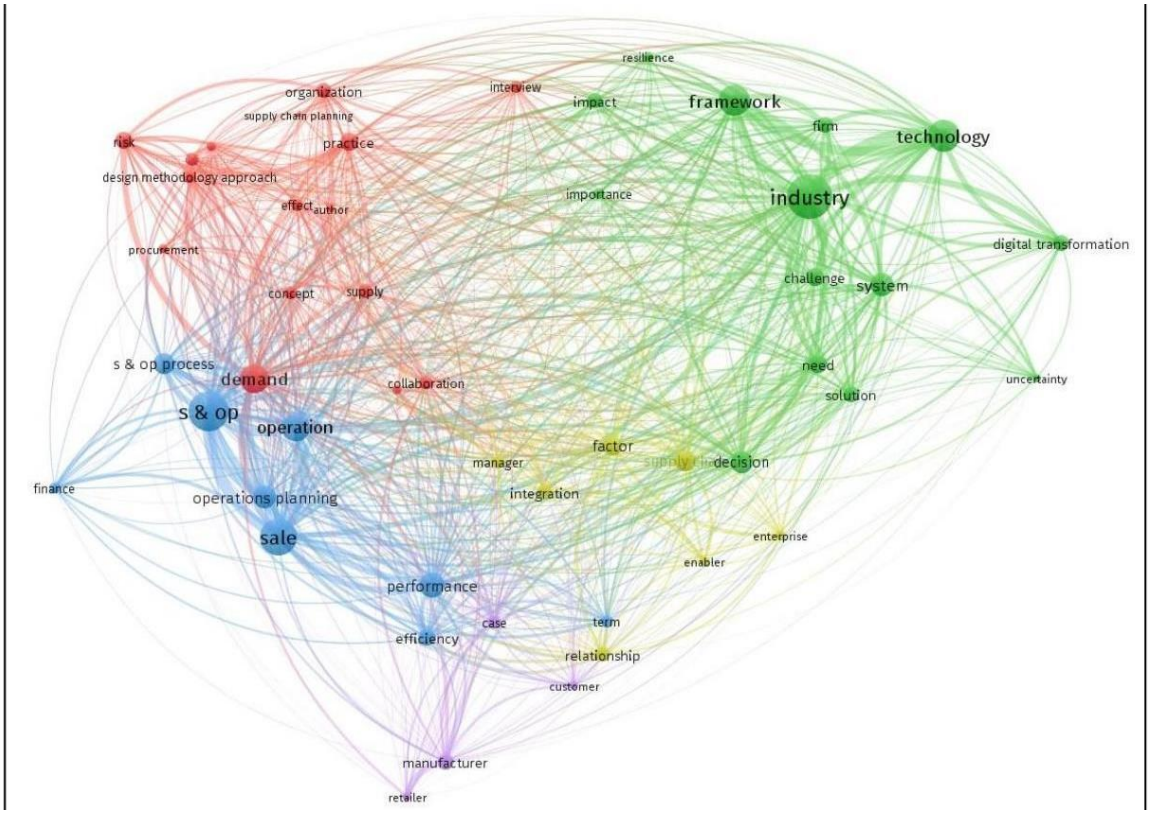
#	Article Title	Author	Year of Publication
1	SCPMATRIX BASED SHIPYARD DESIGN APPLICATION TO LONGTERM PRODUCTION PLAN	NAM, S.; SHEN, H.; RYU, C.; SHIN, J.	2018
2	A SYSTEMATIC LITERATURE REVIEW OF MODELLING APPROACHES AND IMPLEMENTATION OF ENABLING SOFTWARE FOR SUPPLY CHAIN PLANNING IN THE FOOD INDUSTRY	STUVE, D.; VAN, D. M. R; ALI, A. M.	2022
3	TOWARDS A REFERENCE ARCHITECTURE FOR ADVANCED PLANNING SYSTEMS	VIDONI, M; VECCHIETTI, A.	2016
4	A CONCEPTUAL FRAMEWORK FOR CLOUDBASED ADVANCED PLANNING SYSTEMS	GAHM, C.	2022
5	DEVELOPMENT OF PRODUCTION PLANNING SYSTEM FOR SHIPBUILDING USING COMPONENTBASED DEVELOPMENT FRAMEWORK	CHO, S.; LEE, J.; WOO, J.	2021
6	MULTICRITERIA ANALYSIS OF ADVANCED PLANNING SYSTEM IMPLEMENTATION	TRAMARICO, C.; SALOMON V.; MARINS, F.	2017
7	IMPROVEMENT OF DEMAND FULFILLMENT IN ADVANCED PLANNING SYSTEM THROUGH DECENTRALIZED DECISION SUPPORT SYSTEM	MOUSAVI, B.; HEAVEY, C.; MILLAUER, C.; TIAN, Z.; EHM, H.	2023
8	VALUE OF IT IN SUPPLY CHAIN PLANNING	FUCHS, C.; OTTO, A.	2015
9	THE BENEFIT OF INTEGRATING PRODUCTION AND TRANSPORT SCHEDULING	JENS, E. J. ; MICHAEL, F. M.	2016
10	MATHEMATICAL MODELLING OF PRODUCTS ALLOCATION TO CUSTOMERS FOR SEMICONDUCTOR SUPPLY CHAIN	BEHROUZ, A. M. B; RADHIA, A. R; CATHAL, H. C.	2019

Figure 2 illustrates the behavior of scientific publications over time. The years 2016 and 2022 stood out, with 2 articles published in each of these years. In the other years, the number of studies remained constant.

Figure 2: Articles by year

Figure 3 presents the co-occurrence map of keywords and article titles. For this, the VOSviewer software, version

1.6.19, was used. This software allows creating data groupings that show the volumetric distribution and correlation between keywords.



The size of the points represents their weight, and the distance between the points, called "nodes", indicates the intensity of the relationship: the closer they are, the stronger the connection between them. As shown in Figure 3, five groups were identified. The green group forms a "cluster" with terms related to technology, while the blue and red groups highlight terms linked to supply chain planning.

The word cloud presented in Figure 4 was developed based on the keywords of the publications. The highlighted words are the terms with the highest citation frequency in the studies, indicating the predominance of "supply chain management" and "advanced planning systems". These terms are therefore aligned with the theme of the present article.

Figure 4: Word Cloud

In Figure 5, the journals with local citation counts are presented. It can be observed how citations are distributed among the different sources. The items Int. J. Prod. Econ. and Int. J. Prod. Res. stand out, with 12 citations each.

Followed by EUR J OPER RES, INFORM MANAGE-AMSTER and PROD PLAN CONTROL with 9 citations each.

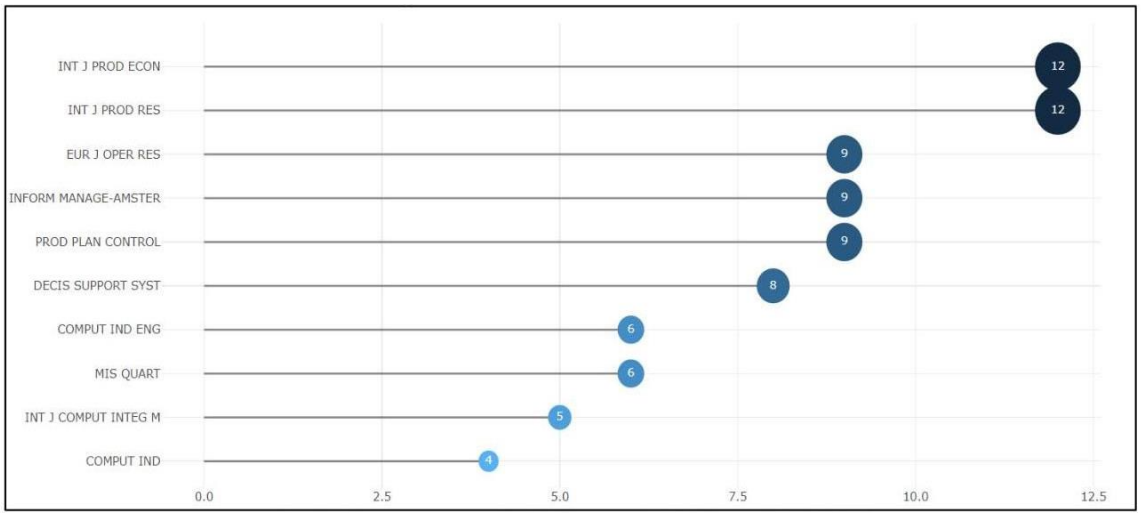


Figure 5: Most Cited Local Sources

When analyzing the authors' publications over a time series, in Figure 6, it is noted that between the years 2021 and 2023, there was a significant number of articles.

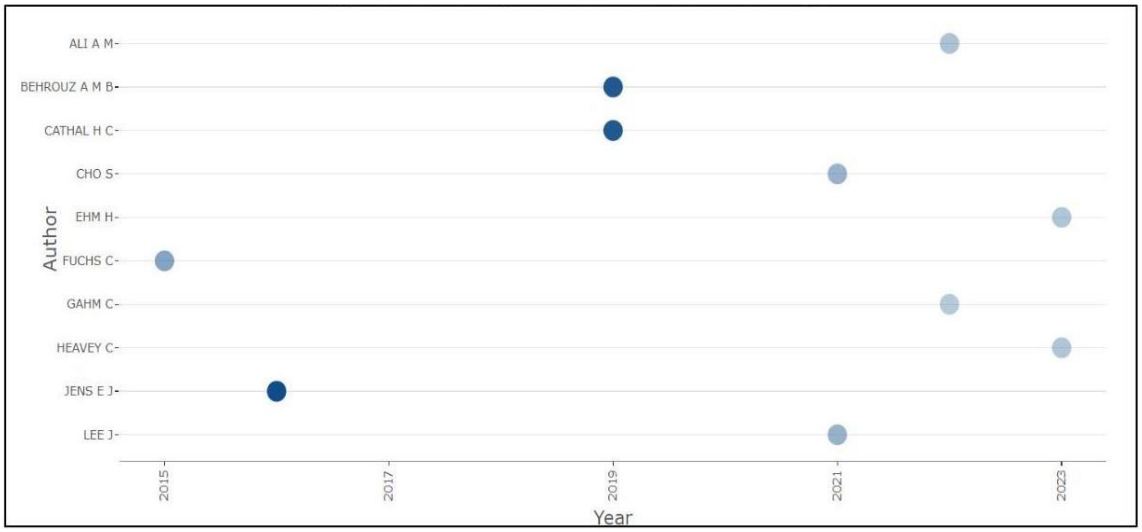


Figure 6: Authors' Publications on Time

Finally, when observing the documents according to the number of global citations, in Figure 7, the item JENS EHM JE, 2016, PROCEDIA CIRP stands out, with 48 citations, followed by BEHROUZ ALIZADEH MOUSAVI BAM, 2019, PROCEDIA Manuf. with 29 citations, NAM SH, 2018, INT J NAV ARCHIT OCEAN ENG with 20 citations and FUCHS C, 2015, J ENTERP INF MANAGE with 18 citations.

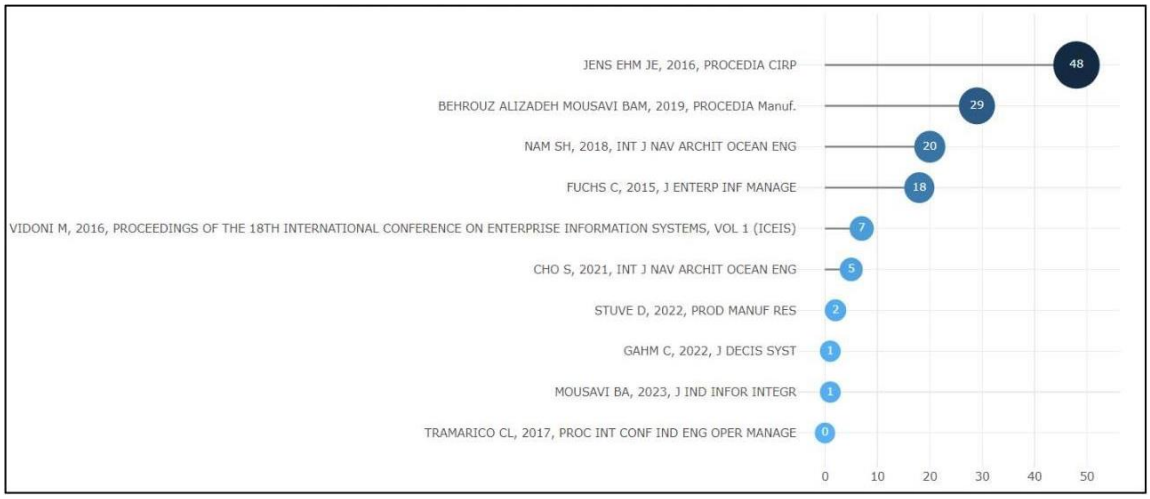


Figure 7: Most Cited Documents Globally

Table 1 presents the functionalities of all APS system modules identified in this literature review. The "Master Production Scheduling" functionality stands out as the topic addressed in the largest number of studies.

Table 1: Functionalities of APS Systems

Features	Authors
Demand Planning	Tramarico; Salomon; Marins, 2017 Stüve et al, 2022 Mousavi et al, 2023 Fuchs; Otto, 2014 Mousavia; Azzouza; Heaveya, 2019 Nam et al, 2018 Ehma; Freitag, 2016
Statistical Forecasting Algorithms	Tramarico; Salomon; Marins, 2017
Demand Collaboration	Tramarico; Salomon; Marins, 2017 Stiive et al., 2022
Demand Consensus	Stiive et al, 2022
Demand Forecast Accuracy Measurement	Stiive et al, 2022
Strategic Supply Chain Planning - Definition of strategy, for example: production locations, distribution center, strategic region for customer service.	Tramarico; Salomon; Marins, 2017 Stüve et al, 2022 Gahm, 2020 Mousavi et al, 2023 Nam et al, 2018 Ehma; Freitag, 2016
Master Production Scheduling - Order Fulfillment Date Forecasting, Production Planning	Tramarico; Salomon; Marins, 2017 Stüve et al, 2022 Gahm, 2020 Mousavi et al, 2023 Fuchs; Otto, 2014 Mousavia; Azzouza; Heaveya, 2019 Nam et al., 2018 Cho; Lee; Woo, 2021 Ehma; Freitag, 2016
Capacity Planning - Identification and Resolution of Bottleneck Resources	Stüve et al, 2022 Vidoni; Vecchietti, 2016 Mousavia; Azzouza; Heaveya, 2019
Material Requirements Planning - Procurement of Inputs	Tramarico; Salomon; Marins, 2017 Gahm, 2020 Mousavi et al, 2023 Fuchs; Otto, 2014 Mousavia; Azzouza; Heaveya, 2019 Nam et al, 2018 Ehma; Freitag, 2016
Production Planning and Scheduling - Batches, Resource Allocation, Scheduling and Sequencing of Production Orders	Tramarico; Salomon; Marins, 2017 Stüve et al, 2022 Gahm, 2020 Mousavi et al, 2023 Nam et al, 2018 Ehma; Freitag, 2016
Inventory Planning	Mousavia; Azzouza; Heaveya, 2019
Distribution Planning	Tramarico; Salomon; Marins, 2017 Gahm, 2020
	Mousavi et al, 2023 Fuchs; Otto, 2014 Mousavia; Azzouza; Heaveya, 2019 Nam et al, 2018 Ehma; Freitag, 2016
Transport Planning	Tramarico; Salomon; Marins, 2017 Gahm, 2020 Mousavi et al, 2023 Fuchs; Otto, 2014 Nam et al, 2018 Ehma; Freitag, 2016
Demand Fulfillment and ATP - Order Promise, Material Availability for Customer Orders	Tramarico; Salomon; Marins, 2017 Gahm, 2020 Mousavi et al, 2023 Fuchs; Otto, 2014 Mousavia; Azzouza; Heaveya, 2019
Scenario Generation / Scenario Comparison	Vidoni; Vecchietti, 2016
Data Consistency Check	Vidoni; Vecchietti, 2016

As observed in Table 1, some functionalities were referenced by only one author, such as: Demand Consensus, Demand Forecast Accuracy Measurement, Inventory Planning, Scenario Generation/Scenario Comparison, and Data Consistency Verification. However, other functionalities have a higher number of citations among the studies.

4. CONCLUSION

This study aimed to identify the functionalities of APS systems through an analysis of publications retrieved from scientific databases. It was observed that these functionalities play an essential role in assisting companies in the supply chain planning process and decision-making.

The functionalities addressed in the articles were: Demand Planning, Statistical Forecasting Algorithms, Demand Collaboration, Demand Consensus, Demand Forecast Accuracy Measurement, Strategic Supply Chain Planning (Definition of strategy, for example: production locations, distribution center, strategic region for customer service), Master Production Scheduling (Order Fulfillment Date Forecasting, Production Planning), Capacity Planning (Identification and Resolution of Bottleneck Resources), Material Requirements Planning (Procurement of Inputs), Production Planning and Scheduling (Batches, Resource Allocation, Scheduling and Sequencing of Production Orders), Inventory Planning, Distribution Planning, Transportation Planning, Demand Fulfillment and ATP (Order Promise, Material Availability for Customer Orders), Scenario Generation / Scenario Comparison, and Data Consistency Check.

The investigation of the articles made it possible to determine that the most addressed functionalities in the articles are related to production planning and demand planning. Only one study referenced the simulation functionality, which contributes to planning by enabling the analysis of positive or negative impacts. These functionalities are available for all modules.

However, the limitations of this study include the low number of available studies on the topic and the restricted number of databases used in the research. For future research, it is suggested to investigate the impacts of these functionalities on planning and in which stages of an integrated planning cycle they are applied, as well as to identify the advantages of these functionalities in planning.

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