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A Review of Production Scheduling for Prefabricated Building Components

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Abstract

The development of prefabricated buildings is changing rapidly, and production scheduling has an important impact on its development, so the optimization of production scheduling for prefabricated building components has been of particular concern to the construction industry in recent years. This paper conducts bibliometric and visuals analysis of production scheduling literature in the Scopus database by using VOS viewer analysis software, and study in-depth a series of methods and optimization techniques developed and adopted in recent years for production scheduling of prefabricated buildings. This paper summarizes the general trends in production scheduling for prefabricated buildings in the last decade and provides insights into the technologies and methods that have enabled the optimization of production scheduling problems in recent years. The potential for effective integration and consolidation between these new technologies in the context of production scheduling is also explored in the future with the rise of emerging technologies such as artificial intelligence techniques and machine learning. In conclusion, production scheduling optimization methods for prefabricated buildings should be continuously innovated and effectively integrated so as to effectively promote the development of prefabricated buildings and accelerate the transformation and upgrading of the construction industry.

Keywords

Prefabricated Building, Production Scheduling; Project Management, Literature Review, Scheduling Optimization

1. Introduction

The traditional construction industry is based on the site, mainly relying on tra-

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ditional manpower and experience to build, its production scheduling is often time-consuming and laborious, and easily confused, so the construction efficiency is extremely low (Xu et al., 2020). In addition, with the gradual disappearance of China's demographic dividend, the cost of labor is also gradually increasing, which correspondingly leads to an increase in production scheduling costs (Jiang & Wu, 2021). With the development of prefabricated building, the construction industry has undergone a sea change, the production method from the site moved to the factory, as in the manufacturing industry, the production efficiency has been well controlled. However, with the rapid development of high technology, people are no longer satisfied with the existing production efficiency, and it has been found that the production and construction process, such as the allocation of resources, coordination of personnel matters, and adapt to fluctuating market demand and other issues on the production scheduling challenges, so it is important to further optimize the production scheduling of the prefabricated building (Yuan et al., 2021b).

At present, the research on production scheduling at home and abroad is relatively mature, but the research on component production scheduling for prefabricated buildings is still relatively limited (Bataglin et al., 2020). This paper uses the VOS viewer analysis tool to measure and visualize the literature on production scheduling in the past ten years, summarizes the research hotspots and development trends of production scheduling for prefabricated buildings in recent years and provides insights into techniques and methods to optimize the production scheduling problems in recent years, and discusses the main research directions for the future development of prefabricated buildings. It also summarizes the research hotspots and trends in production scheduling in recent years, and provides insights into the techniques and methods that can optimize the production scheduling problems in recent years, and discusses the main research directions for the future development of prefabricated buildings.

2. Related Work

In this paper, through a combination of quantitative and qualitative methods, it reads and organizes the classical literature on production scheduling through VOS viewer, and at the same time, this paper use SCOPUS database for keyword search, and focus on 1470 classical literatures in the fields of engineering and technology, management, and operations research, etc., and finally, through systematic screening, we select 212 literatures as the basic data of this paper, and launch the subsequent quantitative analysis.

Based on the above data to conduct a high-frequency co-citation literature study on production scheduling issues, the network visualization mapping was performed by VOS viewer tool, and the results are shown in **Figure 1**. Subsequently, the visual mapping of **Figure 1** was counted into tabular data, analyzed for the top 10 keywords with high citation frequency, and organized as shown in **Table 1**. Combined with the trend graphs in the VOS viewer tool in the past ten years, it can be summarized that the hotspots of production scheduling are mainly

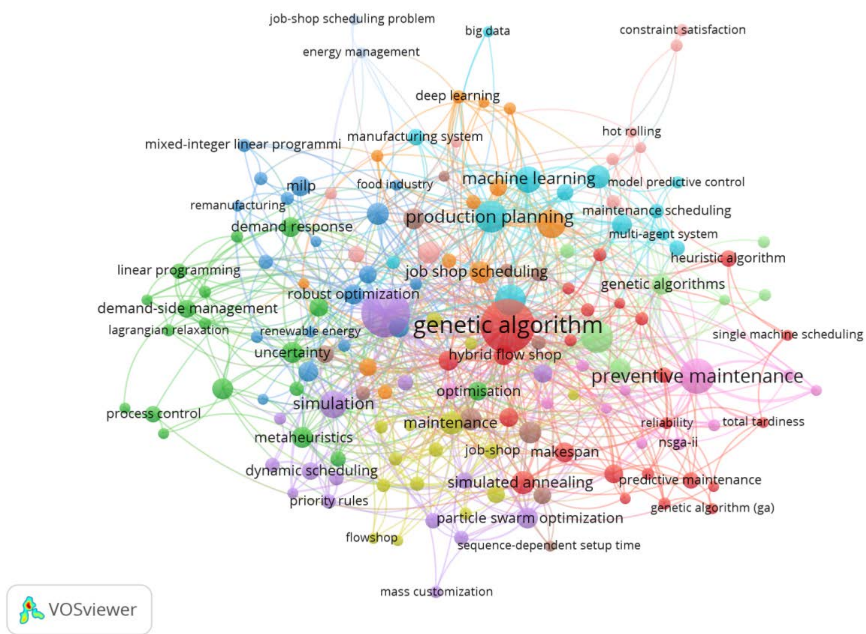

Figure 1. Co-occurrence analysis of production scheduling keywords.

Table 1. High-frequency keywords for production scheduling research.

serial number	byword	frequency
1	genetic algorithm	52
2	robust optimization	48
3	preventive maintenance	23
4	production planning	20
5	machine learning	16
6	simulation	12
7	integer programming	10
8	Job shop scheduling	10
9	Maintenance	8
10	artificial intelligence	6

classified into three categories: optimization algorithms, scheduling models, and production environment factors. First of all, the optimization algorithm is the use of various advanced technologies and scientific means (such as artificial intelligence technology) to update the optimization of mathematical algorithms in recent years, so as to promote the evolution of various types of scheduling models and the establishment of new, and the establishment of the scheduling model in the establishment of the process of the various types of factors of production, so these three categories is the hot spot of the current research (Guo & Zhang, 2022). In addition, it is found that the development of production scheduling tends more and more to the study of complex problems, especially for the study of mass production problems in variable environments and multi-objective constraints, and researchers are paying more and more attention to the diversity and complexity of production scheduling of prefabricated components for prefabricated buildings (Zaalouk et al., 2023).

3. Review of Literature Related to Precast Production Scheduling

The main approaches adopted by domestic and foreign scholars to these hotspot problems are summarized for the three hotspot classifications mentioned above: optimization algorithms, scheduling models and production environment factors.

First of all, optimization algorithms, traditional algorithms including genetic algorithms, simulated annealing algorithms, particle swarm algorithms, ant colony algorithms, and fish swarm algorithms, etc., which have been used in a variety of production scheduling improvement process (Liu et al., 2023), but with the advancement of science and technology, especially with the birth of artificial intelligence, the use of intelligent optimization algorithms to promote and optimize the process of production scheduling has become dominant. At present, there are more and more means of designing algorithmic optimization using artificial intelligence techniques such as machine learning, deep learning and big data, and intelligent optimization algorithms are widely used in solving a variety of practical engineering problems due to their fast solution speed and high accuracy, which can solve many scheduling problems (Chen & Liu, 2023).

Secondly, regarding the scheduling model, the production scheduling model established based on various intelligent optimization algorithms can better solve the complex multi-objective practical engineering problems, and the use of visual 3D simulation technology to simulate the whole process of production scheduling, which can better establish and optimize the scheduling model, so as to make the production scheduling problems better solved (Wang et al., 2018a). Here we must mention the BIM technology which has been widely used in recent years, because BIM technology can make all the major parties involved in the whole life cycle of the project work together and communicate on a unified platform, so it provides more convenient channels for production scheduling, and makes the production scheduling become more efficient (Peiris et al., 2023).

Aspects of production environmental factors, that is, the environmental conditions of production and other uncertain factors. The production scheduling of prefabricated buildings involves many aspects of engineering project management, which is a relatively complex process that involves a very large number of uncertainties, or a variety of interfering factors, and therefore should be controlled through a series of methods or technical means (Wang et al., 2023). Usually in the consideration of the production environment factors are mainly studied in terms of normal working hours, abnormal working hours, overtime; production phase of the preemptive and non-preemptive situation; maintenance of parallel processing capacity; the priority of the production of components; the size of the buffer zone between the production station; the combination and size of the staff, the number of resources, the mixed production strategy, the size of the project; the tooling cost, the cost of labor and inventory costs, and so on. Costs of tooling, labor, and inventory, etc. These influences are diverse, complex and uncertain (Chen & Liu, 2023; Guo & Zhang, 2022).

In summary, during the prefabricated building production scheduling, managers need to fully collaborate with various departments and links, carry out careful planning and effective control, and ultimately achieve the purpose of simplifying the process, reducing costs, reducing waste, saving time and other effective management (Wang et al., 2018b).

4. Synthesis and Analysis

Aiming at the hot issues on production scheduling in recent years, especially on optimization algorithms, this paper carries out further in-depth research, and summarizes its Key Focus, Advantage, Limitation, and Methodology through a systematic review of more than forty typical articles, as shown in **Table 2**.

As can be seen from **Table 2**, the prefabricated components production scheduling problem has been studied in related literature from different perspectives and approaches. Through the above analysis and summary, the study found that some challenges in production scheduling are currently solved using a variety of advanced technologies and optimization algorithms (Yuan et al., 2021a), which are often integrated forms of combining a variety of technologies and algorithms to promote the optimization of production scheduling of prefabricated building components through a variety of combinations and collaborations to improve the production efficiency (Wang & Liu, 2023), reduce the cost, and promote the development of prefabricated buildings (Chang et al., 2022).

1) BIM technology and genetic algorithm integration: first of all, genetic algorithm is an important and very common optimization algorithm in the process of production scheduling improvement (Du et al., 2020), it can improve production efficiency, reduce costs, etc., but with the development of BIM technology, the use of dynamic simulation as well as multidepartmental collaborative work can greatly enhance the original single use of genetic algorithm model efficiency, and further enhance the accuracy of production scheduling (Yuan et al., 2021a).

2) Lean Planning Method Enhanced Biogeography Optimization Algorithm: Lean planning method can achieve real-time adjustment and planning in specific scenarios (Xie et al., 2021), and at the same time enhance biogeography optimization algorithm to promote the optimization and enhancement of production scheduling to help component manufacturers to carry out real-time simulation and planning (Chen et al., 2020), but this method has certain limitations, and it is not suitable for all scenarios (Yuan et al., 2020).

3) Dynamic scheduling model management under the multi-objective optimization (MOO) method: firstly, for the complex and changeable production

Table 2. Research on production scheduling problems of prefabricated building components.

Number	Key Focus	Methodology	Advantage	Limitation
[1]	GA & IFC for prefab scheduling	Genetic Algorithm, BIM integration	High accuracy in scheduling	Complexity in GA implementation
[2]	Lean production scheduling	Enhanced Biogeography-Based Optimization	Effective real-time adjustments	Limited to specific scenarios
[3]	Cost-effective scheduling	Discrete Differential Evolution Algorithm	Cost reduction in production	Requires specific parameter tuning
[4]	IoT for real-time planning in prefab	IoT, Multistage Decision-Making	Real-time data utilization	Dependency on IoT infrastructure
[5]	Parallel operations of serial machines	Genetic Algorithm-based model	Improves overall production time	Complex model implementation
[6]	Resource allocation & machine maintenance	Differential Evolution Algorithm	Balances resources and maintenance needs	May not suit all production scales
[7]	Managing constraints in PHP	Smart Work Packaging, Smart Construction Objects	Efficient PHP process management	Framework validation in real scenarios
[8]	Multi-project scheduling	Niche Genetic-Raccoon Family Optimization	Effective in complex project scenarios	Complex algorithm design
[9]	Site selection for PBIPs	Bi-level programming, Genetic Algorithm, Partan Frank-Wolfe algorithm	Economic and environmental balance	Specific to regional characteristics
[10]	Addressing operational uncertainties in precast production	Simulation-GA Hybrid Model	Cost-effective production scheduling	Requires detailed operational data
[11]	Reducing on-site production time variation	Game theory models	Better time management	Complexity in implementation
[12]	Multi-shift precast production scheduling	Flowshop scheduling model	Enhanced time and resource management	Limited to specific production settings
[13]	Addressing process connection and blocking	Genetic algorithm	Minimized delays	Specific to flowshop environments
[14]	Balancing production and transportation scheduling	Genetic algorithm	Cost and time efficiency	Dependency on specific transport conditions
[15]	Resource-constrained precast component production	Advanced scheduling model	Adaptable to diverse conditions	Requires detailed resource data
[16]	Prefabricated building production scheduling	Hybrid optimization algorithm	Effective in complex scheduling	Algorithm complexity
[17]	Resource-constrained scheduling	Optimization models	Better handling of constraints	Complexity in resource management
[18]	Fuzzy logic in project scheduling	Multi-objective optimization	Flexibility in uncertain durations	Dependence on accurate fuzzy modeling
[19]	Balancing MTO and MTS in production	Hybrid flow shop model	Improved production flexibility	Requires specific production setup
[20]	Prefabricated component scheduling	Artificial Fish Swarm Algorithm	Enhanced optimization capabilities	Algorithm complexity and setup

Continued

[21]	Process connection and blocking in precast production	Genetic algorithm	Improved production flow	Specific to precast production environments
[22]	Production layout optimization	Layout optimization model	Space and resource optimization	Specific to layout constraints
[23]	Fuzzy logic in production planning	Cooperative co-evolution algorithm	Adaptable to uncertain conditions	Complexity in algorithm implementation
[24]	Flow shop scheduling in precast production	Mixed-Integer Linear Programming	Precise and robust solutions	Requires extensive computational resources
[25]	Network planning in precast project scheduling	Network planning techniques	Reduced lead times and costs	Limited to network-compatible projects
[26]	Lean and BIM in ETO prefab systems	Lean principles, BIM integration	Improved project efficiency	Requires Lean and BIM expertise
[27]	Scheduling optimization in prefab construction	Discrete Cuckoo Search Algorithm	Enhanced optimization capabilities	Algorithm complexity and setup
[28]	Scheduling with preventive maintenance	Joint optimization method	Reliable and sustainable processes	Complexity in joint optimization
[29]	Mixed production line efficiency	Ant Colony Optimization Algorithm	Efficient line configuration	Specific to mixed production environments
[30]	Transportation scheduling of prefab components	Hybrid optimization algorithm	Reduced transportation costs	Depends on accurate algorithm tuning
[31]	Lean planning in precast production	Discrete Event Simulation	Waste reduction and efficiency	Reliance on precise simulation modeling
[32]	Production scheduling optimization	Automated optimization techniques	Improved efficiency and accuracy	Complexity in implementation
[33]	Demand fluctuation in prefab production	Dynamic scheduling model	Reduced waste, better resource utilization	Requires accurate demand forecasting
[34]	Scheduling in construction projects	Genetic Algorithm	Reduced time and cost overruns	Dependency on algorithm parameter tuning
[35]	Optimization in PCs production	Gene Expression Programming (GEP)	Effective handling of due date variations	Complex algorithm design
[36]	MOO in project management	multi-objective optimization techniques	Balances multiple project objectives	Requires sophisticated computational tools
[37]	Synergy of BIM and prefabrication	Building Information Modeling (BIM)	Enhances design accuracy and efficiency	Requires expertise in BIM
[38]	Supply chain management in construction	supply chain management (SCM)	Identifies key areas in off-site SCM	Limited integration of new technologies
[39]	Metaheuristics in modular construction	simulation models, optimization algorithms	Effective in complex scheduling	Specific to modular construction contexts
[40]	Optimization in precast production scheduling	linear programming, heuristic approaches	Focus on mainstream practices	May not cover all off-site construction scenarios

scheduling actual situation (Zhai et al., 2019), the method of multi-objective optimization is adopted, and dynamic simulation means are implemented to dynamically control the complex and changeable objectives (Yuan et al., 2021b), so that the simulation tends to be more close to the real scenario, so that the production scheduling can be more rigorous, and the cost can be saved (Yuan et al., 2021a).

4) Multiple algorithms integration optimization: For each stage of production scheduling to optimize one by one, that is, the use of genetic algorithms, mixed integer linear programming, differential evolution and other advanced algorithms for system integration (Li et al., 2019a), for the optimal allocation of resources, for different algorithms for different projects to support in-depth analysis and comparison of strategies (Yu, 2021), so as to carry out effective comparison of the application (Li et al., 2019b).

On the prefabricated components production scheduling problem is complex and variable (Li et al., 2019b), its optimization algorithm has a diversity, in the face of a variety of complex project requirements and environmental constraints should be targeted to put forward the corresponding solutions, and is to consider the problem with dynamic thinking, in the face of constantly changing algorithms and technology, to change should change, and constantly evolve to change the mindset of the optimization of production scheduling (Yu et al., 2022).

5. Future Research Directions for Precast Production Scheduling

With the rapid development of AI technology, production scheduling optimization for prefabricated buildings will add a new boost (Huang et al., 2022). Future production scheduling optimization will be the integration of a variety of optimization algorithms (genetic algorithm, mixed integer linear programming, differential evolution, etc.), and combined with BIM technology and lean planning methods, the use of AI and machine learning and other advanced technologies, through the use of practical application scenarios to validate the effectiveness of the different production scheduling optimization methods to improve the efficiency of the actual project production, so that the theory and practice can be fully integrated and effectively Fusion of various optimization techniques and methods. Of course, the future of production scheduling optimization must be based on the basis of sustainable development, in the full use of a variety of technical methods, to make full use of resources, reduce carbon emissions to reduce waste, etc., to truly realize the purpose of the green sustainable building (Yuan et al., 2020).

6. Conclusion

This paper conducts bibliometric and visualization analysis of production scheduling literature in Scopus database by using VOS viewer analysis software, and deeply study the current status of a series of methods and optimization techniques that have been developed and adopted in recent years in the area of production scheduling for prefabricated buildings, and summarize that hotspots of production scheduling are mainly classified into three categories: optimization algorithms, scheduling models, and factors of the production environment (Song et al., 2023). This paper examines the general trends in production scheduling for prefabricated buildings over the past decade and provides insights into the technologies and methods that have been able to optimize the production scheduling problem in recent years. In the future, with the integration and consolidation of emerging technologies such as BIM technology, AI and machine learning, it will lead to the continuous optimization of production scheduling, with better cost, efficiency, waste reduction, adjustment adaptability, and sustainability, and will further contribute to the continuous development of the entire construction industry (Ruan & Xu, 2022).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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