Systematic Literature review on Industrial Scheduling Optimization

Boukrouma Houcem Eddine[(1)*], Zennir Youcef[(2)], Bendib Riad[(3)]
[1] LRPCSI Laboratory of Skikda, University of 20Août 1955, Skikda 21000, Algeria
[2,3] Automatic Laboratory of Skikda, University of 20Août 1955,Skikda 21000, Algeria
[*]Corresponding Author Email: hd.boukrouma@univ-skikda.dz

Abstract: The optimization of industrial schedules has become an essential pursuit in modern industries, driven by the need to maximize efficiency, minimize operational costs, and enhance sustainability. This literature review investigates the diverse methodologies, strategies, and technological advancements shaping the field of industrial scheduling optimization. Focusing particularly on applications within petrochemical and other high-stakes industries, this review explores the use of artificial intelligence, advanced safety protocols, intelligent maintenance planning, and innovative scheduling algorithms. Through a critical analysis of recent studies, this review identifies key trends and challenges, including the integration of new technologies with legacy systems, the balance of cost and operational demands, and the development of resilient frameworks for unpredictable environments. By addressing these challenges and synthesizing current knowledge, this review highlights areas for further research and provides insights into creating adaptive, efficient, and robust scheduling strategies that can propel industrial operations into a new era of optimized performance.

Keywords: Optimization, schedule, Operational costs, intelligent maintenance.

1. INTRODUCTION

In the dynamic landscape of modern industries, where efficiency and resource utilization are paramount, the optimization of industrial schedules emerges as a critical imperative. As organizations strive to enhance productivity, reduce costs, and meet ever-evolving demands, the scheduling of operational processes becomes a linchpin for success. This literature review undertakes a comprehensive exploration of the diverse strategies, methodologies, and technological advancements that contribute to the optimization of industrial schedules. By navigating through the existing body of knowledge, we aim to discern emerging trends, address gaps, and glean insights that can propel industries toward a new era of streamlined and agile operations.

The optimization of industrial schedules is a multifaceted and crucial aspect within the realm of modern industrial management. As industries continue to evolve and become increasingly complex, the effective coordination and utilization of resources have become essential for competitiveness, cost-effectiveness, and overall operational efficiency. Historically, industrial scheduling has been a fundamental component of manufacturing and production processes. Traditionally, schedules were created based on fixed routines and predetermined timelines, often resulting in suboptimal resource utilization and inefficient operations. However, with the growing complexity of industrial systems, industrial schedules now need to adapt to dynamic and unpredictable conditions, necessitating rigid scheduling approaches and advanced technologies and sophisticated scheduling methods to more adaptive and optimized strategies. The context of industrial scheduling optimization encompasses the need to balance conflicting objectives, including maximizing production output, minimizing costs, reducing lead times, and ensuring the efficient use of resources such as labor, machinery, and raw materials.

In this dynamic context, the literature on the optimization of industrial schedules becomes pivotal. Researchers seek to explore methodologies, algorithms, and technologies to develop scheduling approaches that are not only responsive to the current industrial exigencies but also anticipatory of future

challenges. The literature review aims to dissect and synthesize these contributions, shedding light on the state of the art and identifying avenues for further research and application in the optimization of industrial schedules.

2. LITERATURE REVIEW METHODOLOGY

A systematic literature review is a comprehensive and transparent approach to gathering, critically evaluating, integrating, and presenting findings from multiple research studies on a specific research question or topic. It follows standardized methodologies and guidelines in searching, filtering, reviewing, critiquing, interpreting, synthesizing, and reporting findings from various publications on a particular topic and consists of four stages: planning, selection, evaluation and execution. The purpose of a systematic literature review is to provide a high-level understanding of existing evidence on a specific research question, offering a broader and more accurate level of understanding than a traditional literature review. **[1]**

A. Planning

The purpose of this study is to systematically review the existing literature, analyze the application status of optimization of industrial schedules.

B. Search for literature

Use academic databases (google scholar, IEEE Xplore; SCISPACE) to search for relevant articles, papers, books, and conference papers. With using key words related to the topic and the theme of the thesis.

C. Selection

In this stage, the literature was first explored and filtered, which provided a preliminary understanding of the literature. Based on the findings in the preliminary literature exploration, we established the practical screen criteria for the following literature retrieval activities.

D. Evaluation

Review for each article found in the previous process, the title, abstract, and introduction and conclusion sections to determine their relevance. Then we read the full text of selected sources to evaluate their quality, methodology and contribution to our research. Sources that are completely related optimization of industrial schedules were discarded. After this process, 53 sources were selected in this review for intensive reading.

E. Execution

Organize the gathered sources by categorizing them into categories based on their relevancy to the main objectives of the thesis and grouping sources into sections. The main sections by which we categorize resources are as follow:

- Built up of new strategies to control the resources and utilities used in the operation of a typical petrochemical plant.
- Improvement of the safety measures to protect the equipment, environment and health from any expected dangers.
- The use of artificial intelligence methods as tool to build new strategies to protect health and equipment and environment in industry.
- Improvement of maintenance strategies to minimize the cost of shutdowns and abnormal situations.
- Minimize the cost of execution time of any operation by developing intelligent schedules.

The literature review is organized into five sections to systematically address the multifaceted requirements of industrial scheduling optimization within complex environments like petrochemical plants. This division not only structures the extensive body of knowledge into targeted areas but also aligns with the overarching goals of improving operational efficiency, safety, and cost-effectiveness. Here is how each section contributes to these objectives:

Built-up of New Strategies to Control Resources and Utilities: Resource control and efficient utility management are foundational to optimizing industrial operations, particularly in energy-intensive sectors like petrochemicals. This section examines strategies that enhance resource utilization, reduce waste, and ensure sustainability—key factors in optimizing overall productivity and reducing operational costs. By focusing on these methods, the review establishes a baseline understanding of strategies for efficient resource management.

Improvement of Safety Measures: Safety is critical in industrial operations, where equipment and environmental risks are significant. This section addresses

methodologies aimed at protecting equipment, personnel, and the environment from industrial hazards. Improved safety protocols are essential not only for regulatory compliance but also for minimizing downtime due to accidents or equipment failure, thus contributing to more stable and reliable scheduling practices.

Use of Artificial Intelligence for Health, Equipment, and Environmental Protection: Artificial intelligence (AI) has emerged as a powerful tool for developing intelligent safety and protection strategies. This section explores AI applications that enhance risk detection, safety monitoring, and real-time decision-making capabilities. Incorporating AI into industrial systems fosters proactive approaches that can prevent disruptions and streamline operations, thereby supporting more adaptive and resilient scheduling practices.

Improvement of Maintenance Strategies: Effective maintenance strategies are vital to prevent costly shutdowns and unexpected equipment malfunctions. This section reviews maintenance methodologies that reduce the likelihood and impact of abnormal situations. Optimized maintenance scheduling minimizes production interruptions and extends equipment lifespan, directly contributing to cost savings and operational efficiency.

Minimization of Execution Time Costs through Intelligent Scheduling: In industries with complex, interconnected processes, reducing the cost and time associated with task execution is essential. This section focuses on the development of intelligent scheduling techniques that leverage optimization algorithms to minimize delays and ensure timely resource allocation. By examining these scheduling innovations, the review highlights the role of smart scheduling in balancing production demands with resource availability, ultimately reducing execution costs.

3. FINDINGS

3.1 Built up of new strategies to control the resources and utilities used in the operation of a typical petrochemical plant

The operation of a typical petrochemical plant can be optimized through various strategies to control resources and utilities. These strategies can include measures to reduce energy costs, increase energy efficiency, decrease emissions, and evaluate alternative processes. One approach is the implementation of digital transformation projects, which can provide custom reports for understanding optimization actions, real-time monetary savings, and monitoring of fuel usage and greenhouse gas emissions **[2]**. Additionally, advanced control strategies, such as model-predictive control and adaptive control, can play a vital role in the automation and process control of petrochemical plants, contributing to improved operational efficiency **[3]**. Furthermore, optimal operation of energy management systems in petrochemical plants can be achieved through utility optimization systems based on mixed integer linear programming, aiming to minimize the net cost of energy supplied to the plant **[4]**. These approaches can help in achieving cost savings, energy efficiency, and environmental sustainability in the operation of petrochemical plants. So many articles discussed this issue; the most relevant ones are discussed in this literature review.

In the maintenance unit of a petrochemical complex where the intervention of human is necessary a good strategy is mandatory that's what **Sharareh Mousavipour in (2016)** made when the unsafe actions of staff are investigated. Findings show that, there has been a rise in the number of unsafe actions in machinery and maintenance service units compared to other maintenance units. A new strategy has been implemented to control these actions, a strategy based on the safety behavior and its improvement by close monitoring of health safety environment (HSE) officials on the implementation of regulations **[5]**. The maintenance operation is mostly implemented by human intervention that is why this work focused on the unsafe actions of workers as a main reason of the accidents.

However, as a strategy based on the behavior of workers has a big limitation, which is the lack of workers commitment. To solve this problem an estimation is mandatory to estimate the results and the development of the new strategy, to find the gaps and improve it.

Modeling, Design, and Simulation is the first complete introduction to process control that fully integrates software tools helping you

master critical techniques hands-on, using MATLAB-based computer simulations. Author **B. Wayne Bequette (2003)** includes process control diagrams, dynamic modeling, feedback control, frequency response, analysis techniques, control loop tuning, and start-to-finish chemical process control case studies. Gain practical experience with process control by using MATLAB(R) simulations and real-world applications. Through computer simulations based on the well-known MATLAB environment, professionals and students may learn essential skills firsthand with this comprehensive introduction to process control, which is the first to combine software tools. Process Control: Modeling, Design, and Simulation provides comprehensive exercises with thorough derivations, pertinent software files, and additional techniques available on a companion website. It teaches the most important techniques, behaviors, and control problems in the field through real-world examples **[6]**.

The digital plant is predicated on having a connection to the information space that links equipment suppliers and maintenance providers. Instantaneous information flow between the participants in this interaction environment directly affects the quality of decision-making, ensuring the absence of mishaps and downtime **[7]**. To find a solution for energy efficiency and resource conservation, the author suggests developing a novel plan to boost manufacturing efficiency, especially through process automation. It takes into account the fundamental instruments for petrochemical plants, process automation, and process enhancements.

This work focused on the management plans and how to use the automation in the development of an optimal plan. However, in fact the work only talked about some specific strategies and did not give a new one, or the optimal one among them. In addition, the technical field of petrochemical industry is absent in this work, in my opinion the most effective way to optimize a management plan for maintenance, is to optimize measurable variables in the system.

In other hand, **A. Vargas on 2000** worked ona time-optimal control strategy for a discontinuous aerobic bioreactor. The control strategy regulates the feed rate to maintain a constant optimal substrate concentration in the reactor, which in turn minimizes the reaction time. Peristaltic pumps, an electronic oxygen meter, and a personal computer equipped with real-time software tools and data gathering hardware made up the controller. Three tests were carried-out: one to determine the parameters and calibrate the observer; one to confirm the time-optimal plan; and one to assess how well a completely automated time-optimal operation performed. When the controller and observer were properly calibrated, the bioreactor's overall efficiency increased and reaction times were shortened. The observer also produced reasonable estimations **[8]**. In this study, they only used a simple mathematical model or simulator to optimize time of reaction in the reactors. However, in the real process the problem will be more complicated to be solved with such a simple simulation model. The study of the reality of the system, using a more efficient methods to overcoming the complexity of the real process.

Based on an analysis of the driving force for smart factory development, **Defang Li (2016)** proposes a lifecycle blueprint and consensus-based operating and technology roadmap **[9]**. In this study, the understanding of new technologies and their ability to be implemented is ignoring the old systems that already installed and operating in nowadays. We find that the technology changing is very expensive and hard to carry out for many factors, proposing the changing of technology in no applicable always due to its expensive charges. So the optimization objective is not achieved in this work because the cost of the implementation of the new technology in not taken into consideration.

Through the constant pursuit of meeting energy and transportation requirements, there are legitimate concerns about the environmental and safety issues associated with these industries, it is very difficult to imagine how industrialized societies could sustain a high standard of living without chemical products **[3]**. In this work, **Dale E Seborg (2009)** provides an overview of process control objectives and methodology in the chemical and petrochemical industries. This work is a good introduction to the petrochemical process control. In addition, we can talk about the use of the artificial

intelligence to help in the decision-making in the process control.

In order to determine the role of automation of the main systems of petrochemical production, **A I Shinkevich1 (2020)** showed how industrial automation affects gross national product growth by optimizing production and logistics operations, labor efficiency, increasing equipment productivity, improving research and development and product development **[10]**. This work based on the improvement of the benefit of the petrochemical companies regarding the requirement of the market by the implementation of strategies of production cost and time optimization.

3.2 Improvement of the safety measures to protect the equipment, environment and health from any expected dangers.

To improve safety measures and prevent industrial accidents, several strategies can be implemented. Firstly, emphasizing the concept of "safety first, prevention first and comprehensive management" is crucial **Yu, Wang. (2022)[11]**. Regular investigation and analysis of safety accidents, along with continuous improvement, are necessary to prevent their reoccurrence Do, **Woo, Kim. (2022)[12].** Additionally, the use of deep learning and artificial intelligence can enhance safety production supervision, early warning, and intelligent operation in industrial enterprises **[13]**. Policy countermeasures, such as increasing the visibility of patrols and conducting on-site inspections, can also contribute to reducing death accidents **Heonseok, Kim (2021)[14]**. Furthermore, applying design thinking and other problem-solving techniques can help find innovative solutions to prevent industrial accidents **Hyeogsic, Kwon (2022)[15]**. Strengthening the execution capacity of safety management in the field and utilizing safety practice indexes can establish a mature safety culture and effectively prevent accidents. By implementing these measures, companies can create safer work environments and mitigate the risks of industrial accidents. Below is the discussion of most relevant articles.

For any firm, health, safety, environment, and ergonomics (HSEE) are critical components. To help organizations with this process, **Pourreza, Pooya (2018)** suggests a fuzzy cognitive map–Bayesian network (BN) model in this research. By using this, the authors determine which input component has the greatest influence on HSEE quantification, which can then be controlled to increase an organization's adherence to HSEE **[16]**. For limitation of this work we can talk about the data gathering method that has been choose in the work which is a survey, the questionnaire used and divided among the workers is a relative method which means that the data could be effected by social culture or belief that the workers in the company are believe. Lot of factors can affect the general opinion in the company.

Chalaris, Michail. (2022) highlighted in his book the importance of effectively managing occupational health and safety, and the environment during general industrial activities. Where they mentioned that an effective management of safety, health and environment in all workplaces has many benefits, the improved overall wellbeing of the workforce, increased productivity, reduced work-related accidents, injuries and fatalities **[17]**. This book discusses the impotency of flexible technologies in the HSE aspect to improve the effectiveness of management systems and the productivity. The author proposes to reach such an aim to integrate technologies of big data and internet of things and data analysis. For more improvement, we can also propose the using of artificial intelligence to help in decision-making. That is the aim of this work.

Mrozowska, Alicja&Mrozowski, Piotr. (2019) in their article describe how important Job Safety Analyses are for proper operations. The main aim of the article is to indicate steps and the best way of performing job safety analysis on board of the offshore installation to reduce the risk of emergency. The authors use the analysis of available international reports, the experience gained while working on different types of the offshore vessels and installations. In addition, focusing at the using of a job safety analysis JSA in the improvement of work condition **[18]**. In consequence, prevent environmental risks in oil and gas industry, specifically offshore installation. The use of technology to improve the implementation of the JSA is highly recommended in such situations where the major risks are taking place. As additional, the use of intelligent

technology will improve the rapidity and the effectiveness of management system.
Operators of Major Hazard Facilities have found that the discipline of process safety management is a useful tool for helping them concentrate on the critically vital "few," giving them more attention than the "many" less crucial but nonetheless significant components of a process system **[19]**. Major Accident Risks can change during the course of an asset's life in terms of probability and severity. In this work, **Vandenberg, Erik (2023)**aims to reduce risks related to major hazard facilities by a good risk assessment procedure. The best and the most effective way to assess risks is the quantitative methods. The quantitative methods need the quantification of risks parameters. The simulation of events by mathematical equation will facilitate the minimization of the value of the targeted events, in other hand we know that the equations that express real events are not linear or simple. That is why the use of analytic methods will not help in the minimization of objective function due to the variety of its variables. To solve such issue, using the metaheuristic methods is more effective.
Bragatto, Paolo (2018) made a work aims to assess how the use of smart safety systems applied to critical equipment can improve the safety, reducing the likelihood of incidents occurrence or mitigating the consequences related to the loss of containment of hazardous substances. The author proposes a method, based on some primary criteria, useful for the stakeholders to address the choice of the smart safety systems and to assess the benefits for risk reduction. This work gives a bright idea to assess to effectiveness of a smart safety system. It passed on the calculation of the reliability of the system as criteria, and then after a good knowledge of the process, the way of risk management will be integrated to increase the reliability of the system **[20]**. Creating a standard communication protocol for smart safety systems is one of the goals of continuing research, as this will enable systems to communicate with one another and, crucially, with the safety management system, which should combine all the different features.
According to **DORMOHAMMADI, Ali (2021)**, Studies have concluded that the use of technical safety measures is not adequate to protect human, economic and environmental assets in industries. Therefore, developing Health, Safety and Environment (HSE culture), as an alternative method, is of considerable importance **[21]**. This study set out to assess and control the HSE culture among workers in the industrial sector. Data collected from the questionnaire was analyzed after the development of an HSE culture questionnaire. The study came to the conclusion that organizational and environmental elements should be looked into in addition to psychological and individual factors in order to promote safety culture in a workplace. In this manner, the real issues would be found, suitable approaches to solving them would be put into practice, and eventually the number of events would be decreased. This work present an important aspect in risk reduction, which is the safety culture. Nevertheless, we cannot consider it as an alternative to the technical solutions. Instead we should implement all the aspect together personal culture, organization and technical factors.

3.3 The use of artificial intelligence methods as tool to build new strategies to protect health and equipment and environment in industry.

Artificial intelligence (AI) can be used to protect health, equipment, and the environment in industry. AI technology for **Ghadimi, Mehdi (2023)** can help manage and improve environmental conditions by observing and analyzing data in real-time without getting tired as humans do **[22]**. Also **Pachot, Arnault (2023)** sees that AI can make reasonable plans in a much shorter time than humans can, by utilizing big data analysis and intelligent programs **[23]**. **Roumen, Trifonov (2022)** in their work show that AI can also be used for intrusion detection in industrial systems, helping to understand and counter the actions of malicious actors **[24]**. Furthermore, AI may be applied in a number of ways to enhance workplace health and safety, including risk prediction and prevention, ergonomics and worker well-being, real-time workplace monitoring to quickly identify safety hazards, and continuous improvement and optimization. Artificial intelligence (AI) can be used to reduce the risk of injuries to human workers by doing

hazardous tasks like handling toxic substances or working in severe settings, as well as monitoring environments for possible hazards like gas leaks or broken equipment and alerting workers in real-time. We collect the most relevant articles where the authors and scientists tried to implement AI to improve the safety of human, equipment and environment.

Shaji, Harikrishnan (2022) automated methods for improving productivity, safety, and efficiency in modern industrial facilities using artificial intelligence (AI)-based techniques. It examines the difficulties and things to keep in mind when applying these methods to make sure there are no mistakes for real-world use. Depending on the application, both numerical input models and image processing models are covered under AI techniques. Safety observations made during maintenance tasks are recorded using image processing models, which also automate inspection data analysis. On the other hand, the numerical input models are mostly employed from the standpoint of process and planning optimization **[25]**. the limitation of using deep learning is the lack of data. In addition, the image processing models presented in the paper need to be trained on some particular situations where the training is putting systems in risk simulation, which is very expensive.

Deep learning can be used for the early warning, and intelligent operation **[26]**. In his paper **wang Yu (2022)**, studies the work safety in the supervision and early warning mechanism abides by the selection principle of the management system. The paper discusses how artificial intelligence can be used in industrial enterprise safety production supervision to provide technical assistance for effectively controlling safety accidents. Deep learning and artificial intelligence can be used for safety production supervision and early warning in industrial enterprises. Deep learning analysis ability is related to the range of sample data and the most significant issue in industrial studies is the lack of data so to make good training to the AI model we need time and lot of simulations.

According to **PetyaBiolcheva's (2023)** perspective, the progressive introduction of autonomous technologies is necessary to ensure expert peace of mind and maximize accuracy in their capabilities. This study aims to present an artificial intelligence (AI) based approach to intelligent safety for the maritime sector **[27]**. In order to achieve the highest degree of safety in the maritime industry, the effort aims to combine the speed of artificial intelligence with human expertise.

Alonso, Ricardo (2021) aims in their study to protect workers in automated and robotized agile production environments from dangerous scenarios. To do this, artificial intelligence (AI) agents will collect data, audio, and video via arrays of cameras and microphones placed throughout the workspace. The new system will use Deep Reinforcement Learning (Double Deep Q Networks) and Deep Learning models to recognize abnormal patterns in behavior and workers' levels of attention, weariness, and distraction **[28]**. Due to emotion fluctuations and other factors that are incomprehensible to artificial intelligence, the prediction of human behavior based on ECG data and video recordings is ineffective. The deployment of such a technology, with its high expenses and unsatisfactory precision for human prediction is not recommended.

In his work, **Tang Kai (2019)** also focus on the improvement of workers behavior, using data value of big data mining and intelligently recognizes and processes images and voices to support innovative management models and applications, and provides safety technology support for smart factories and intelligent manufacturing **[29]**.

In addition,**Doherty, Mike and Esmaeili, Behzad (2020)**, propose algorithms scan images from jobsites for safety hazards. Such as workers not wearing protective equipment, and correlate the images with accident records; identify unsafe worker behavior and suggest training and education priorities; or track the real-time interactions of workers, machinery, and objects on the site and alert supervisors of potential safety issues **[30]**. This paper does not explore the limitations or challenges of implementing AI-based algorithms for scanning images from jobsites for safety hazards, in addition to the training and data issue there is other considerations such as false positives or false negatives in hazard detection.

based on **Rajesh Pillai (2020)** The ability of artificial intelligence (AI) systems to handle, process, and apply complicated algorithms to large amounts of data can increase aviation industry safety. The purpose of this study is to

employ artificial intelligence responsibly in order to increase aircraft safety. The study focuses on how artificial intelligence can be used to lessen the effects of variables that affect aviation safety, such as pilot weariness, unfavorable weather, and misleading alerts [**31**]. This work does not discuss the specific AI algorithms or technologies that could be utilized to improve aviation safety. In addition, the paper does not discuss the potential costs or resource requirements associated with implementing AI solutions for aviation safety.

In this work **Ahmed, Salim (2021)**, identifies a few points that researchers need to consider for impactful research on process safety utilizing AI and suggests a systematic methodology to incorporate human knowledge and expertise in the development of a tool and during its use **[32]**.

Production control in petrochemical industry involves complex circumstances and a high demand for timeliness that's why smart controls are important components of intelligent manufacturing in the petrochemical industry **Min, Qingfei (2019)** uses digital twins, along with the internet of things (IoT), data mining, and machine learning technologies, as a potential in the transformation of nowadays manufacturing paradigm toward intelligent manufacturing. This work proposes a framework and approaches for constructing a digital twin based on the petrochemical industrial IoT, machine learning and a practice loop for information exchange between the physical factory and a virtual digital twin model to realize production control optimization **[33]**. It integrates machine learning and real-time industrial big data to train and optimize digital twin models.

3.4 Improvement of maintenance strategies to minimize the cost of shutdowns and abnormal situations.

According to **Yu, Zhao (2022)** Maintenance strategies can be improved to minimize the cost of shutdowns and abnormal situations by implementing optimized preventive maintenance (PM) cycles and planning horizons. This can be achieved by finding the optimal couple of PM cycle and planning horizon that minimizes the total maintenance cost **[34]**. Additionally, **Sofiene, Dellagi (2021)** sees that the impact of imperfect maintenance actions on equipment failure rate and the resulting number of failures should be considered. Performing PM actions more frequently can help reduce the expected number of corrective maintenance actions and the corresponding total cost **[35]**. Furthermore, the use of innovative maintenance strategies that take into account the system's reliability and the occurrence intensity of shocks can be effective. Based on **Raza, Naseem (2022)**, these strategies divide the system reliability into stages and implement maintenance activities accordingly, such as performing corrective maintenance or replacing the system **[36]**. By considering the effect of maintenance on structure performance and estimating reliability instead of assuming a reliability function, **Yanpei, Shi (2022)** established a general optimization model for preventive maintenance strategy **[37]**. Overall, optimizing maintenance strategies based on cost, reliability, and efficiency can help minimize shutdown costs and abnormal situations. We try to collect more articles, talking about this aspect, and discuss them.

The issue of planning routine maintenance tasks for oil and gas facilities is examined in this research. Every maintenance item has a different set of maintenance procedures and need for brief equipment shutdowns. Which are expensive and seriously impair productivity **[38]**. By combining maintenance items with similar shutdown requirements into campaigns short-term maintenance operations the aim is to reduce equipment shutdowns. Handling tens of thousands of maintenance items in real plants makes it extremely difficult to manually schedule the campaigns. In order to minimize the overall shutdown cost, **Seif, Zeinab (2020)**efficiently allocate maintenance items to campaigns using a mixed-integer linear programming model that they construct in this study.

By increasing productivity, proper equipment maintenance can drastically lower total operating expenses. Although maintenance is sometimes seen as an expense by management staff, seeing it as a profit center is a more constructive perspective. In light of this new understanding, the requirements for maintenance management have undergone a significant transition from the conventional "fix-it-when-broken" mentality to a more sophisticated strategy that calls for the

adoption of a maintenance strategy for a more integrated approach and alignment **[39]**. **Behniaa, Foroogh (2023)**uses Goal Programming (GP) in their work to determine the most economical way to maintain a few essential pumps used in the paper industry. We can conclude from this work that the preventive maintenance approach is more cost effective then the corrective maintenance approach. but this is not always correct. Due to the specifications of some industrial systems, where the preventive maintenance will need a shutdown of the system and the use of special team, which make this option very expensive. That is why managers choose to take the corrective maintenance as the optimal strategy for those systems.

In order to assess the efficacy of the recommended maintenance method, **Mirsaeedi, Hamed (2023)**suggests a mixed-integer linear programming approach to maintenance budgeting that considers restoration time uncertainty. Case I of the analysis assumes that no maintenance actions are carried out in the system. In Case II, the maintenance expenditure is divided equally across all distribution feeders. In Case III, the recommended formulation allots the best maintenance budget based on restrictions **[40]**. The proposed method seeks to minimize total costs by determining the best budget for maintenance jobs in distribution network feeders. This covers the overall cost of the customer's interruption, the total cost of energy that is not supplied, the total cost of the materials and personnel needed for repairs, and the total cost of maintenance.

At some time, complete production lines will need to be shut down in order to do major maintenance or work that is too large to be completed while the facility is in operation. We call this closure a maintenance outage. Even if it would be feasible to only shut down the areas of the plant that require maintenance, it also makes the greatest financial sense to shut down the entire facility. When extensive maintenance needs to be performed on all plant equipment, it is far less expensive to shut down the entire plant at once than it is to shut down smaller sections of the plant more frequently **[41]**. **Kister, Timothy (2006)**sheds light on the financial losses resulting from the plant's complete shutdown because of the time lost from output and the associated maintenance expenses. The paper suggests planning maintenance as a solution to this problem, where the main requirements for successfully carrying out the plant shutdown for major maintenance are starting the outage with a workable schedule, complete work packages, and both material and personnel resources arranged for and available for contracted work as well as in-house efforts.

Another work of **Mirsaeedi, Hamed (2018)** proposes a practical method for reliability-centered maintenance budgeting. The proposed method determines the optimal maintenance actions and their execution times in electrical system. The objective is to minimize the total reliability cost. Including: the total customer interruption cost and total energy not supplied cost. Where the results show that maintenance budgeting with time allocation reduces total cost and improves reliability **[42]**.

We conclude our research on the topic of the impact of choosing the right maintenance strategies to minimize the cost of abnormal situations by presenting a handbook covering a wide range of topics related to maintenance management and engineering **[43]**. The book discuss the different aspect of maintenance (strategies tools and resources) to achieve a good management of maintenance activities to reduce likelihood and severity of risks.

3.5 Minimize the cost of execution time of any operation by developing intelligent schedules

Based on **Jiepin, Ding (2023)** intelligent scheduling in industry offers several benefits. It allows for the transformation of traditional production modes into intelligent factory modes, enabling green and sustainable development **[44]**. Moreover, for **D, Zhang (2022)**intelligent scheduling helps in meeting personalized customer needs by rational allocation of order size and resources, improving production efficiency **[45]**. In the process industry, optimal production schedules obtained through intelligent scheduling minimize delays, leading to robustness, economic advantages, and minimizing costs, improving production and safety. These challenges highlight the need for advanced techniques and algorithms to address the complexities and uncertainties involved in developing intelligent schedules.

N. Mirahmadi (2019) proposed stochastic mathematical model provides a scientific and helpful guideline for manufacturing system to plan production and maintenance simultaneously, with both economic and environmental benefits. The proposed stochastic model, combined with the Genetic Algorithm (GA), aims to minimize the expected makespan in the scheduling problem, with a focus on reducing CO2 emissions in an actual workshop **[46]**.

Prostean, Gabriela (2007) proposes an operations scheduling intelligent system that deals with constraint handling decision in manufacturing operations, providing various optimization techniques and their application to production scheduling. The system is developed with a friendly graphical user interface that guides the user during the progress of the planner, providing warnings and suggestions for adjusting in real time the planner **[47]**.

Shrouf, Fadi (2014)proposed in his papera mathematical model to minimize energy consumption costs for single machine production scheduling during production processes. Where genetic algorithm technology has been utilized. By making decisions at machine level to determine the launch times for job processing, idle time, when the machine must be shut down, “turning on” time, and “turning off” time, a comparison between the analytical solution and metaheuristic solutions is presented. This solution shows that the metaheuristic solution provides the optimal solutions in most test cases and nearly optimal solutions in others **[48]**. The results show that, when the computation time for longer schedules is relatively high, the metaheuristic solution is preferable.

Using metaheuristic (bio-inspired algorithm) in schedule optimization where a distributed job shop scheduling problem where the allocation of jobs to different factories needs to be done and additionally, the determination of good operation schedules for each factory is solved **[49]**. **Vivek, S (2022)** uses ant-colony optimization algorithm on each factory after the allocations, to get a solution that is close to the most optimal solution.

Klusáček, Dalibor (2015) proposes new complex and well-designed approaches that involve the use of metaheuristic, which periodically optimizes job-scheduling plan using several real life based optimization criteria **[50]**. **Broderick Crawford (2014)** used set of metaheuristics to solve Software Project scheduling problem as a combinatorial optimization problem, showing the resolution structure and its application **[51]**. Among these, we can find Simulated Annealing, Variable Neighborhood Search, Genetic Algorithms, and Ant Colony Optimization.

Podolski, Michał (2022)proposes the use of two metaheuristic methods the simulated annealing algorithm and the tabu search algorithm, completing each other to solve scheduling optimization problem. The simulated annealing algorithm is used to find the global optimum by iteratively searching for better solutions and accepting worse solutions with a certain probability. The tabu search algorithm is used to explore the search space by maintaining a tabu list that prevents revisiting previously visited solutions **[52]**.

Khan, Muhammad (2023) presents different types of metaheuristic algorithms can be used to optimize industrial processes, thus making them more sustainable in the context of Industry 4.0, such as design, product development, forecasting, scheduling, and so on **[53]**.

4. Conclusion

The optimization of industrial schedules is a complex and evolving field, driven by the increasing demands for efficiency, cost-effectiveness, and sustainability across various industries. This literature review has explored a range of strategies, methodologies, and technological advancements applied to industrial scheduling, highlighting the significant role of artificial intelligence, safety improvements, and the development of intelligent maintenance and production systems. Several trends have emerged from the review. First, the integration of digital tools and artificial intelligence has proven critical in improving operational efficiency and safety within industries, especially in sectors like petrochemicals. Techniques such as metaheuristic algorithms (e.g., genetic algorithms, ant-colony optimization) have been instrumental in addressing complex scheduling problems, providing near-optimal solutions in diverse contexts such as production planning,

maintenance scheduling, and safety management. Second, despite the progress made, certain challenges and gaps persist. Many studies focus on isolated aspects of optimization without offering comprehensive, integrated solutions that consider both technical and organizational factors. Additionally, the cost of implementing advanced technologies, such as AI systems, can be prohibitive, especially when dealing with legacy systems that may not easily accommodate new innovations. These gaps present opportunities for future research and development, particularly in creating cost-effective, scalable solutions that balance technological advances with practical, real-world applications. In conclusion, this review has underscored the importance of continuous improvement in industrial scheduling optimization. The insights gathered from the literature provide a foundation for further investigation into more adaptive and integrated approaches. Future research should focus on addressing the current limitations by developing comprehensive frameworks combine technical, environmental, and human factors, ultimately driving industries toward more efficient and sustainable operations.

REFERENCES

[1] Pati D, Lorusso LN. How to Write a Systematic Review of the Literature. HERD. 2018 Jan;11(1):15-30. https://doi.org/10.1177/1937586717747384.

[2] Case Study: Petrochemical Complex Reduces Utility Costs Real-time energy management system saves fuel and cuts emissions; Rita Trelewicz; May 9, 2022; accessed on 03/01/2024

[3] Seborg, Dale E. "Automation and control of chemical and petrochemical plants." Control Systems, Robotics and Automation. Oxford: Eolss (2009)

[4] Yeo, YK.,Roh, HD., Kim, IW. et al. Optimal operation of utility systems in petrochemical plants. Korean J. Chem. Eng. 20, 200–206 (2003). https://doi.org/10.1007/BF02697229

[5] MousavipourSharareh&Variani, Ali &Mirzaei, Ramazan. (2016). A Study of the Unsafe Actions of Staff in the Maintenance and Overhaul Unit at a Petrochemical Complex and the Presentation of Control Strategies. Biotechnology and Health Sciences. In Press. 10.17795/bhs-32561.

[6] Bequette, B.. (2003). Process Control: Modeling, Design, and Simulation / B.W. Bequette.. IEEE Control Systems.

[7] Shinkevich, A. &Barsegyan, N. &Shinkevich, M. &Ostanina, S. &Galimulina, F. &Nadezhdina, M.. (2019). Reserves for improving the efficiency of petrochemical production on the basis of “Industry 4.0”. E3S Web of Conferences. 124. 04006. 10.1051/e3sconf/201912404006.

[8] Vargas, Alejandro & G., Soto & Moreno, Jaime &Buitrón, Germán. (2000). Observer-based Time-optimal Control of an Aerobic SBR for Chemical and Petrochemical Wastewater Treatment. Water Science & Technology. 42. 163-170. 10.2166/wst.2000.0510.

[9] Li, Defang. (2016). Perspective for Smart Factory in Petrochemical Industry. Computers & Chemical Engineering. 91. 10.1016/j.compchemeng.2016.03.006.

[10] Shinkevich, A. I., Barsegyan, N. V., Dyrdonova, A. N., &Fomin, N. Y. (2020, April). Key directions of automation of petrochemical production. In Journal of Physics: Conference Series (Vol. 1515, No. 2, p. 022016). IOP Publishing.

[11] Yu, Wang. (2022). Safety Production Supervision of Industrial Enterprises Based on Deep Learning and Artificial Intelligence. Mobile Information Systems, doi:10.1155/2022/1820082

[12] Do, Woo, Kim. (2022). Operation Status and Improvement of Patrol Car for the Prevention of Industrial Accident Prevention: Focusing on increasing the visible effectiveness of patrols. Community safety and environmental design, doi: 10.26470/jcssed.2022.13.2.147

[13] (2022). Potential Dangers and Prevention Measures of Industrial Accidents Using EDIC and DMAIC. The Journal of Humanities and Social sciences 21, doi: 10.22143/hss21.13.5.225

[14] Heonseok, Kim., Jong-In, Kim., Dongho, Rie. (2021). A Study on the Application of the Safety Practice Index to Reduce Safety Accidents in the Manufacturing Industry. Sustainability, doi: 10.3390/SU131910990

[15] Hyeogsic, Kwon.,Dae-Hoon, Kwak., Wangyoul, Ko. (2022). Measures to Improve Safety Management of Small-Scale Hazardous Substance Factories. Hangukbangjaehakoenonmunjip, doi: 10.9798/kosham.2022.22.1.95

[16] Pourreza, Pooya&Saberi, Morteza&Azadeh, A. & Chang, Elizabeth & Hussain, Omar. (2018). Health, Safety, Environment and Ergonomic Improvement in Energy Sector Using an Integrated Fuzzy Cognitive Map–Bayesian Network Model. International Journal of Fuzzy Systems. 20. 1346–1356. 10.1007/s40815-018-0461-z

[17] Chalaris, Michail. (2022). Occupational Health and Safety, and Environmental management on the age of Fourth Industrial Revolution. Technium Business and Management (ISSN 2821-4366). 2. 1–5. 10.47577/business.v2i3.6941.

[18] Mrozowska, Alicja&Mrozowski, Piotr. (2019). How to Improve Safety on the Offshore Installations. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation. 13. 291-296. 10.12716/1001.13.02.04.

[19] Vandenberg, Erik. (2023). Improving process safety for the operation of Major Hazard Facilities. The APPEA Journal. 63. S332-S336. 10.1071/AJ22041.

[20] Bragatto, Paolo & Ansaldi, Silvia & Mennuti, Canio. (2018). Improving Safety of Process Plants, through Smart Systems for Critical Equipment Monitoring. Chemical Engineering Transactions. 67. 49. 10.3303/CET1867009.

[21] DORMOHAMMADI, Ali & Hamid, Iraj& NEZHAD, Zahra. (2021). Providing an Approach for Evaluating the Organizational Level of Contractors in Terms of Safety, Health and Environment (HSE). Occupational Hygiene and Health Promotion. 5. 10.18502/ohhp.v5i2.7012.

[22] Ghadimi, Mehdi. (2023). Application of Artificial Intelligence to Advance Environmental Health Research: A Review.

[23] Pachot, Arnault&Patissier, Céline. (2023). Toward Sustainable Artificial Intelligence: An Overview of Environmental Protection Uses and Issues. Green and Low-Carbon Economy. 10.47852/bonviewGLCE3202608.

[24] Roumen, Trifonov. Ognian, Nakov. Georgi, Tsochev.Plamen, Nakov. (2022). The Use of Intelligent Methods to Protect Industrial Systems. doi: 10.1109/COMSCI55378.2022.9912603

[25] Shaji, Harikrishnan&Bishnu, Sumit& Mishra, Tarun& Ramakrishna, M. & S., Nikhil & K., Renil& David, Daniel. (2022). Artificial Intelligence for Automating and Monitoring Safety, Efficiency and Productivity in Industrial Facilities. 10.4043/32018-MS.

[26] Wang, Yu. (2022). Safety Production Supervision of Industrial Enterprises Based on Deep Learning and Artificial Intelligence. Mobile Information Systems. 2022. 1-9. 10.1155/2022/1820082.

[27] Biolcheva, Petya&Valchev, Evgeni. (2023). Safety through Artificial Intelligence in the Maritime Industry. Strategies for Policy in Science and Education-StrategiinaObrazovatelnata i NauchnataPolitika. 31. 170-280. 10.53656/str2023-3-3-saf.

[28] Alonso, Ricardo. (2021). Deep Tech and Artificial Intelligence for Worker Safety in Robotic Manufacturing Environments. 10.1007/978-3-030-53829-3_27.

[29] Tang, Kai &Luo, Xiaohua& Sun, Lifeng& Xu, Yuan & Fang, Chao. (2019). AI Empowers the Application of Industry Safety Intellectualization. 520-525. 10.1109/IICSPI48186.2019.9095870.

[30] Doherty, Mike &Esmaeili, Behzad. (2020). Application of Artificial Intelligence in Electrical Safety. 1-6. 10.1109/ESW42757.2020.9188324.

[31] Pillai, Rajesh &Devrakhyani, Poonam&Shetty, Sathvik&Munji, Deepak. (2020). Artificial Intelligence for Air Safety. 10.1007/978-3-030-63396-7_39.

[32] Ahmed, Salim. (2021). Artificial intelligence and machine learning for process safety: Points to ponder. Process Safety Progress. 40. 10.1002/prs.12321.

[33] Min, Qingfei& Lu, Yangguang& Liu, Zhiyong& Su, Chao & Wang, Bo. (2019). Machine Learning based Digital Twin Framework for Production Optimization in Petrochemical Industry. International Journal of Information Management. 49. 10.1016/j.ijinfomgt.2019.05.020.

[34] Yu, Zhao., Ping, Li., Kunpeng, Tian., Xingwei, Fei. (2022). Maintenance

Strategy Optimization Based on AP-913 in Relay Protection Field. Volume 1, doi: 10.1115/icone29-93089
[35] Sofiene, Dellagi., Mohamed, Noomane, Darghouth. (2021). An improved imperfect maintenance strategy for multiperiod randomly failing equipment with stochastic repair times. Journal of Quality in Maintenance Engineering, doi: 10.1108/JQME-10-2020-0105
[36] Raza, Naseem. (2022). A maintenance strategy based on system reliability considering imperfect corrective maintenance and shocks. Computers & Industrial Engineering, doi: 10.1016/j.cie.2021.107886
[37] Yanpei, Shi., Hong-Zhong, Huang., Yu, Liu., Yanfeng, Li., Enrico, Zio., Yicheng, Zhou. (2022). A new preventive maintenance strategy optimization model considering lifecycle safety. Reliability Engineering & System Safety, doi: 10.1016/j.ress.2022.108325
[38] Seif, Zeinab&Mardaneh, Elham&Loxton, R. & Lockwood, A.. (2020). Minimizing equipment shutdowns in oil and gas campaign maintenance. Journal of the Operational Research Society. 72. 1-19. 10.1080/01605682.2020.1745699.
[39] Behniaa, Foroogh&Ahmadabadi, Habib&Schuelke-Leech, Beth-Anne &Mirhassani, Mitra. (2023). Developing a Fuzzy Optimized Model for Selecting Maintenance Strategy in Paper Industry: An Integrated Fgp-Anp-Fmea Approach. SSRN Electronic Journal. 10.2139/ssrn.4374902.
[40] Mirsaeedi, Hamed & Hassankashi, Alireza & Sajjadi, Mahsa & Siano, Pierluigi. (2023). A Mixed-Integer Linear Programming Approach to Maintenance Budgeting in Electrical Distribution Networks Considering Repair Time Uncertainty. 1-6. 10.1109/FES57669.2023.10182631.
[41] Kister, Timothy & Hawkins, Bruce. (2006). Special Case. 10.1016/B978-075067832-2/50010-0.
[42] Mirsaeedi, Hamed&Fereidunian, Alireza&Mohammadi-Hosseininejad, Seyed Mohsen &Lesani, Hamid. (2017). Electricity Distribution System Maintenance Budgeting: A Reliability-Centered Approach. IEEE Transactions on Power Delivery. PP. 10.1109/TPWRD.2017.2772202.
[43] Ben-Daya, Mohamed &Duffuaa, Salih&Raouf, A &Knezevic, Jezdimir&Ait-Kadi, Daoud. (2009). Handbook of Maintenance Management and Engineering. 10.1007/978-1-84882-472-0.
[44] Jiepin, Ding.,Mingsong, Chen., Ting, Wang., Junlong, Zhou., Xin, Fu., Keqin, Li. (2023). A Survey of AI-Enabled Dynamic Manufacturing Scheduling: From Directed Heuristics to Autonomous Learning. ACM Computing Surveys, doi: 10.1145/3590163
[45] D., Zhang.,Jiayue, Pan. (2022). An Intelligent Scheduling Model of Computer Human Resources in Complex Scenarios Based on Artificial Intelligence. Wireless Communications and Mobile Computing, doi: 10.1155/2022/8546634
[46] N. Mirahmadi and S. Taghipour, "Energy-efficient optimization of Flexible Job Shop Scheduling and Preventive Maintenance," 2019 Annual Reliability and Maintainability Symposium (RAMS), Orlando, FL, USA, 2019, pp. 1-7, doi: 10.1109/RAMS.2019.8768908.
[47] Prostean, Gabriela. (2007). Considerations above Operations Scheduling Intelligent System. 173-178. 10.1109/ICCCYB.2007.4402030.
[48] Shrouf, Fadi&Ordieres-Meré, Joaquín&García-Sánchez, Álvaro & Ortega-Mier, Miguel. (2014). Optimizing the production scheduling of a single machine to minimize total energy consumption costs. Journal of Cleaner Production. 67. 197–207. 10.1016/j.jclepro.2013.12.024.
[49] Vivek, S. &Rakesh, Kishan& Mohan, Biju. (2022). Optimized Distributed Job Shop Scheduling Using Balanced Job Allocation and Modified Ant Colony Optimization. 10.1007/978-981-19-1520-8_21.
[50] Klusáček, Dalibor&Rudová, Hana. (2015). A Metaheuristic for Optimizing the Performance and the Fairness in Job Scheduling Systems. Studies in Computational Intelligence. 607. 3-29. 10.1007/978-3-319-19833-0_1.
[51] Crawford, Broderick & Soto, Ricardo & Johnson Parejas, Franklin &Misra, Sanjay & Paredes, Fernando. (2014). The Use of Metaheuristics to Software Project

Scheduling Problem. 215-226. 10.1007/978-3-319-09156-3_16.

[52] Podolski, Michał. (2022). Effective allocation of manpower in the production of precast concrete elements with the use of metaheuristics. JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT. 28. 247-260. 10.3846/jcem.2022.16383.

[53] Khan, Muhammad &Sinha, Amit&Anand, Ankush. (2023). Use of metaheuristics in industrial development and their future perspectives. 10.1016/B978-0-323-91781-0.00011-9.