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Recent Progression Developments on Process Optimization Approach for Inherent Issues in Production Shop Floor Management for Industry 4.0

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Abstract: In the present industry revolution, operations management teams emphasize implementing an efficient process optimization approach with a suitable strategy for achieving operational excellence on the shop floor. Process optimization is used to enhance productivity by eliminating idle activities and non-value-added activities within limited constraints. Various process optimization approaches are used in operations management on the shop floor, including lean manufacturing, smart manufacturing, kaizen, six sigma, total quality management, and computational intelligence. The present study investigates strategies used to implement the process optimization approach provided in the previous research to eliminate problems encountered in shop floor management. Furthermore, the authors suggest an idea to industry individuals, which is to understand the operational conditions faced in shop floor management. The novelty of the present study lies in the fact that a methodology for implementing a process optimization approach with an efficient strategy has been reported for the first time that eliminates problems faced in shop floor management, including industry 4.0. The authors of the present research strongly believe that this research will help researchers and operations management teams select an appropriate strategy and process optimization approach to improve operational performance on the shop floor within limited constraints.

Keywords: process optimization approach; waste elimination; shop floor management; non-productive activities; non-value-added activities; computational intelligence

1. Introduction

In the present worldwide industrial scenario, sustaining higher productivity with available resources is a challenging task in shop floor management [1]. To overcome this challenge, appropriate process optimization approaches are used to eliminate problems encountered during operations management on the shop floor. The process optimization approach is used to enhance productivity within limited constraints [2]. Various process optimization approaches are used in current scenarios, including lean manufacturing (LM), kaizen, total quality management (TQM), six sigma (SS), smart manufacturing (SM), lean six sigma (LSS), and computational intelligence (CI). These approaches are implemented for operations management in production shop floor management in several industries, such as automobile, aerospace, construction, food, electronics, electrical, mining, mining machinery, chemical, pharmaceuticals, etc.

Process optimization approaches act as a booster for production management on the shop floor. It has been found that to implement these approaches with an appropriate strategy, it is necessary to analyze the production conditions. To do this analysis, mainly, available resources, production records, worker skills, awareness of adaptation approach in employees, ergonomic factors, etc. data are collected [3,4]. Analyzing identifies all non-value-added activities and problems on the shop floor, and helps in implementing an approach with an appropriate strategy according to the desired productivity [5,6]. All non-value-added activities and problems are eliminated by the implementation of a suitable technique. Non-value-added activity means waste, known as Muda. Muda is mainly responsible for higher production times [7,8]. Waste is found in mainly eight forms in operations management on the shop floor, including defects, waiting, overproduction, transportation, non-utilized skills, motion, inventory, and excess processing.

The main objective of the process optimization approach is to analyze production activities and eliminate all non-value-added activities by using a suitable strategy [9]. Lean manufacturing is the first process optimization approach. It is a prominent approach in the present industrial environment that provides a new production plan with a higher productivity level [10,11]. Kaizen provides an improvement in production planning by visual inspection of the shop floor [12]. Smart manufacturing is used to enhance operational excellence by implementing advanced monitoring systems for operations management on the shop floor [13]. Total quality management improves the performance of the overall production process, and helps to obtain higher customer satisfaction in terms of product [14]. The six sigma approach achieves a high level of quality and efficient production on the shop floor [15]. In the present industry, six sigma and lean manufacturing are implemented simultaneously as hybrid tools called the lean six sigma approach [16]. It minimizes waste on the shop floor and has the capability to maximize profits with higher quality improvements [17]. Computational intelligence helps management systems control shop floor activities, and suggests how to improve production conditions on the shop floor [18]. It may also provide superior production planning by virtual analysis of observed production data [19,20].

Researchers and industrialists working in this area are facing problems in selecting a suitable approach for process optimization of shop floor management, including industry 4.0. Several factors are analyzed while selecting the strategy and process optimization approach. The factors may be resource availability, customer demand, downtime, ergonomics factors, and production records [21,22]. Nowadays, researchers are implementing hybrid tools on various shop floors to improve customer satisfaction, product quality, production time, resource utilization, productivity, etc. [23,24].

1.1. Process Optimization Approach Used in Operation Management on the Shop Floor

In the present scenario, industry personnel use process optimization approaches to improve operational management. The process optimization approach is used to enhance shop floor management efficiency within limited constraints. Various process optimization approaches are currently used, including lean manufacturing, kaizen, smart manufacturing, total quality management, and computational intelligence. These approaches are used to improve operational conditions by eliminating waste on the shop floor [25]. Industry individuals use several techniques to implement process optimization concepts on the shop floor, as shown in Figure 1.

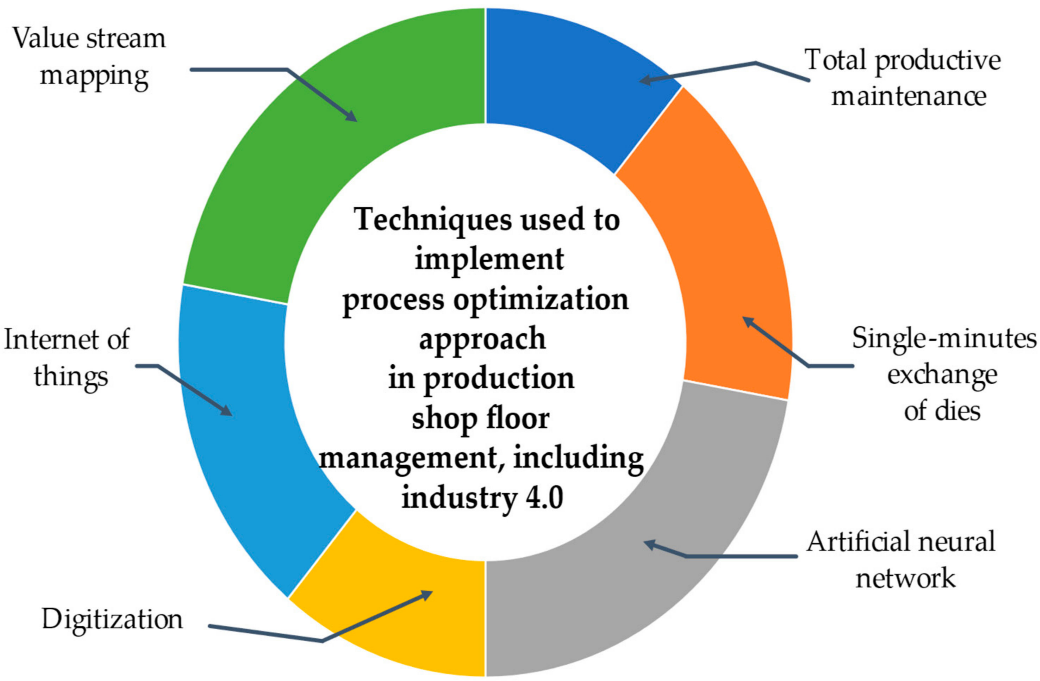


Figure 1. Preferred techniques for implementing a process optimization approach.

Lean manufacturing is found as a prevalent approach in reviewing previous research work. The lean approach can improve operational performance by arranging activities in a suitable manner on the shop floor. Motwani [26] discussed lean manufacturing implementation experience in a medium-sized automotive manufacturing industry. The data was collected from interviews, questionnaire surveys, and archival sources. The results showed that manufacturing batch sizes have shrunk from a 30-day lot size to 16 days or less and are continuing to shrink and set-up times in most plant areas have been reduced by half. Verma et al. [27] developed an energy value stream mapping model based on value stream mapping to identify the non-productive energy-consuming processes. The developed model allowed a comprehensive analysis of energy and material flow within the production process. In the study, a focused approach was developed to fill the gap between lean manufacturing and green manufacturing. It was identified that overall productivity was the measure of green manufacturing.

For industry 4.0, articles related to implementing a hybrid approach to delivering productivity enhancements by eliminating operational management problems on the shop floor between 2012 and 2022 were considered. Our consideration here was restricted to publications that met the inclusion and exclusion criteria and were eventually included. Figure 2 shows the number of articles published each year.

A systematically performed bibliography-map review as illustrated in Figure 3 indicates the utilization of process optimization approaches for improvement in operational management, and to enhance shop floor management efficiency within limited constraints over the last 10 years.

Singh et al. [28] developed an approach to convert the cumbersome machine into a lean machine. The approach helped to reduce the cost of manufacturing and increased productivity by reducing cycle time and downtime. The workers and skilled people working on the process were brought together to tap into their experience and skills to generate a plan for the reduction in non-value-added activities and process improvement. The developed approach was applied to Munjal Showa Limited for development and manufacturing. The concept implemented in the study has increased productivity by 3.45 times and has reduced the cost. The results showed that a cumbersome machine was transformed into a lean machine with the help of the identification and elimination of non-value-added activities. It has been observed by reviewing previous research that industry individuals support the implementation of lean manufacturing to improve operational performance by eliminating waste on the shop floor. Song et al. [29] studied the production process of a shipbuilding enterprise. The enterprise was facing problems, such as an unbalanced production line, a low utilization rate of personnel, and a long manufacturing cycle. The study implemented a lean production model in a shipbuilding mode to eliminate the problems. The results showed a reduction in the number of workers, the ship production cycle, and production balance rate by 16.7%, 76.7%, and 81%, respectively.

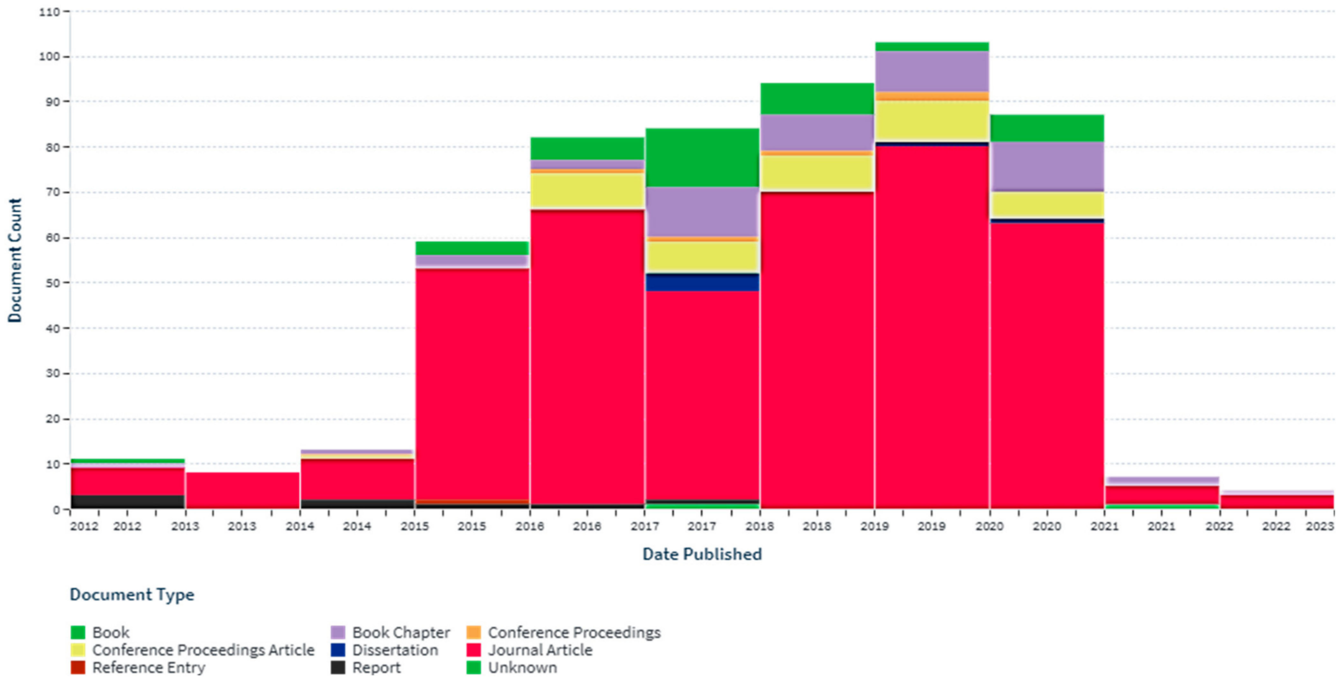


Figure 2. Scholarly works over time.

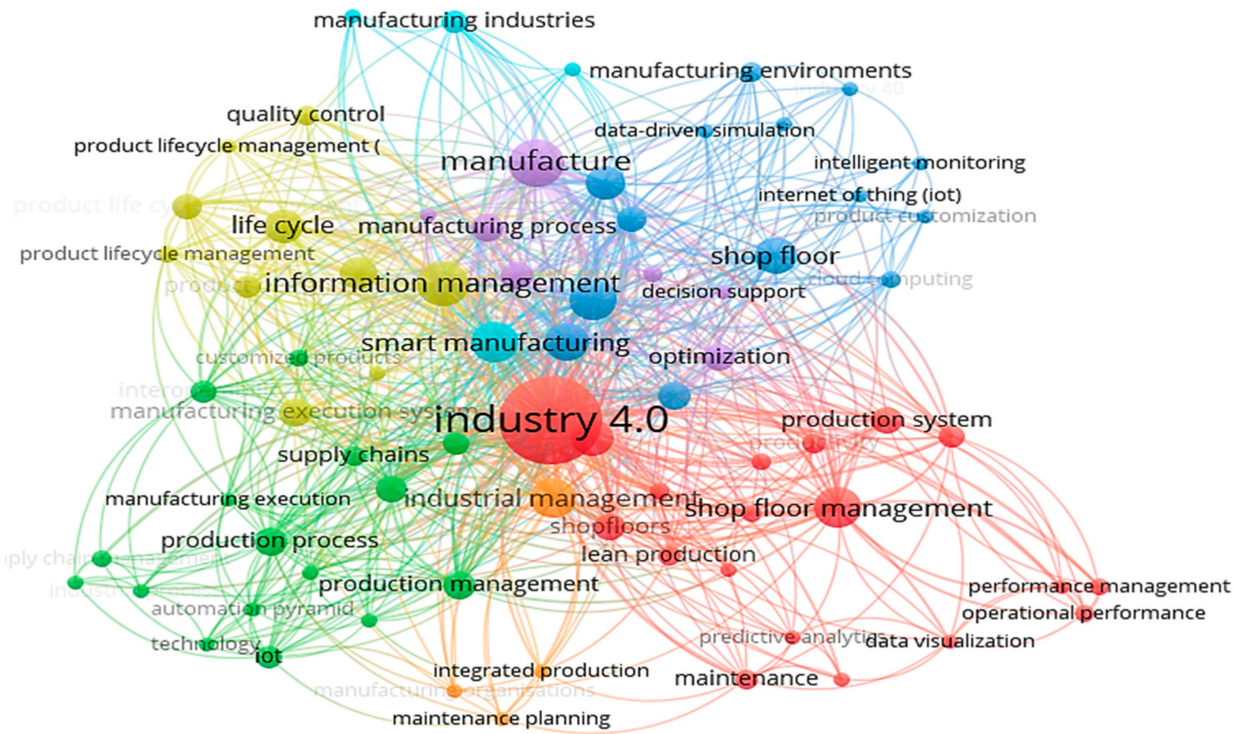


Figure 3. Cluster analysis illustrated industry 4.0 index keywords and key trends.

1.2. Introductory Glance and Scientific Advancement on Production Shop Floor Management System

Process optimization approaches can provide operational efficiency by maximizing the utilization of resources within limited constraints. It can be possible by providing advancements in operational management systems. Various technologies have been used in the previous research works for obtaining improvement in operational performance on the shop floor. The researchers focused on implementing a smart system to control overall production activities, workforce, resources, and energy consumption. The process optimization approach with advanced technologies can improve operational activities and enhance productivity [30]. The smart system helps to provide precise data and information through monitoring operational performance in the production shop floor management system [31]. Figure 4 shows the recent advancements in production shop floor management, including industry 4.0.

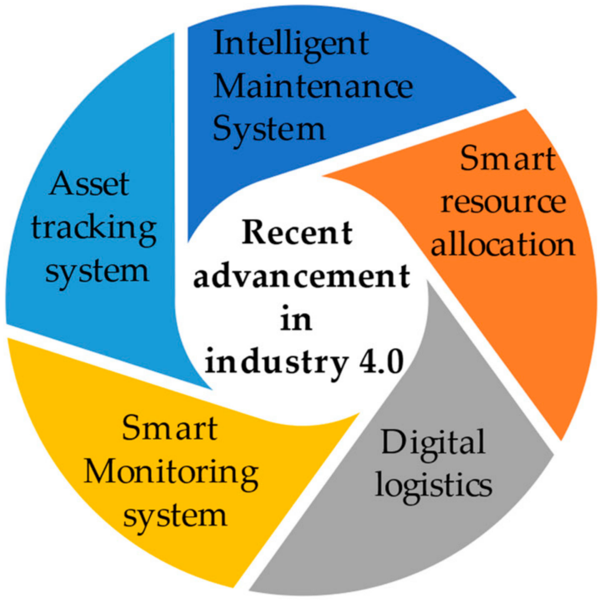


Figure 4. Recent advancements in operations management in production shop floor management in industry 4.0.

1.3. Hybrid Integration of Lean, Six Sigma, and Smart Manufacturing Approach for the Purpose of Enhancing the Operational Excellence and Productivity

Industry individuals need improvement in operational management by developing a sustainable strategy. A sustainable strategy helps to control production activities and enhances operational performance by providing efficient action planning on the shop floor. At present time, researchers use an integration of approaches to make their dream come true of achieving operational excellence on the shop floor. The integrated approach concept uses more than one process optimization approach for improving the impact of an individual approach in the production shop floor management, including industry 4.0 [32]. The preferred integrated approaches include lean kaizen, lean six sigma, total quality management and total productive maintenance, lean smart, and lean computational intelligence. The integrated approach provides revolutionary operational management and helps to improve operational efficiency on the shop floor. It has been found that previous researchers achieved improvement in operational excellence drastically in the production shop floor management system by implementing hybrid approach concepts [33–36]. Similar work has been reported by Chiarini et al. [37] and discussed the integration of lean six sigma and industry 4.0 technologies. In the study, the data was collected through observations and interviews with manufacturing managers of ten Italian industries. The results revealed that lean six sigma was able to achieve efficient outcomes by integrating with industry 4.0 technologies. Amjad et al. [38] developed a framework for integrating lean, green, and industry 4.0. The framework was verified by implementing it in the auto-parts industry.

The results showed that the developed framework efficiently reduced lead time, greenhouse gas emissions, and non-value-added time emissions effectively by 25.60%, 55%, and 56.20%, respectively. Byrne et al. [39] discussed the implementation of the lean six sigma methodology in a pharmaceutical manufacturing site. The lean six sigma methodology was used in the study to eliminate waste by following a 7-step customized problem-solving procedure. The results showed that the lean six sigma method could identify the root causes of problems and provide financial profitability by implementing continuous improvements.

Previous researchers focused on identifying a suitable problem-solving strategy and process optimization approach for improving operational performance by eliminating the source of problems in available resources. Various approaches have been implemented with different strategies in previous research. The approaches were used to enhance operational excellence by implementing an efficient action plan in the production shop floor management system. It has been observed that very few research studies have been done to identify a suitable strategy and approach for improving the production of shop floor management systems, including industry 4.0. The main objective of the present study is to provide a detailed summary of previously reported work on the implementation of process optimization approaches for shop floor management, including industry 4.0. This paper will help researchers and industry individuals to select an appropriate process optimization approach and strategy needed for improvement in production shop floor management.

After an extensive review of previous research papers, it has been found that researchers have provided no generalized strategy for implementing a suitable process optimization approach for eliminating problems and challenges faced in production shop floor management. Researchers found desperation in operational excellence in confined constraints in operational management on the shop floor because of the lack of efficient approaches. The present research work defines the different strategies used by previous researchers to achieve operational excellence within available resources through an efficient process optimization approach on the shop floor. Various strategies are implemented for improving operational performance by eliminating waste on the shop floor. The strategies are categorized into five forms: S1, S2, S3, S4, and S5. These strategies are implemented to eliminate different problems faced in production shop floor management. The problems are categorized into five forms: P1, P2, P3, P4, P5, and P6. The present work thoroughly reviewed the production conditions, factors, and parameters used in operational management on the shop floor. The present research provides a methodology for implementing an efficient process optimization approach with the help of a suitable strategy for achieving operational excellence by eliminating problems faced in production shop floor management.

The present research is organized into six sections. Section 1 describes the process optimization approaches, scientific advancements in shop floor management, and hybrid approaches used for achieving operational excellence. Section 2 discusses the purpose and methodology used in the present research work and is defined in five sub-sections. Section 3 demonstrates the knowledgeable insights of current research work. Section 4 describes the results and visualizes the improvements achieved by the present position in shop floor management, including industry 4.0. Section 5 discusses the strategies and suitable approaches for eliminating problems faced in production shop floor management. Finally, Section 6 covers the conclusions and future scope of the study.

2. Purpose and Methodology

In the present study, a systematic literature review methodology was used to analyze the previous related research works on recent progress on process optimization approaches used for improvements in operational management on the shop floor, including industry 4.0. The research methodology helps to analyze and identify precise issues and methods used in improving operational performance by effective waste elimination on the shop floor. The research methodology consists of six steps. In the first step, the research objectives are decided by brainstorming the present operational management conditions found on the shop floor, including industry 4.0. The second step involves the selection of relevant research works on process optimization methods implementation for improving production shop floor management, including industry 4.0. In the third step, different strategies, problems, and factors are identified by thoroughly reviewing previous studies. The fourth step describes the findings obtained by analyzing the selected research works. Finally, concluding remarks are reported on the operational management conditions on the shop floor, including industry 4.0. In the fifth step, concluding remarks describe the outcomes of the fifth step for implementing appropriate strategies suitable for monitoring and controlling operations management effectively on the shop floor, including industry 4.0. Figure 5 shows the research methodology used in this research paper.

Figure 5. Research methodology.

2.1. Formulating the Research Objective

The present research objective is to provide a review report on the present operational management conditions faced in production shop floor management. The report helps industry individuals and researchers achieve operational excellence within available resources by implementing an accurate strategy with efficient action planning. Figure 4 illustrates the research objectives of this paper. The main objective of this review report is to provide concise strategies, approaches, and problems faced over the last decade by researchers and industry individuals in production shop floor management, including industry 4.0. In this paper, the categorization of literature falls into two sections; in the first section, selected articles are divided according to strategies applied by researchers from the extensive literature available in the related field of lean manufacturing. Strategies adopted are categorized into five forms: S1, S2, S3, S4, and S5. In the second section, related articles are classified into six types according to the identified problems. Identified problems in previously published work by various authors are shown as P1, P2, P3, P4, P5, and P6. This paper thoroughly discusses the strategies used for the elimination of problems faced in production shop floor management, including industry 4.0. The research objectives of this paper are described in Figure 6.

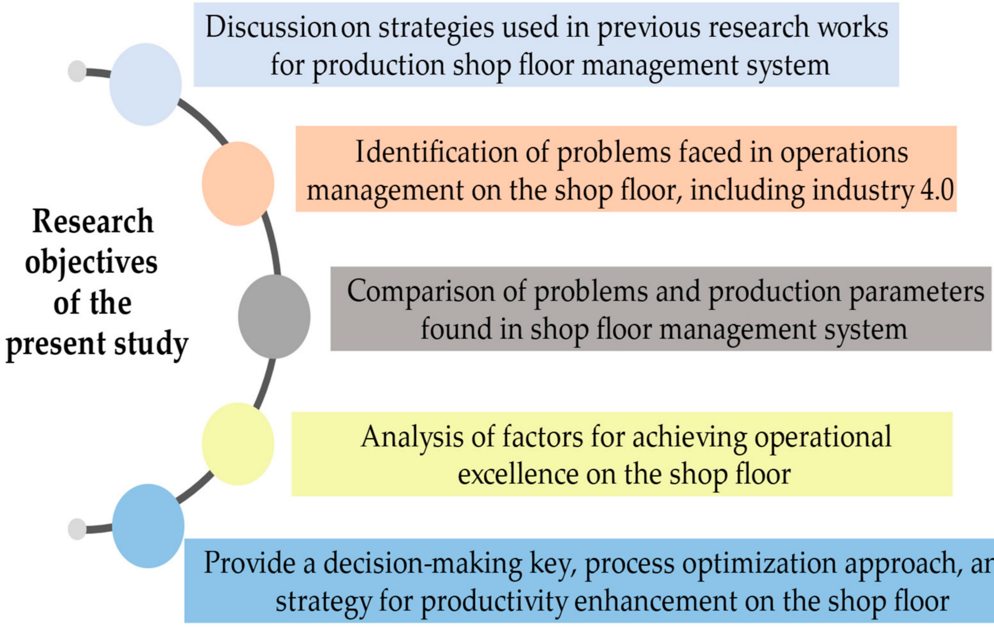


Figure 6. Research objectives.

2.2. Selecting Relevant Research in Process Optimization Methods Implementation for Production Shop Floor Management

The process optimization approach is used to enhance productivity by improving operational performance and eliminating waste on the shop floor [40,41]. It has been observed that researchers have used various process optimization approaches for production shop floor management, including lean manufacturing, smart manufacturing, kaizen, Kanban, six sigma, total quality management, and computational intelligence. This paper thoroughly discusses the strategies used in previous research to achieve operational excellence in production shop floor management. In this paper, various databases were used to collect relevant research work, as shown in Figure 7. In this research work, a total of 191 research articles were reviewed. Table 1 shows the number of articles published by different publishers according to indexing in SCI and Scopus Journals. A review of journals finds that Elsevier and MDPI publishers have promoted research achieving operational excellence on the shop floor in the recent couple of years. The contributed research work in different years and in various industries used to implement the process optimization approach in previous research work is shown in Figure 8.

Table 1. Analysis on research works according to publisher and journals indexed in different journals.

Source of Research Work	Publisher	WoS/Scopus	Number of Research Work
International Journal of Advanced Manufacturing & Technology	Springer	WoS	15
Journal of Pharmaceutical Innovation	Springer	WoS	2
Arabian Journal of Science and Engineering	Springer	WoS	2
Journal of Ambient Intelligence and Humanized Computing	Springer	WoS	5
Journal of The Institution of Engineers (India): Series C	Springer	Scopus	2
International Journal of Production Research	Taylor & Francis	WoS	9
Production Planning and Control	Taylor & Francis	WoS	16
International Journal of Logistics Research and Applications	Taylor & Francis	WoS	1
International Journal of Computer Integrated Manufacturing	Taylor & Francis	WoS	1

Table 1. *Cont.*

Source of Research Work	Publisher	WoS/Scopus	Number of Research Work
Journal of the Operational Research Society	Taylor & Francis	WoS	2
Cogent Engineering	Taylor & Francis	Scopus	2
Quality Management Journal	Taylor & Francis	Scopus	1
International Journal of Construction Management	Taylor & Francis	Scopus	1
Production and Manufacturing Research	Taylor & Francis	Scopus	1
Total quality Management & Business Excellence	Taylor & Francis	WoS	2
Sustainability	MDPI	WoS	8
Processes	MDPI	WoS	4
Journal of Sensors and Actuator Networks	MDPI	WoS	1
Applied Science	MDPI	WoS	2
Sensors	MDPI	WoS	1
Batteries	MDPI	Scopus	1
Resources	MDPI	Scopus	1
Mathematics	MDPI	WoS	1
Processes	MDPI	WoS	1
Journal of Open Innovation: Technology, Market, and Complexity	MDPI	Scopus	1
International Journal of Production Economics	Elsevier	WoS	5
Computer and Industrial Engineering	Elsevier	WoS	1
Journal of Cleaner Production	Elsevier	WoS	5
Sustainable Production and Consumption	Elsevier	WoS	1
Omega	Elsevier	WoS	1
Procedia CIRP	Elsevier	Scopus	3
Material Today: Proceeding	Elsevier	Scopus	2
Procedia Social Behavioral Science	Elsevier	Scopus	2
Procedia Engineering	Elsevier	Scopus	3
Procedia Manufacturing	Elsevier	Scopus	7
Procedia Economics and Finance	Elsevier	Scopus	1
Journal of Manufacturing Technology & Management	Emerald insight	WoS	2
International Journal of Lean Six Sigma	Emerald insight	WoS	5
Benchmarking: An International Journal	Emerald insight	WoS	1
International Journal of Productivity and Performance Management	Emerald insight	Scopus	3
Journal of Quality and Maintenance Engineering	Emerald insight	Scopus	1
International journal of productivity and performance management	Emerald insight	Scopus	2
Industrial Management and Data Systems	Emerald insight	WoS	1
The TQM Magazine	Emerald insight	Scopus	1
Measuring Business Excellence	Emerald insight	Scopus	2
The TQM Jounal	Emerald insight	Scopus	1
International Journal of Quality & Reliability Management	Emerald insight	WoS	1

Table 1. *Cont.*

Source of Research Work	Publisher	WoS/Scopus	Number of Research Work
Mathematical Problem in Engineering	Hindawi	WoS	2
Decision Sciences	Wiley	WoS	1
Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science	SAGE	WoS	1
International Journal of Services and Operations Management	Inderscience	Scopus	1
International of Six Sigma and Competitive Advantage	Inderscience	Scopus	1
Jordan Journal of Mechanical and Industrial Engineering	Hashemite University	WoS	1
Journal of Applied research and Applied Engineering	AIHE, Iran	Scopus	1
International Journal of Mechanical and Mechatronics Engineering	IJENS	Scopus	1
Proceeding	ASME	WoS	1
International conference	IEEE	Scopus	10
International conference	ACM Digital library	International conference	1
International Conference	Springer	Scopus	4
International Journal of Industrial Engineering and Management	University of Novi Sad	Scopus	1
World Academy of Science, Engineering and Technology	WASET	Scopus	1
International Journal of Mechanical and Production Engineering Research and Development	TJPRC	Scopus	1
Other	-	-	29
			Total—191

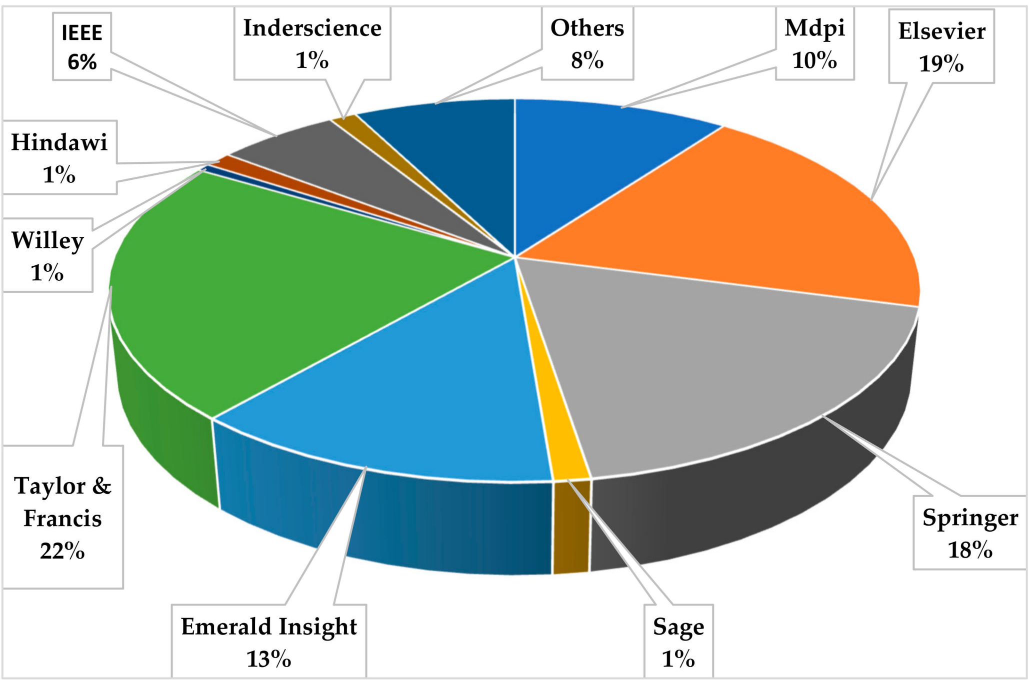


Figure 7. Description of the database used for collecting research works.

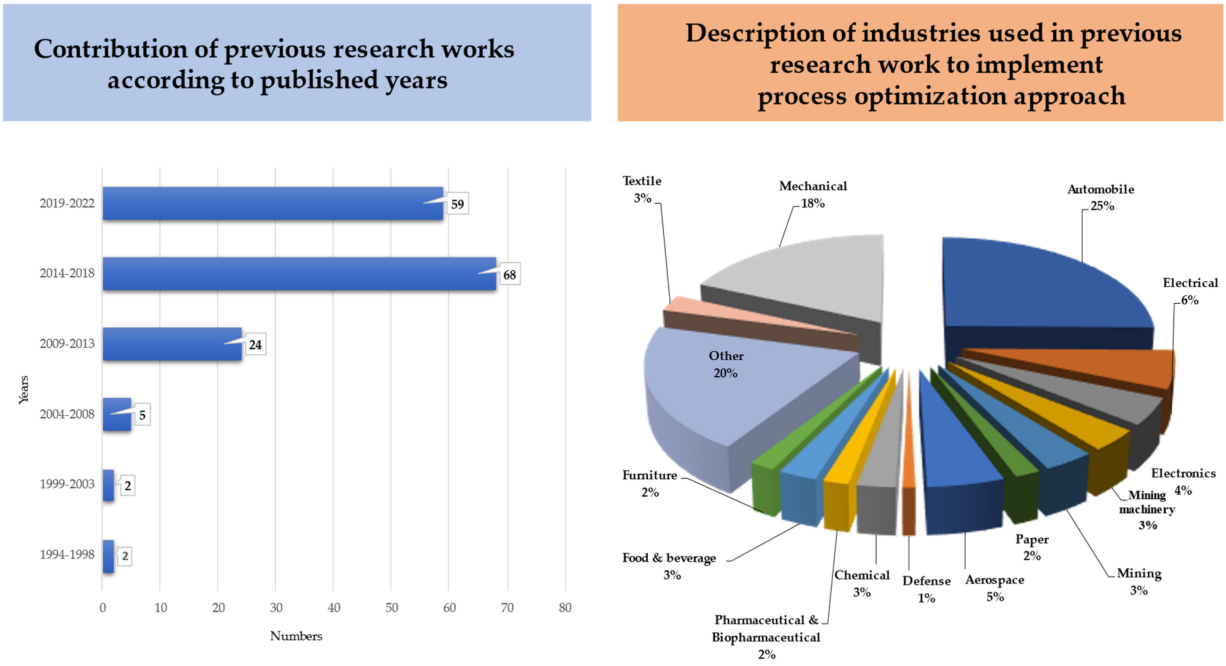


Figure 8. Analysis of the contribution of research works in different years and industries used in the previous literature.

2.3. Reviewing Previous Research Works for the Identification of Different Strategies and Problems

This study extensively reviewed previous research work to provide concise information on the implementation of a suitable process optimization approach with an efficient strategy. Process optimization approaches are implemented for the improvement of operations management within limited constraints on the shop floor [42,43]. Several process optimization approaches used for shop floor planning have been developed during the present era. Researchers are working on these approaches to make them efficient for all types of production environments. This study helps to identify suitable strategies for eliminating problems and categorizes them according to the nature of the production shop floor management system. Selected strategies for the process optimization approach in production shop floor planning are discussed below.

2.3.1. Identification of Strategies for the Implementation of an Optimization Approach

Several research articles were analyzed to identify the strategy that has been selected for the implementation of process optimization approaches in shop floor planning, including industry 4.0. These strategies are categorized as follows:

- S1 Implementing process optimization approach.
- S2 Analyzing worker's perception.
- S3 Analyzing the impact level of process optimization approaches on operations management.
- S4 Developing a production shop floor management system.
- S5 Implementing hybrid approaches for enhancing operations management efficiency on the shop floor.

In the above category, S1 contains articles in which wastes of production are eliminated by the implementation of process optimization techniques/computational intelligence. In S2, a situation of process optimization approach and improvements required in an industry are performed based on the perception of employees from the discussions, interviews, and questionnaires. S3 includes the articles involved related to an analysis conducted for measuring impact and implementing a level of process optimization approach in the industries. S4 contains articles in which the production system has been modified or developed. At last, in S5, elimination of non-value-added activities of industries is eliminated by the implementation of hybrid approaches (two or more tools integrated or implemented simultaneously). Figure 9 illustrates the strategies selected by previous researchers for the implementation of process optimization approaches according to published years.

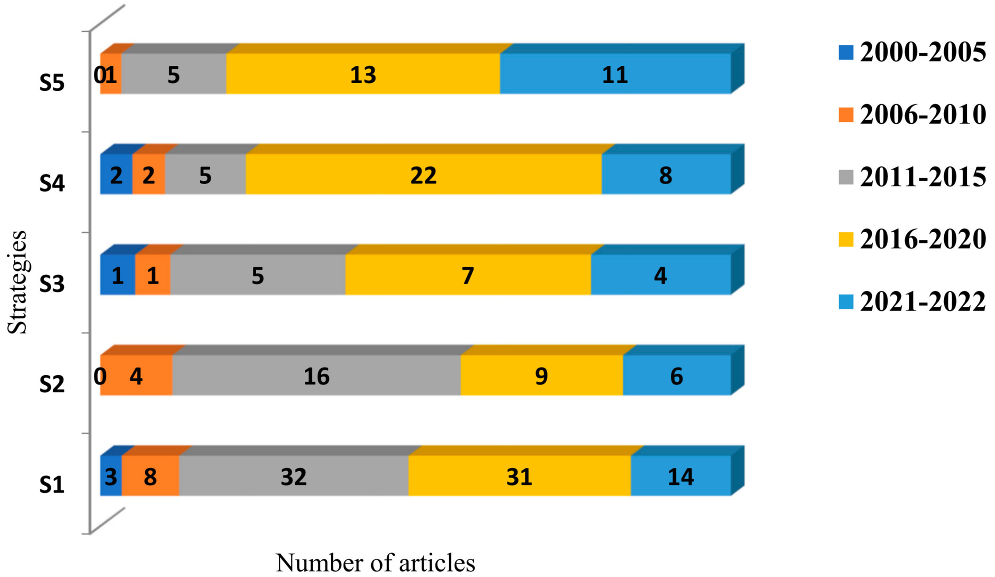


Figure 9. Strategies selection in previous research works according to the published year.

It has been observed by analyzing strategies selected in previous research works for the implementation of process optimization approaches that S1 and S4 were preferred by researchers to enhance operations management efficiency in production shop floor management. It was also found that in the present scenario, S5 is in trend and is efficient in enhancing operational excellence on the shop floor, including industry 4.0. Table 2 illustrates the categorized strategies implemented in the previous research work.

Table 2. A Detailed description of the strategies implemented in previous research works.

Strategy	Author
S1	Detty et al. [44]; Mcdonald et al. [45]; Seth et al. [46]; Singh et al. [47]; Bragila et al. [48] Eswarmoorthi et al. [49]; Schaeffer et al. [50]; Coppini et al. [51]; Gurumurthy et al. [52]; Salleh et al. [53]; Jiménez et al. [54]; Bertolini et al. [55]; Rifqi et al. [56]; Jasti et al. [57]; Kumar et al. [58]; Choomlucksana et al. [59]; Mwanza et al. [60]; Rohani et al. [61]; Tyagi et al. [62]; Chlebus et al. [63]; Ali Naqvi et al. [64]; Prasad et al. [65]; Omogbai et al. [66]; Al Askari et al. [67]; Al-Refaie et al. [68]; Kumar et al. [69]; Roriz et al. [70]; Méndez et al. [71]; Diaz et al. [72]; Seth et al. [73]; Kurilova-Palisaitiene et al. [74]; Prasad et al. [75]; Kumar et al. [76]; Kumar et al. [77]; Cannas et al. [78]; Munteanu et al. [79]; Garza-Reyes et al. [80]; Dadashnejad et al. [81]; Stadnicka et al. [82]; Choudhary et al. [83]; Shou et al. [84]; Yadav et al. [85]; Mahajan et al. [86]; Ur Rehman et al. [87]; Masuti et al. [88]; Balamurugan et al. [89]; Aghdasinia et al. [90]; Gopi et al. [91]; Sutharsan et al. [92]; Amrani et al. [93]; Sivaraman et al. [94]; Khan et al. [95]; Jayanth et al. [96]
S2	Hodge et al. [97]; Rahani et al. [98]; Boateng-Okrah et al. [99]; Mandahawi et al. [100]; Bertolini et al. [55]; Rahman et al. [101]; Jasti et al. [57]; Choomlucksana et al. [59]; Mwanza et al. [60]; Lingam et al. [102]; Schneider et al. [103]; Marodin et al. [104]; Tyagi et al. [62]; Thomas et al. [105]; Seth et al. [73]; Kurilova-Palisaitiene et al. [74]; Yadav et al. [106]; Bevilacqua et al. [107]; Dadashnejad et al. [81]; Azyan et al. [108]; Suhardi et al. [109]; Benkarim et al. [110]; Shou et al. [84]
S3	Bhaskaran et al. [111]; Jiménez et al. [54]; Timans et al. [112]; Alhuraish et al. [113]; Salonitis et al. [114]; Prasad et al. [65]; Al Askari et al. [67]; Raja Sreedharan et al. [115]; Iranmanesh et al. [116]; Gonzalez et al. [117]
S4	Dotoli et al. [118]; Unver et al. [119]; Barbosa et al. [120]; Sana et al. [121]; Tyagi et al. [62]; Thomas et al. [105]; Al-Refaie et al. [68]; Yadav et al. [106]; Kumar et al. [76]; Belekoukias et al. [122]; Gijo et al. [123]; Zhang et al. [124]; Widiasih et al. [125]; Choudhary et al. [83]; Shou et al. [84]; Ramani et al. [126]; Yadav et al. [85]; Gleeson et al. [127]; Qu et al. [128]; Amrani et al. [93]; Khan et al. [95]; Shou et al. [84]
S5	Stump et al. [129]; Mandahawi et al. [100]; Timans et al. [112]; Ismail et al. [130]; Indrawati et al. [131]; Thomas et al. [105]; Al-Refaie et al. [68]; Raja Sreedharan et al. [115]; Yadav et al. [106]; Hill et al. [132]; Gijo et al. [123]; Widiasih et al. [125]; Choudhary et al. [83]; Gleeson et al. [127]; Suhardi et al. [109]; Mundra et al. [133]

2.3.2. Identification of Problems in Implementation of Process Optimization Approach for the Shop Floor Management

Problems faced in industries from the beginning to the end of production of the product were analyzed. To get rid of these problems, they are discussed in the production plan before starting production and a suitable strategy and approach are selected. It was found in the literature that the industries and researchers who had prepared the production plan keeping these problems in mind received qualitative results. In this article, by analyzing the previous research work, it was concluded that some problems in production are usually present. In this section, these problems are divided into seven types, as stated below.

- P1 Lack of clarity in the production planning.
- P2 Unsystematic layout.
- P3 Higher downtime.
- P4 Ergonomic issues of the shop floor.
- P5 Instability of production conditions.
- P6 Selection of an appropriate approach.

P1 Lack of Clarity in the Production Planning

In order to start production, it is necessary to first know the demands of the customer so that the production process can be planned. In a production where it is not clear what the customer's demands are regarding quality and delivery time, it becomes a problem for production management. This type of problem also occurs when production plans are not made according to the state of the production system, which makes it difficult to control production, and desired productivity is not achieved.

P2 Unsystematic Layout

To make efficient production in the industry, the plan layout contributes immensely according to the resources available in the production. Plan layout is prepared so that production can be done within the prescribed time frame [134]. From the literature review, it was found that when the plan layout is disarranged, it emerges as a problem for production management and severely affects production on the shop floor [135,136]. It also increases the production time drastically.

P3 Higher Downtime

An increase in downtime in any industry proves to be a curse. In the literature review, it is identified that several reasons are responsible for the increased downtime, including excessive break time, machinery shutting down for any reason, unplanned maintenance time, lack of resources, or malfunctions [137–139]. If the production management fails to reduce the downtime, then production cannot be done in a limited time frame, and as a result, both production cost and time increase.

P4 Ergonomic Issues of the Shop Floor

The improved work capacity of workers plays a huge role in strengthening the production of industries [140]. To maintain the working efficiency, the production management arranges the workstation, the appropriate material handling equipment, the robust workplace, the proper break time and safety, etc. on the shop floor. In previous works, it was found that the work in which production management did not pay attention to the arrangement of these factors tend to reduce productivity and result in more production time, higher costs, and lower quality.

P5 Instability of Production Conditions

To measure any production, it is very important to know the status of production work so that the production situation can be analyzed and the problems faced in production can be removed through an appropriate strategy and approach. To do this, production parameters are calculated, and output is measured. These parameters mainly include resource availability, overall equipment effectiveness, workers' status, idle time, non-value-added time, working hours, etc. It has been found that if an error takes place in the calculation of the parameters, industry individuals face problems in operations management on the shop floor.

P6 Selection of an Appropriate Approach

The deployment of an appropriate approach is a fundamental requirement to improve production. For this, choosing an appropriate strategy and technique is a very important step to achieving a high production level. It has been found that production management process optimization uses some methods for selecting the approach, including a survey of industries, questionnaires, interviews, discussions with employees, production records of the industry, reviewing the results obtained from process optimization approaches, etc. [141,142]. If the applicability and competence of the process optimization approach in the production system are not checked, the desired improvement in the production level will not be achieved and industries will suffer a loss as a result. Table 3 shows the key factors and problems faced in the previous research work.

Table 3. Illustration of key factors and issues in shop floor management.

Key Factors	Problems	Author
Operational excellence	P1, P3, P5	Östlin et al. [143]; Sahoo et al. [144]; Das et al. [145] Esa et al. [146]; Amrani et al. [93]; Ramdan et al. [147]; Tyagi et al. [62]; Seth et al. [73]; Schneider et al. [103]; Henríquez-Alvarado [43];
	P1, P3, P5	Bevilacqua et al. [107]; Stadnicka et al. [82]; Rahman et al. [101]; Vinodh et al. [148]; Sahoo. et al. [144]; Gati-Wechsler et al. [149]; Lingam et al. [102]; Hill et al. [132]; Garre et al. [150]
	P1, P3, P5, P6	Garee et al. [150]; Suhardi et al. [109]; Chen et al. [151]; Tripathi et al. [3]
	P3	Mwanza et al. [60]; Prasad et al. [65]; Chien et al. [152]; Vinodh et al. [148]; Gibbons [153]; Sabaghi [154]
	P3, P5	Fore et al. [155]; Nallusamy et al. [156]; Edwin et al. [157]; Afefy [158]; Nurprihatin et al. [159]; Méndez et al. [71]
Manpower efficiency	P1, P2, P5	Ragatz et al. [160]; Das et al. [145]; Tripathi et al. [13]
	P4	Brito et al. [161]; Tortorella et al. [162]; Botti et al. [163]; Maia et al. [164]; Tripathi et al. [2]; Sana et al. [121]
	P1, P6	Kurdve et al. [165]; Ben Ruben et al. [166]; Prashar et al. [167]; Iranmanesh et al. [116]
Operations management	P1, P2, P4, P5, P6	Sahoo et al. [143]; Singh et al. [168]; Chen et al. [151]; Kumar et al. [77]; Belhadi et al. [169]; Ismail et al. [130]; Balamurugan et al. [89]; Jasti et al. [57]; Lingam et al. [102]; Zahraee et al. [170]
	P5, P6	Esa et al. [146]; Jeyraj et al. [171]; Singh et al. [172]; Gati-Wechsler et al. [149]; Tripathi et al. [9]
	P1, P2	Rohani et al. [61]; Tripathi et al. [173]
	P1, P5, P6	Jayanth et al. [96]; Ahuja et al. [174]; Subramaniam et al. [175]; Sharma et al. [176]
Financial profitability	P1, P2, P3, P6	Jayanth et al. [96]; Barbosa et al. [120]; Kumar et al. [77]; Lu et al. [177]; Andrade et al. [178]; Saqlain et al. [179]; Chien et al. [152]

Table 3. *Cont.*

Key Factors	Problems	Author
	P1, P5, P6	Priya et al. [180]; Iranmanesh et al. [116]; Diaz et al. [72]; Dadashnejad et al. [81]; Tyagi et al. [62]
	P1, P2, P3, P4, P5	Rahman et al. [101]; Longhan et al. [181]; Bertolini et al. [55]; Choomlucksana et al. [59]; Thomas et al. [105]; Asif et al. [182]; Zahraee et al. [170]; Ramani et al. [126]; Liao et al. [183]; Abubakr et al. [184]; Cherrafi et al. [185]

2.4. Analysis of the Findings Obtained in Achieving Operational Excellence on the Shop Floor

In this study, previous research work has been extensively reviewed to identify strategies and problems in production shop floor management systems.

The implementation of the strategies discussed in Table 1 illustrates that S1 has been mostly selected, with the lean manufacturing, smart manufacturing, lean six sigma, and kaizen approach. S1 is the most preferred strategy, among other approaches discussed above. Lean manufacturing can be implemented in any industrial environment, and superior results are achieved by it. In the literature review, it was observed that hybrid approaches (S5) have been implemented in the last two decades. In the last five years, S5 has been mostly selected by industries because of its high improvement levels in production. The hybrid approach is competent to optimize production processes on the shop floor. It achieves higher improvements in comparison to process optimization approaches (S1) that are implemented separately on the shop floor. Figure 10 shows the process optimization approaches included in the research work. Table 4 shows the production parameters affected due to problems.

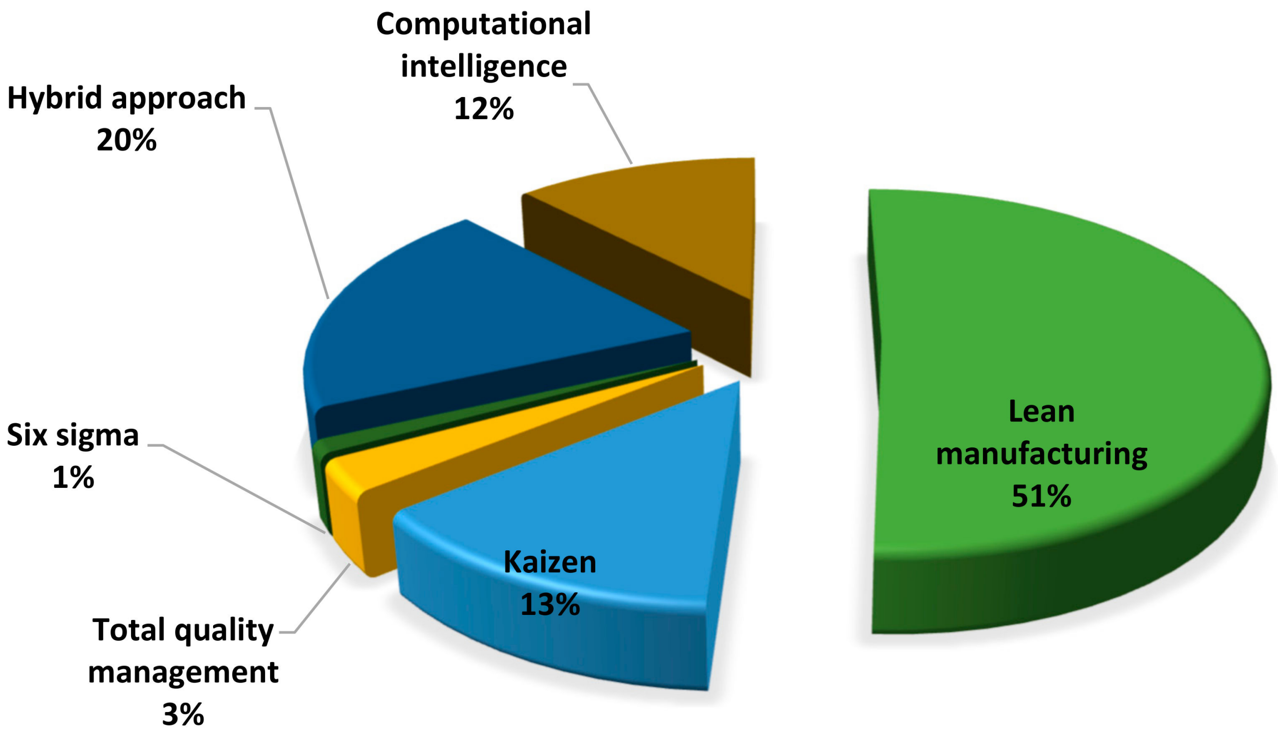


Figure 10. Contribution of process optimization approaches in industry.

Table 4. Production parameters affected due to problems.

Problem Type	Production Parameter									
	Product Quality	Production	Production Efficiency	Delivery Time	Worker Utilization	Productivity	Production Cost	Non-Value-Added Time	Break Time	Production Time
P1	x			x	x	x	x	x	x	x
P2				x		x	x			x
P3		x	x	x	x	x	x	x	x	x
P4	x			x	x		x			x
P5	x	x	x	x	x	x	x	x		x
P6	x			x	x	x	x	x	x	x

2.5. Outcomes for Achieving Operational Excellence on the Shop Floor within Limited Constraints

This study provides a decision-making key for achieving operational excellence and yield efficiency in production processes through improvements in operations management on the shop floor. It is possible by implementing a suitable process optimization approach using an efficient strategy in production shop floor management. The problems that occur commonly are encountered by the operations management team members. To overcome all these problems, production-related factors are taken into consideration before production, and only after analyzing them, process optimization approaches are implemented. These factors include layout, customer product demands, maintaining machinery, ergonomic issues, production parameters, and review of production records. In this present work, by analyzing all these problems and factors, it is suggested to choose the appropriate strategy and process optimization approach, which will prove useful for new researchers and production management in selecting an appropriate strategy and process optimization approach according to the production situation. Figure 11 shows the factors that need to be analyzed before production begins. All factors are demonstrated according to the discussed problems (P1, P2, P3, P4, P5, and P6).

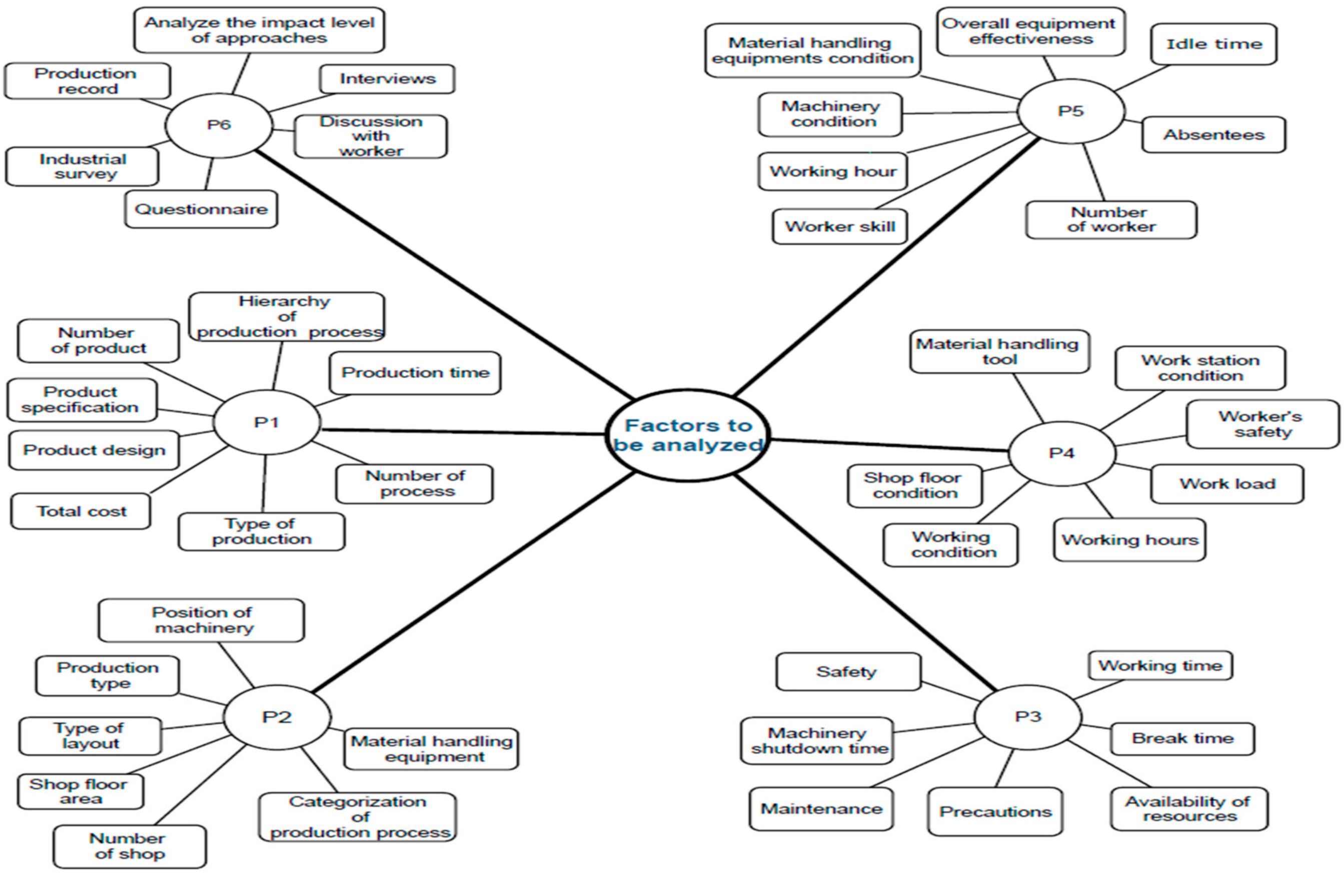
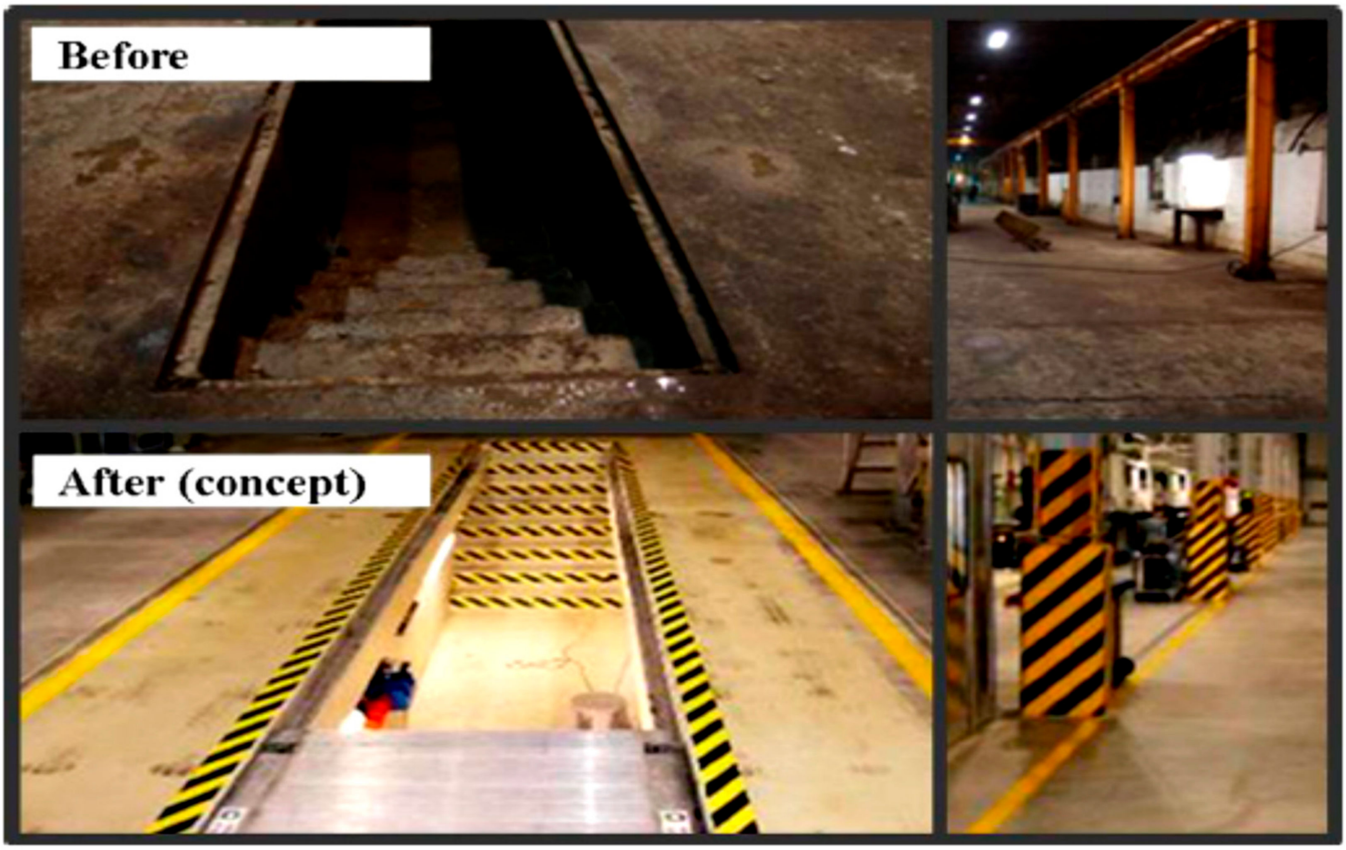


Figure 11. Analyze factor for the elimination of problems.

Figure 12a,b shows the improvements in shop floor management that were made possible by the elimination of the identified problems with the process optimization approach.

(**a**)

Figure 12. *Cont.*



(b)

Figure 12. (a) Improvement in shop floor management (Choomlucksana et al. [59]). (b) Improvement on the shop floor (Chlebus et al. [63]).

3. Incorporation of the Knowledgably Insights in This Work

Research conducted in the field of shop floor management through a process optimization approach has been investigated. The results obtained from various research [2,7,12,36,46,62,88,107,152,172,186] showed that the improvement of production, quality, and productivity was possible by the implementation of the right strategy and approach of process optimization. From the work conducted so far, it has been found that it is very difficult to achieve productivity improvement by eliminating non-value-added activities and implementing a single process optimization approach. Various production factors, such as workers, shop floor management, production process, product specification, downtime, etc., affect the efficiency of the production system. To improve production on the shop floor, several research studies were carried out by revising and developing various process optimization strategies and approaches that led to better production improvements. Figure 13 demonstrates the difficulties faced during the implementation of the process optimization approach for production improvement. To fill these research gaps, lean six sigma, smart manufacturing, and computational intelligence are newly emerging techniques to help increase productivity levels with better quality and to strengthen production management systems.

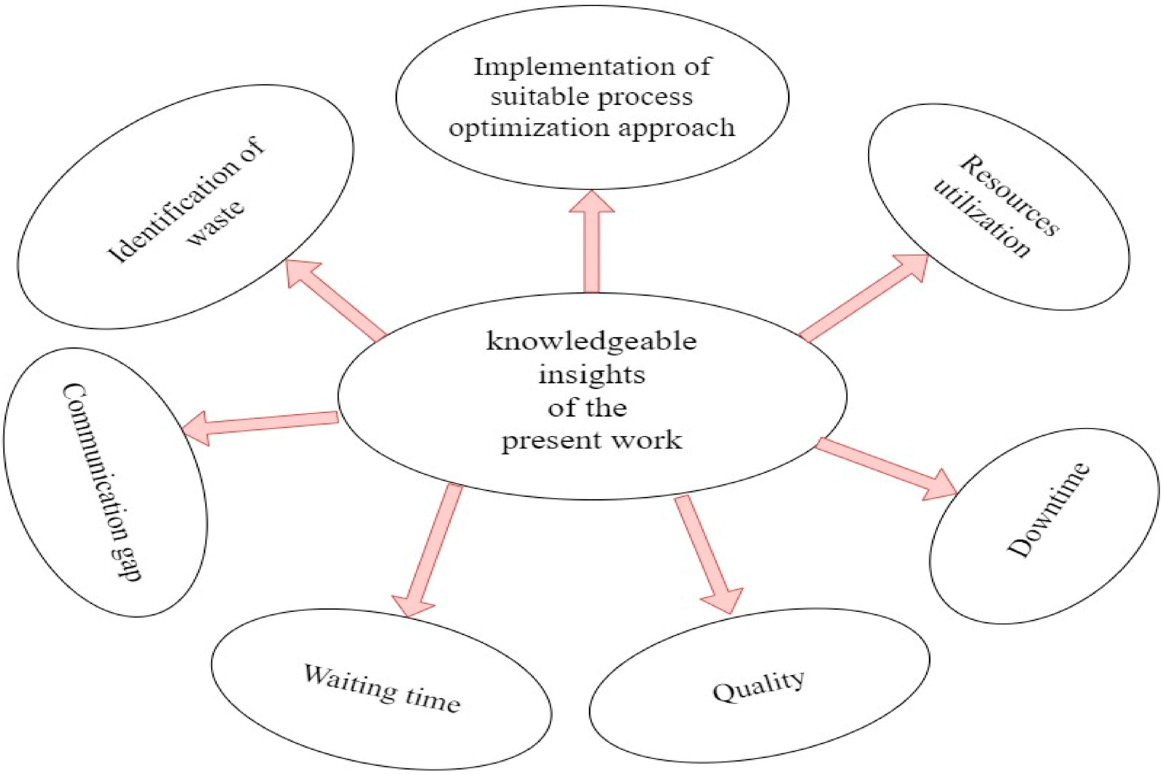


Figure 13. Valuable insights from the shop floor management.

4. Results and Discussion

From a thorough literature review of the reported work, it has been clear that the implementation of the strategy and technique chosen to apply various process optimization approaches to production management has been the subject of extensive research over the past several years. The main reason for this research is that the need for a process optimization approach is increasing day by day in the industry because an efficient strategy and technique are needed to eliminate problems and waste during production so that higher production levels can be achieved. Table A1 describes the strategies used in previous research to eliminate problems encountered in shop floor management (shown in Appendix A). Table 3 shows the issues according to critical factors in operations management on the shop floor. Finally, Table 4 shows the production parameters affected due to problems. Table 5 shows the selection of strategies according to the identified type of problem in shop floor management.

Table 5. Selection of strategy according to the type of problem.

Challenges	Strategies				
	S1	S2	S3	S4	S5
P1	x			x	x
P2	x			x	x
P3	x	x	x	x	x
P4	x	x	x		x
P5	x	x	x	x	x
P6				x	x

It is observed that lean manufacturing, kaizen, smart manufacturing, and lean six sigma were the main process optimization approaches adopted by researchers in previous studies. However, some researchers have also implemented other process optimization approaches such as six sigma and total quality management [7,79]. Most research cases have been studied to optimize one type of problem factor at a time. However, fewer tasks have been performed related to multipurpose production optimization. It is a necessity of the industry to manufacture a product, keeping in mind the cost and quality of production.

Keys for Enhancing Operational Excellence in Shop Floor Management System in Industry 4.0 by Comparing with the Present and Previous Research Findings in Operations Management

In reviewing previous research work, it has been found that the shop floor management team members face several problems in achieving operational excellence [25,46,57,69,84,93,145,180]. The problems were found in work planning, layout, higher downtime, ergonomics issues, and the working environment. The industry personnel were worried about improving operational excellence by implementing a sustainable and suitable strategy. The present study suggests an appropriate plan with an efficient process optimization approach for achieving productivity enhancement on the shop floor. It has been concluded that productivity, financial profitability, and machinery utilization were improved by 56%, 45%, and 28%, respectively, and reduced defects by 95%. However, the operations management teams struggle to achieve yield efficiency in production processes with available resources. The hybrid integrated approaches were preferred and supported by researchers and industry individuals in the present scenario of industry 4.0 for shop floor management. The hybrid system boosts the individual process optimization approach for eliminating waste on the shop floor. The present study provides a suitable strategy for operations management teams to enhance operational excellence by controlling the overall activities at the beginning of production processes on the shop floor. Figure 14 illustrates the novelty of the present study in comparison with previous research outcomes.

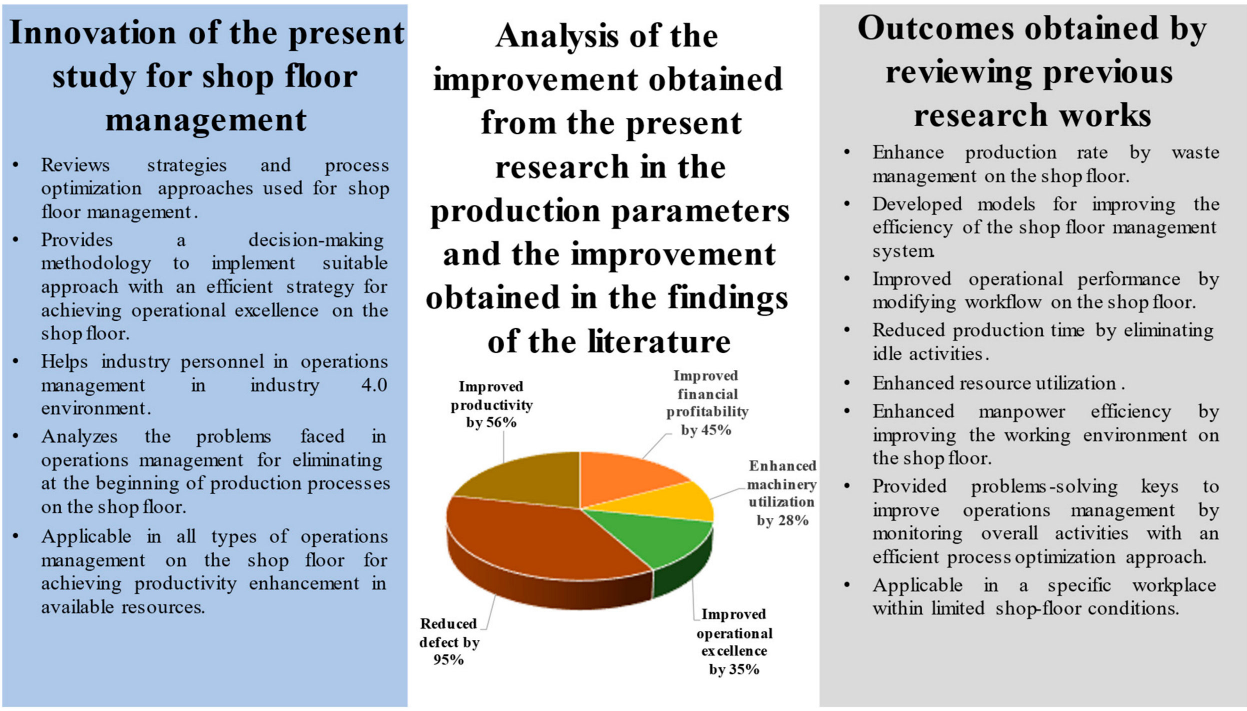


Figure 14. Comparison of the present study with previous research findings.

5. Enhancement in Productivity, Operational Excellence, Financial Profitability, and Resource Utilization Using a Suitable Strategy with an Efficient Process Optimization Approach

In the present industrial scenario, operations management team members are focused on enhancing operational excellence with available resources. Industry individuals use various strategies and approaches for production shop floor management. Strategies helped operations management team members implement the process optimization approach in an efficient way. The process optimization approach was used to enhance operational efficiency by eliminating idle and non-value-added activities in the production shop floor management system [186]. However, in an exhaustive literature review, it has been found that the efficiency of the lean approach can be improved by integrating it with other process optimization approaches. Industry individuals have achieved drastic improvements in operational performance by implementing integrated process optimization approaches. The present study provides a concise report on strategies and process optimization approaches implemented by researchers for improvement in operations management on the shop floor. The present review helps to implement an efficient approach with a suitable strategy and enhances operational performance within limited constraints.

5.1. Implementation of a Suitable Process Optimization Approach for Enhancing Operational Efficiency in Production Shop Floor Management Systems

Implementation of a process optimization approach plays a critical role in operations management on the shop floor. The process optimization approach provides an efficient action plan for enhancing productivity within limited constraints. In the present scenario, industry individuals support the integrated approach concept with advanced technologies for improving operational excellence on the shop floor. Advanced technologies enhance the efficiency of production shop floor management systems by establishing intelligent monitoring systems [187]. Smart monitoring systems are able to control overall production activities and the workflow of production processes efficiently [188]. Industry personnel can improve any discrepancies in the operations management on the shop floor using advanced technologies, including the internet of things, digitization, asset tracking systems, automation, cloud computing, etc. It has been observed that advanced technologies can enhance operational performance by maximizing resource utilization and establishing a safer working environment within limited constraints.

5.2. Improvement in Operational Performance through Identification of the Problems in Industry 4.0

Industry individuals face several problems in achieving productivity enhancement on the shop floor. Problems are responsible for idle activities, and they can be eliminated by implementing a suitable action plan [189]. Idle activities can never provide any positive value in operations management on the shop floor [190]. The production shop floor management systems focus on implementing an efficient process optimization approach with a suitable strategy. The present study provides a report on the strategy and approaches used for operations management in previous research works. The present study could help industry personnel and researchers identify problems at the beginning of the production processes on the shop floor, including industry 4.0. Industry individuals can improve operational efficiency using advanced techniques and integrated approaches when they know about the source of problems at the start of the production process on the shop floor [191]. The main sources of the problem include an unfriendly working environment, resource unavailability, a lack of condition monitoring systems, and inefficient resource allocation planning. The present study helps to implement an appropriate process optimization approach with advanced techniques and strategies.

5.3. Contribution in Production and Organization Management in Industries

The present study extensively reviewed previous research on enhancements in production shop floor management system efficiency using process optimization approaches. The review report provides an overview of strategies and process optimization approaches used by researchers for achieving operational excellence in production shop floor management, including industry 4.0. A suitable strategy helps operations management teams control production activities in an efficient way and provides an improvement in operational efficiency on the shop floor. The present study provides problem-solving and decision-making for production management using advanced techniques and appropriate process optimization approaches. It has been concluded that the integrated process optimization approach concept with advanced techniques provides operational excellence and flexibility in production shop floor management.

A robust production system is a basic need of the industry, and its demand has increased in worldwide industries in the present scenario. To fulfill this demand, there is a need to develop a strategy for implementing a suitable process optimization approach for shop floor planning, including industry 4.0. The strategy for the enhancement in production through suitable process optimization approaches has been reported. Process optimization approaches for shop floor management have to be preferred by researchers and production management systems due to higher improvements in production time and quality, as well as cost-saving with limited resources. The deployment of process optimization approaches across industries has led to an improvement in production levels and product quality as well as a reduction in production costs, therefore, the process optimization approach has attracted the attention of researchers and production management systems. Mainly six process optimization approaches, including lean manufacturing, kaizen, smart manufacturing, total quality management, six sigma, and computational intelligence, are in practice in industries. These approaches improve the shop floor planning and enhance overall production by eliminating waste. The production shop floor management becomes a challenge for industry personnel when production parameters and factors are not taken into consideration while planning production. The research direction for shop floor management by process optimization approaches has been represented in Figure 15. Figure 15 shows different production parameters and research opportunities present in the field of improvement in shop floor management through process optimization approaches. Researchers are trying to highlight the different issues in shop floor management. Thus, to improve the process optimization of shop floor management, it is necessary to perform more optimization in theoretical aspects.

Figure 15. Production parameters for shop floor management.

From the results of the research work done so far, it has been known that an efficient approach is needed for shop floor management, including industry 4.0 so that production-related results can be improved. It improves shop floor management and increases more production than other strategies. The hybrid approach is an emerging efficient approach to optimize shop floor management.

6. Conclusions

After an extensive review, the implementation of the strategy for the process optimization approach and problems encountered in production has been analyzed. The following conclusions were obtained:

- i It has been observed that the selection of process optimization approach plays a vital role in achieving operational excellence on the shop floor, including industry 4.0.
- ii The present research describes the strategies used to implement the suitable process optimization approach for achieving yield efficiency in the production processes on the shop floor by eliminating problems encountered in operations management on the shop floor.
- iii It has been observed that hybrid approaches like lean six sigma, smart lean manufacturing, lean-kaizen, and computational intelligence were superior to other individual process optimization approaches in relation to improving operational performance on the production shop floor management.
- iv The present research provides a decision-making key for achieving economic sustainability for industry personnel.
- v The present review work would provide revolutionary changes in the production shop floor management scenario and enhance operational excellence in available resources within confined constraints.

In the present advanced operations management scenario, industry personnel focus on enhancing operational excellence in available resources within confined constraints by implementing a suitable process optimization approach on the shop floor. This research provides a methodology for implementing an appropriate approach to achieve productivity enhancement by eliminating problems faced in operations management on the shop floor, including industry 4.0. In the future, the developed methodology and strategy can be extended by evaluating the improvements achieved in parameters and factors in operations management on the shop floor. Furthermore, it can enhance the strategy's applicability by implementing hybrid and intelligent methods in production shop floor management, including industry 4.0.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Classification of the articles according to the strategy adopted.

S. No.	Year	Reference No.	Industry/Area/Applied	Strategy				
				S1	S2	S3	S4	S5
1	2000	Detty et al. [44]	Electronic product	x			x	
2	2002	Mcdonald et al. [45]	Industrial motor	x			x	
3	2005	Seth et al. [46]	Motorcycle frames	x				
4	2006	Singh et al. [47]	Die casting unit	x	x			
5	2006	Bragila et al. [48]	Refrigerator production	x			x	
6	2008	Sahoo et al. [144]	Forging company	x	x			
7	2009	Pattanaik et al. [7]	Ammunition components	x			x	
8	2009	Vinodh et al. [148]	Crankshaft gear manufacturing	x				
9	2009	Stump et al. [129]	Mass customization					x
10	2010	Eswarmoorthi et al. [49]	Machine tool industry	x		x		
11	2009	Vinodh et al. [148]	Stiffer camshaft	x	x			
12	2010	Schaeffer et al. [50]	Mechanical products, Mechanical components, Elevators	x	x			
13	2011	Coppini et al. [51]	Industrial gear box	x				
14	2011	Gurumurthy et al. [52]	Poly-vinyl chloride door and window	x				
15	2011	Hodge et al. [97]	Textile industry	x	x			
16	2012	Rahani et al. [98]	Front Disc	x	x			
17	2012	Dotoli et al. [118]	Forklift trucks	x			x	
18	2012	Unver et al. [119]	Manufacturing intelligence system				x	
19	2012	Salleh et al. [53]	Forming	x				
20	2012	Bhaskaran et al. [111]	Automotive component			x		
21	2012	Jiménez et al. [54]	Wine sector	x		x		
22	2012	Boateng-Okrah et al. [99]	Mining company	x	x			
23	2012	Mandahawi et al. [100]	Paper manufacturing		x			x
24	2012	Timans et al. [112]	SMEs			x		x
25	2013	Das et al. [145]	Air conditioning coil manufacturing	x				
26	2013	Bertolini et al. [55]	Bottling lines	x	x			
27	2013	Jeyaraj et al. [171]	Rear front pedestal manufacturing	x				
28	2013	Ismail et al. [130]	Biopharmaceutical					x
29	2013	Rahman et al. [101]	Automotive manufacturer	x	x			
30	2014	Amin et al. [28]	Shock absorber	x				
31	2014	Barbosa et al. [120]	Aircraft production	x			x	
32	2014	Jasti et al. [57]	Ancillary component	x	x			
33	2014	Kumar et al. [77]	Hydraulic cylinders	x				
34	2015	Choomlucksana et al. [59]	Sheet metal stamping	x	x			
35	2015	Mwanza et al. [60]	Chemical manufacturing	x	x			
36	2015	Rohani et al. [61]	Industrial and building paint	x				
37	2015	Esa et al. [146]	Automotive manufacturing	x				
38	2015	Lingam et al. [102]	T-shirt manufacturing	x	x			
39	2015	Alhuraish et al. [113]	French industries	x		x		
40	2015	Andrade et al. [178]	Clutch discs	x				
41	2015	Schneider et al. [103]	Pharmaceutical company	x	x			
42	2015	Marodin et al. [104]	Automotive, electronic component	x	x			
43	2015	Wang et al. [42]	Solar module production line	x			x	
44	2014	Vinodh et al. [148]	Automotive component					x
45	2015	Sharma et al. [176]	Machine tool industries	x		x		
46	2015	Singh et al. [172]	Steel manufacturing	x	x			

Table A1. *Cont.*

S. No.	Year	Reference No.	Industry/Area/Applied	Strategy				
				S1	**S2**	**S3**	**S4**	**S5**
47	2015	Tyagi et al. [62]	Gas turbine manufacturer	x	x		x	
48	2015	Chlebus et al. [63]	Copper mines	x				
49	2015	Indrawati et al. [131]	Iron ore industry					x
50	2015	Helleno et al. [40]	Automotive vehicle	x	x			
51	2016	Salonitis et al. [114]	Greek manufacturing sector	x		x		
52	2016	Thomas et al. [105]	Aero structures		x		x	x
53	2016	Ali Naqvi et al. [64]	Switchgear	x				
54	2016	Prasad et al. [65]	Foundry industry	x		x		
55	2016	Omogbai et al. [66]	Print packaging manufacturing	x				
56	2016	Al Askari et al. [67]	Soft drink company	x		x		
57	2016	Al-Refaie et al. [68]	Electro-erosion process	x			x	x
58	2017	Chugani et al. [34]	Kick starter	x				
59	2017	Méndez et al. [71]	Auto-parts for automotive assembly plants	x				
60	2017	Roriz et al. [70]	Carton company	x				
61	2017	Diaz et al. [72]	Wing spar	x				
62	2017	Seth et al. [73]	Power transformer	x	x			
63	2017	Garre et al. [150]	Pressure vessel (Aerospace manufacturing)	x				
64	2018	Kurilova-Palisaitiene et al. [74]	Forklift trucks manufacturer, engine remanufacturer, computer, and smartphones remanufacturer, a remanufacturer of filling machines	x	x			
65	2018	Nallusamy et al. [156]	Foundry industry	x		x		
66	2018	Tripathi et al. [190]	Automobile industry	x			x	
67	2018	Raja Sreedharan et al. [115]	Indian manufacturing industries			x		x
68	2018	Yadav et al. [106]	Indian machine tool manufacturing		x		x	x
69	2018	Kumar et al. [69]	High-density polythene and linear low-density polythene water tank and drums	x	x		x	
70	2018	Hill et al. [132]	Aerospace engine maintenance repair and overhaul facility					x
71	2019	Sana et al. [121]	Plastic industry	x			x	
72	2018	Cannas et al. [78]	Chocolate and confectionery	x			x	
73	2018	Munteanu et al. [79]	SMEs in Romania	x				
74	2018	Garza-Reyes et al. [80]	Manufacturing organizations	x		x		
75	2018	Gijo et al. [123]	Auto ancillary				x	x
76	2018	Zhang et al. [124]	Plant layout design				x	
77	2019	Dadashnejad et al. [81]	Gas ball valve	x	x			
78	2019	Stadnicka et al. [82]	Door seals (Automotive industry)	x			x	x
79	2019	Choudhary et al. [83]	Packaging-manufacturing	x			x	x
80	2019	Shou et al. [84]	Turnaround maintenance	x			x	
81	2019	Ramani et al. [126]	Gas-insulated switchgear	x			x	
82	2020	Yadav et al. [85]	Pump part manufacturing	x	x		x	
83	2019	Mahajan et al. [86]	Motor manufacturing	x				
84	2019	Gleeson et al. [127]	Manufacturing productivity				x	x
85	2019	Gonzalez et al. [117]	U.S. industries	x		x		
86	2019	Ur Rehman et al. [87]	Water heater manufacturing	x				
87	2019	Suhardi et al. [109]	Dining armchair manufacturing		x			x
88	2019	Masuti et al. [88]	Excavator manufacturing	x				
89	2019	Liao et al. [183]	Production delivery				x	
90	2020	Priya et al. [180]	Automotive assembly plants					x
91	2020	Qu et al. [128]	Solar industry	x			x	
92	2020	Mundra et al. [133]	Interpretive structural modeling					x

Table A1. *Cont.*

S. No.	Year	Reference No.	Industry/Area/Applied	Strategy				
				S1	S2	S3	S4	S5
93	2020	Balamurugan et al. [89]	Connecting rod manufacturing	x				
94	2020	Aghdasinia et al. [90]	Rotary kiln	x				
95	2020	Prasad et al. [75]	Textile industry	x				
96	2020	Saqlain et al. [179]	Auto-ancillary unit	x				
97	2020	Abubakr et al. [184]	Network of discrete				x	x
98	2020	Sutharsan et al. [92]	Mono block shallow well jet pump	x				
99	2020	Amrani et al. [93]	Aerospace	x	x		x	
100	2020	Sivaraman et al. [94]	Engine assembly	x				
101	2020	Khan et al. [95]	Power generation system	x			x	
102	2020	Jayanth et al. [96]	Electronics	x				
103	2021	Tripathi et al. [173]	Earthmoving equipment	x	x		x	
104	2018	Tripathi et al. [190]	Mining Machinery	x	x		x	x

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