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Review Article

A Survey of Machine Learning Use Cases (Applications) in Project Planning and Scheduling Process

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Abstract: The swift changes in the complexity of the project, scarcity of resources, and pressure on the organization have demonstrated the necessity of more intelligent and data-driven planning and scheduling methods. Conventional methods tend to be less effective in the tasks of uncertainty management, dynamic environment, and dynamism of the project ecosystems of the modern world. The application of machine learning (ML) in the planning and scheduling of projects is thoroughly reviewed in this paper, and it is evident that ML may help to improve the accuracy of forecasts, optimize resource distribution, and make decisions. This paper offers an analysis of the basic concepts of project management, evidence-based practices, and how supervised and unsupervised learning, as well as reinforcement learning concepts, can be combined in the scheduling process. Furthermore, the new literatures are examined to bring out new techniques, including predictive modelling, optimization algorithms, simulation-based planning and adaptive scheduling models. The review determines the main strengths, weaknesses, and gaps in the research that impact the adoption of ML-driven approaches. All in all, the paper describes the ways in which machine learning technologies can change the traditional way of project management by creating efficient, resilient, and proactive planning systems.

Keywords: Project Management, Project Planning, Project Scheduling Process, Artificial Intelligence (AI), Machine Learning (ML)

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1. Introduction

The world is always changing, and businesses need to be able to quickly respond to projects that help them reach their goals. To do this, they need to be able to handle the project well so that it meets its goals and is completed on time and on budget. In project acceptable management, the goal is to plan and control the creation of an acceptable system within a given time frame and at a minimum cost [1]. Uncontrolled changes in project scope, delays in delivery, cost overruns, and unmet or unknown needs are all results of poor project management. Everyone and everything associated with the project feels the effects of delays. Delaying the project's launch would make it harder to get the anticipated revenue and drive-up financial expenses, which is particularly problematic for the owner's company. Furthermore, the owner could encounter many additional challenges stemming from the obligations assumed in relation to the contract's specified delivery date [2]. Cost overruns are a common problem for contractors when project execution times are extended. This is because there are several factors that contribute to these overruns, such as increased spending on management staff, higher material costs, higher finance costs, contract penalties, and so on. In addition, contractors whose projects are late may have their reputations damaged and their ability to secure new contracts hindered, due to the typical competitive atmosphere in the construction sector [3].

The goal of project planning and scheduling is to complete tasks in accordance with the project schedule as intended, and if there are any delays, the process can be adjusted accordingly. Since time is associated with every aspect of a project, whether directly or indirectly, controlling it means controlling the entire planning system [4]. Alternatively, it can be said to be the act of organizing, guiding, and regulating resources, protocols, and procedures to accomplish predetermined objectives in solving every day or scientific problems [5]. The most common, but not exclusive, purposes and objectives of projects are to bring about positive change or increase value. Projects are ad hoc endeavors with beginnings and endings, and they typically have particular deliverables, time constraints, and budget constraints. Projects tend to have a shorter duration than operations, which are more permanent or semi-permanent functional activities that produce goods or services. Project planning and control are cornerstones of project management. Tasks including project scheduling, status reporting, baseline plan comparison, deviation analysis, out-of-control scenario discovery, and suitable corrective action taking involve a myriad of choice concerns [6]. In response to these decision-making challenges, numerous approaches, methodologies, and resources have emerged during the past few decades.

Artificial intelligence (AI) refers to a computer's or machine's capacity to solve difficult and complicated tasks. The merging of information technology with physiological intelligence has led to computerized artificial intelligence, which can be utilized to accomplish objectives [7]. Massive increases in computing capacity, advances in AI techniques (such as DL), and the proliferation of massive data are driving forces behind the emergence of AI and ML [8]. Due to the widespread use of software, there is a wealth of data available regarding software projects that can be used by AI approaches [9]. AI transform software project management in many ways, in my opinion. It automates mundane administrative tasks, improve project planning, streamline analytics-driven risk assessments and predictions, and offer practical recommendations.

Structure of the Paper

The paper follows the following structure: Section II gives the major terms in the project planning and scheduling. Section III states about data-driven approaches and methods of analysis. In Section IV, the author explores ML methods that can be used in planning and scheduling. Section V is the review of recent literature and key findings. Section VI includes the conclusion and the future research directions.

2. Project Planning and Scheduling

A number of resources (human and financial, physical and digital, and ancillary) inside a single company come together in a project to accomplish its goals. Project planning entails looking ahead to current tasks and conditions, establishing goals and objectives, and deciding on policies, programs, a timeline, a power source, an operational budget, and a procedure for implementing the project's policies and procedures [10]. Project scheduling is the process of figuring out how long certain tasks, resources, and activities within a project take to finish.

2.1. Core Concepts of Project Planning

The completion of a project within the allotted time and money, as well as its performance meeting or exceeding expectations set out in the original plan, constitute its success. Thus, preparation is key to a project's overall success. All of these projects, as illustrated in Figure 1, have distinct stages that, when completed, determine the total amount of work and the extent to which they affect the project's success. A project's planning phase is among its most important components [11]. Although numerous elements have been explored in previous research, one of the most essential ones is planning. Prior studies have shown that inadequate planning is a contributing factor to project failure.

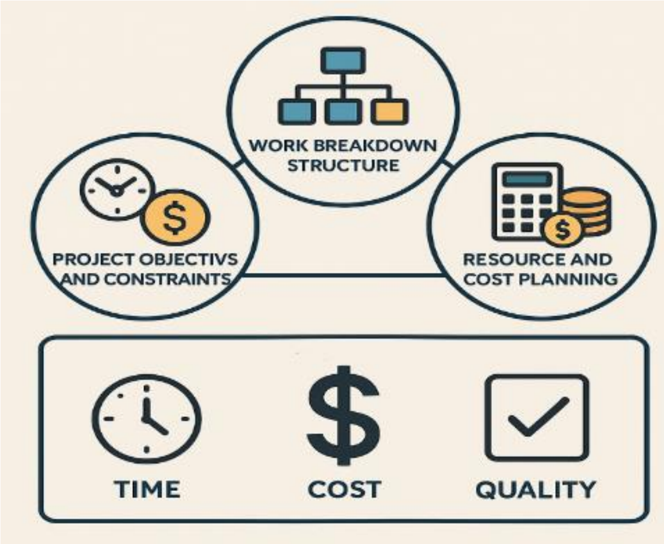

Figure 1. Concepts of Project Planning and Scheduling

2.1.1. Project objectives and constraints

The importance of time, money, and quality as project success factors has led to their widespread adoption as metrics for monitoring project status. The need of resolving disputes or compromises among the project's objectives was recognized by managers as crucial to the project's successful management [12]. In understanding this necessity, the projects are usually being limited by the lack of resources, deadlines, and predetermined costs, which directly affects the decision-making. Project goals cannot be achieved due to the insurmountable balancing act between these constraints and the constant pressure to satisfy stakeholders' expectations and performance requirements.

2.1.2. Work Breakdown Structure (WBS)

Project scope is defined by the end results, and the Work Breakdown Structure (WBS) is a method for organizing those results into manageable chunks. Work breakdown structures (WBSs) are useful for organizing and defining project scopes because they group the various work components of a project according to their product orientation. In order to illustrate the logical connections between different parts of a project, a hierarchical framework called a Work Breakdown Structure (WBS) can be useful [13]. At each stage, a project component is further specified and split. Its primary function is to design, assign, and monitor the scope of individual tasks at various points in a project's lifetime. All of the project's actions are bound together by its structure and code. It is guaranteed that each control account has its own unique WBS element by meticulously establishing the WBS.

2.1.3. Resource and Cost Planning

A project's cost variances defined as any changes to the budget or actual costs are a major factor in the project's cost performance. During the comprehensive planning stage, the design, specs, scope, and final cost are created. An alternative method for estimating the potential range of costs is to use the award of contract, which is the final, agreed-upon price at the outset of the construction process [14]. The interplay between the several subprocesses that make up project cost management, including planning, estimating, budgeting, financing, managing, and controlling expenses is essential to completing a project within the allotted budget.

2.2. Project Scheduling Techniques and Practices

The software manager's workload is heavy, and one of the most taxing responsibilities is project scheduling. Distribution of estimated effort across the planned period of a project is accomplished by this activity, which involves assigning that effort to specific engineering tasks. Project scheduling, in its simplest form, is the process of dividing a large project into smaller tasks and approximating the time required to finish each one [15]. In addition, managers are tasked with estimating the resources that required to finish each mission. Faster problem detection, time savings, consistency building, increased visibility, problem resolution, and countless other benefits are all part of software project scheduling. Figure 2 shows an example of the standard project scheduling diagrams that include the Work Breakdown Structure (WBS), activity dependencies, and personnel allocation. The following is a list of some of the various methods to schedule software projects.

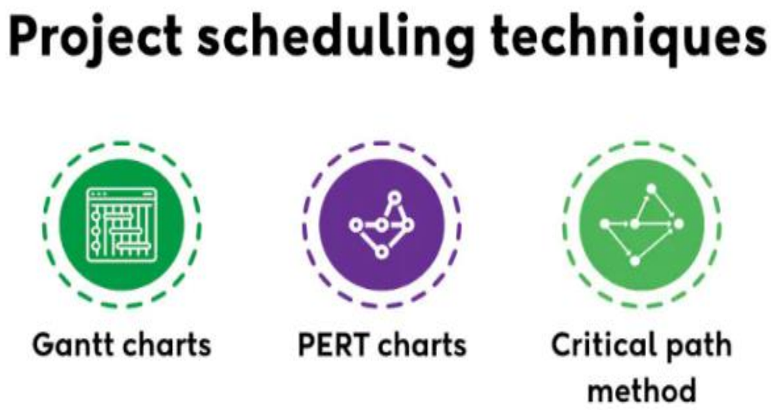

Figure 2. Project Scheduling Techniques

2.2.1. CPM and PERT Techniques

A deterministic decision-support system (DSS), Critical Path Method (CPM) and the Project Evaluation and Review Technique (PERT) were the forerunners of computerized project management. Contrarily, PERT is all about creating and overseeing project timelines in situations where there is a lot of unpredictability [16]. An approach to stochastic analysis is what its engine is based on. Processing times and budget consumption can be very unpredictable in different project setups, according to many sources. In order to entice buyers, it also guarantees performance criteria. Appropriate planning and scheduling of major projects makes use of both the CPM and the PERT [17]. As a result, project managers are better able to track how each phase is progressing. The main distinction is that CPM uses deterministic durations to plan the tasks.

2.2.2. Resource Allocation

The purpose of resource allocation is to distribute available resources in a cost-effective manner. It incorporates the principles of managing resources. Allotting resources in project management entails planning tasks and the resources needed to complete them within the constraints of the project timeline and the available resources [18]. The project schedule is a useful tool for communicating the tasks that need to be done, the resources that assigned to those tasks, and the deadlines for those executions. To complete the project on time, the timeline must include all activities.

2.2.3. EVM Monitoring

The most critical way to keep an eye on a project's status is to compare it to the plan and note the discrepancy. To do this, can compute a number of indices, including critical ratios (CR), performance indices, and performance variances. The EVM is a foolproof way to manage a project's success. The time, money, and production progress of a project can be better reported by comparing the actual results to the anticipated and budgeted ones [19]. The three primary requirements of EVM are anticipated budget for work scheduled (BCWS), actual budget for work performed (BCWP), and actual cost for work completed (ACWP).

3. Data-Driven Methods for Project Planning and Scheduling

Project managers may plan, track, and control projects with data-driven management, ensuring they are completed on time and under budget. Data may aid professionals in making more informed judgments; this much is obvious. For instance, risk analysis and knowing what to do when uncertainty threatens a project both require data analysis [20]. It's all about making smarter decisions using data. In the absence of evidence, "you're just another person with an opinion," as Edward Deming put it. Integrating the two approaches is the goal of data-driven project management: As projects progress, make better decisions by combining facts (data) with experience (opinions).

3.1. Data Collection and Analysis in Project Management

Shipment and examination of data within the project management entail collecting correct project data and converting the data into practical information that aids planning as well as decision-making. Good data practices maintain credible documentation of project activity, resources, project schedule, and performance measures see Figure 3. The companies can determine patterns, determine risks, and increase forecast accuracy by using the historical and real-time data of projects. A more efficient project schedule and planning process can be achieved with this analytical foundation.

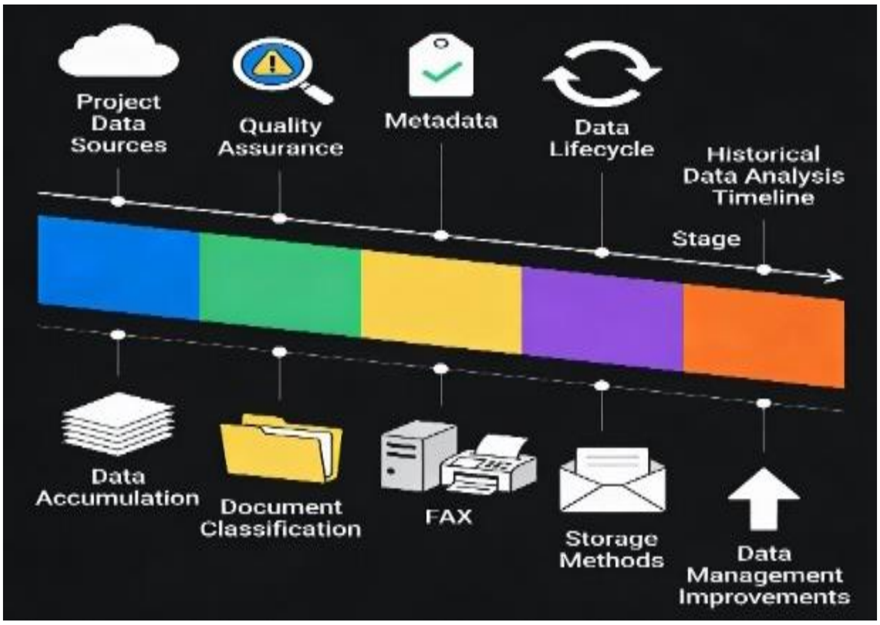

Figure 3. Data Analysis Concepts of any Project

3.1.2. Project Data Sources and Quality

Data quality concerns may be a major motivator for sharing and curating data. Concerns over data quality, abuse, or misunderstanding can arise for data owners. On the flip side, users might be hesitant to trust or even refuse to use the data due to a lack of knowledge about or access to the procedures that created it [21]. Decisions and discoveries are only as good as the data used to make them. In order to make good decisions or to defend, verify, and assess past choices and outcomes, it is crucial to have access to high-quality data for the long haul. The same data or metadata might have varying degrees of value in different activities and at different periods, and it can be used for multiple purposes; this is known as the data lifecycle. For research to be repeatable, process-level analysis of data, metadata, and data quality assurance is required.

3.1.3. Historical Data Analysis for Planning

There is a significant skill gap when it comes to operating computerized data systems, which makes it hard to gather and organize data. This is because projects are evaluated primarily on qualities such as site experience and know-how, rather than computer skills. To address these issues, it is necessary to enhance the system for managing historical data in order to extract ineffective factors. Therefore, it is necessary to merge the departments responsible for data management. Data accumulation is the primary emphasis of the examination and analysis of a domestic company's historical data, as illustrated in Figure 4. This survey makes it clear that there is a vast amount of historical data kept in a cabinet and that each field uses its own unique system for document classification. The primary means of data transmission between the headquarters and the fields, as well as between individual fields, are facsimile machines and electronic mail.

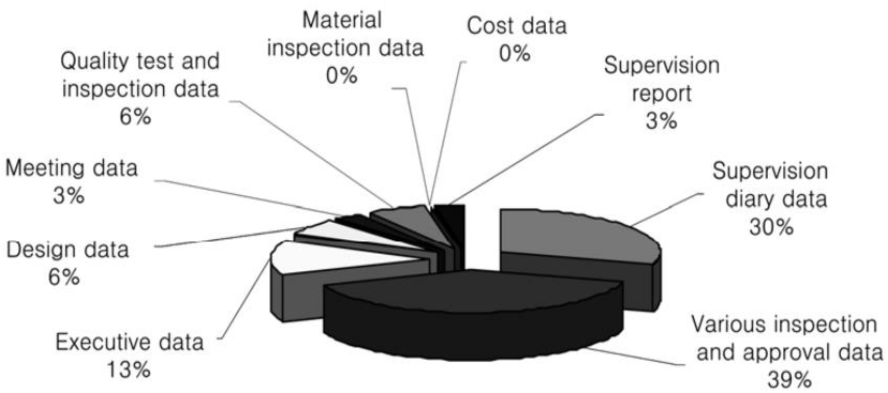

Figure 4. Historical Data Frequency

3.2. Predictive and Decision-Support Methods

Predictive and decision-support approaches make use of analytical models to determine the outcomes of a project, and inform decision-makers (planners) on informed decisions. Such methods involve historical data, performance trends, and calculations to approximate activity durations, cost and possible schedule risks. Project managers might assess various timeline scenarios, optimize resource use, and anticipate bottlenecks with the help of forecasting tools and decision support systems. Project planning and scheduling are made more precise, adaptable, and efficient with the help of these methods.

3.2.1. Forecasting project performance

The conventional method for managing a project is keeping tabs on actual performance, comparing it to anticipated performance, analyzing the difference, and finally, forecasting the outcomes that dictated by management's actions [22]. Performance indicators, such the schedule performance index (SPI) and the cost performance index (CPI), change throughout a normal project. During the initial stages of a project, the management may face challenges or encounter poor performance. Therefore, the project's performance in the subsequent reporting period(s) is not static and identical to the previous one, but rather it is adaptable, changing, and influenced by the previous one.

3.2.2. Data-driven scheduling and optimization

Practical researchers are showing a lot of interest in the RCPSP. Taking into account the resource needs and the precedence linkages between tasks is an important part of project scheduling. For instance, the academic topic has numerous applicable real-world counterparts in the construction and consulting industries, leading to a difficult list of cases with different optimization goals. Autonomous agents for scheduling projects in multiple modes Learning agents for the multi-mode project scheduling problem. The MRCPSP is a more generalized form of the RCPSP; for instance, it would take six days for two people to dig a hole with shovels alone, but just two days with four people plus an additional barrow [23]. Both the RCPSP and its generalization, the MRCPSP, are proven to be NP-hard optimization problems.

4. Machine Learning Techniques for Project Planning and Scheduling

The goal of ML, a subfield of computer science, is to enable computers to learn automatically, without the need for human intervention. Project planning and scheduling rely on a set of analytical techniques and processes designed to organize activities, allocate resources, and control project timelines effectively ML techniques are divided in three approaches: Supervised learning, unsupervised learning and Reinforcement learning as shown in Figure 5. There are modern planning systems that combine computational tools that assist in the sequencing of activities, coordination of resources and monitoring of performances. ML as a sophisticated direction of artificial intelligence helps in this field of research because it allows predicting and making decisions based on data [24]. Intimately connected with computational statistics, ML offers the models that can predict the project durations, costs, and risks. Its close relationship with mathematical optimization also maximizes the efficacy of the scheduling because it provides tools and models of better resource allocation and project delays reduction.

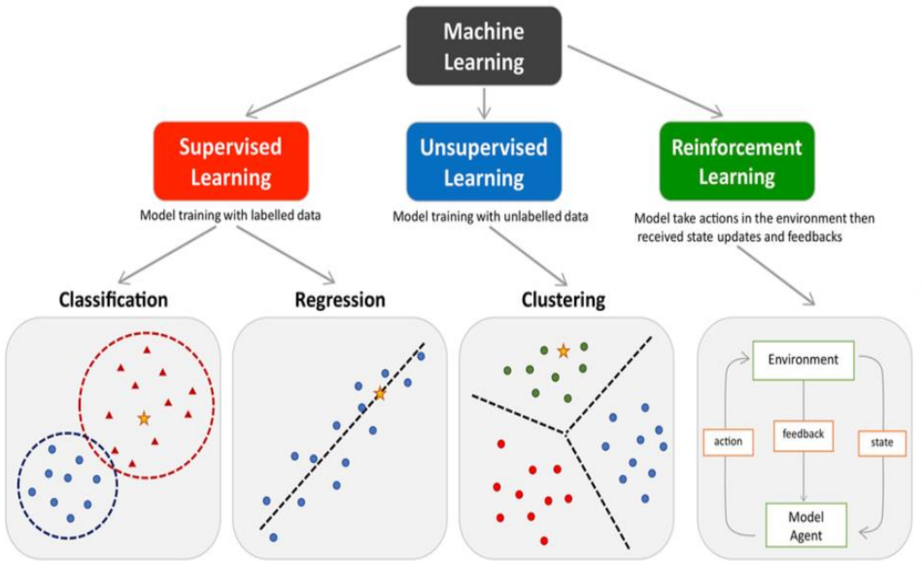

Figure 5. Machine Learning Techniques

4.1. Supervised Learning

Training an AI model with accurate classifications on a subset of a data source enables supervised learning to discover hidden correlations and patterns in the full dataset. The objective of learning process is to come up with a model that can make correct predictions on new real-life data. Supervised learning involves the use of ground-truth data to receive a model of the relationship between inputs and outputs and the labeled datasets are the point of reference of this mapping. After training, the model uses the relationships learnt to make predictions on new, unseen data [25]. Supervised learning is also extensively applied in project planning and scheduling to predict the duration of the activities, the cost of the project, and schedule risks of a project with the help of historical project data. Such forecasts enable project managers to come up with more precise schedules and enhance decision-making pertaining to the allocation of resources and optimization of schedules.

4.2. Unsupervised Learning

Unsupervised ML approaches allow one to analyze raw data and produce meaningful insights on unlabeled datasets simpler. The development of factor analysis, latent models, hierarchical learning, clustering schemes and outlier detection have immensely contributed to the ability of unsupervised learning. Recent progress [26], such as the use of DL as an unsupervised method, is another advancement that enhances the field by allowing automated identification of patterns without a lot of feature engineering or domain-specific processing. These methods play a useful role in the process of project planning and project scheduling to determine the existence of hidden patterns in the project performance data, grouping similar activities of the project and identifying of irregularities or inefficiency in the resources. These insights can aid better decision-making when it comes to the planning processes and assist organizations in identifying systemic problems that can influence the future project timelines.

4.3. Reinforcement Learning

RL is a ML paradigm where an autonomous agent learns the act of making decisions by interacting with the environment as well as being given feedback in terms of rewards or penalties. Rather than using labeled data, RL refines its strategy via trial error, and over time it finds actions that result in cumulative reward being maximized [27], This method is especially effective when operating in sequential decision-making problems, where the results of an action are sensitive to the dynamics of the environment, as well as the long-term consequences of its action. Applications of RL techniques in project planning and scheduling include optimization of activity sequencing, resource allocation where limited resources are used and schedule adjustments to project uncertainties like delays or cost change. Learning the best policies with time helps the RL-based systems be more adaptive and efficient in the process of project management, as project planners are able to test other scheduling alternatives and react to the evolving project conditions proactively.

5. Literature Review

The above literature review indicates that determining and ranking critical success factors is an important step in enhancing the outcomes of projects and decision-making. Nevertheless, most of the studies are constrained by the small sample sizes, limited external validity, and the use of subjective ways of evaluation.

Wang et al. (2019) released a sub-model for proactive scheduling of several projects. Reactive scheduling incorporates the proactive scheduling scheme as its baseline scheduling scheme in the case that the activity is discontinued. To meet this need, propose a genetic simulated annealing method that, when applied to the provided model, can provide several scheduling options. Using a buffer change operator (SC) and a crossover operator, a genetic simulated annealing approach is built to guarantee the early generation and protection of an ideal individual [28].

Shimoda, Wilairath and Kounosu (2019) Project operations are viewed as a two-tiered structure comprising of value realization and means realization; this is what defines the suggested method. Thus, the nine parts of the project activity are an amalgamation of the five V-model steps for means realization and the five PMBOK process groups for value realization. The proposed approach avoids a major scope creep while creating WBS, and studies done by college students show that even novices can grasp it with ease [29].

Zachko and Kobylkin (2018) The proposed approach is grounded on the theory's basic principles, and its practical use in studying the effectiveness of people's mass evacuation is proven. Throughout the simulation, used new methods, including one to mimic the object's operational life cycle with a big number of people on board and another to simulate an event—the object's evacuation due to a notice of substitution—throughout. The use of simulation modeling tools built on the Anylogic multi-agent modeling environment classes allowed us to see the project management process in action [30].

Kusturica et al. (2018) discussed various concepts from the SimCast research project, which is a collaboration between the Kassel and Zwickau universities. During project planning, it seeks to provide a technique for task duration estimation. Based on the researched state-of-the-art, the requirements, planning process, and present technical infrastructure of the predicted modular prototype are outlined. The project management process may already be benefiting from the first plug-ins that have been introduced [31].

Hameed et al. (2017) Previous issues with scheduling and personnel were the primary focus of the solution-finding process. Suggested an approach that involves optimizing particle swarms. For project managers, the proposed algorithm is illustrative of activities related to personnel and scheduling. Domain or problem type-specific efficient management plan creation is the algorithm's primary goal. The most efficient and economical method for achieving a complete and ideal project timeline is also shown [32].

Rihm and Trautmann (2017) constructed a novel MILP model based on explicit assignment and sequencing variables; enhanced the model's performance by excluding certain symmetric solutions from the search space and modifying the sequencing limits to account for incompatible activity pairings. For four common literature test sets, this one-of-a-kind model outperforms two state-of-the-art models in the constrained resource situation [33].

Peralta et al. (2016) provided multiple examples of the time record as outlined in the Personal Software Process. Both managers and employees benefit from the study, which yields a set of notes and suggestions for handling different kinds of work and scheduling in different contexts [34].

Table 1 is a summary of the previous studies on project scheduling and planning, including research objectives, research methods, main findings, and research constraints. The results validate the performance gains by the use of modern models, but also expose typical limitations in terms of reduced validation, scalability and context-specific validity.

Table 1. Summary of Recent Studies on Project Scheduling, Planning, and Optimization Approaches

Reference	Study on	Approach	Key Findings	Challenges / Limitations	Future Directions
Wang et al. (2019)	Proactive and reactive multi-project scheduling	An approach for genetic simulated annealing that incorporates proactive scheduling into reactive scheduling and makes use of buffer change and crossover operators	Generates alternative schedules efficiently and protects optimal solutions in early algorithm stages	Computational complexity and dependency on algorithm parameter tuning	Enhancement of algorithm scalability and application to real-time dynamic project environments
Shimoda, Wilairath & Kounosu (2019)	Work Breakdown Structure (WBS) creation	Two-layer activity structure combining PMBOK process groups and V-model steps	Improves beginner understanding and reduces scope loss in WBS creation	Validation mainly limited to student-based experiments	Application in industrial-scale projects and empirical validation with experienced project managers
Zachko & Kobylkin (2018)	Evacuation efficiency in mass-occupancy facilities	Simulation modeling using AnyLogic multi-agent environment and event-based evacuation scenarios	Enables visualization and efficiency analysis of evacuation processes	Focused on specific evacuation scenarios and infrastructure types	Extension to broader emergency scenarios and integration with real-time sensor data
Kusturica et al. (2018)	Project task duration estimation	Modular prototype with plug-ins based on state-of-the-art planning processes	Demonstrates potential benefits for improving project duration estimation accuracy	Prototype-level implementation with limited empirical evaluation	Full-scale deployment and validation across diverse project domains
Hameed et al. (2017)	Staffing and scheduling optimization	Particle Swarm Optimization (PSO)-based scheduling and staffing model	Produces cost-effective and efficient project schedules	Performance sensitive to problem domain characteristics	Hybrid optimization techniques and real-world case study validation
Rihm & Trautmann (2017)	Resource-constrained project scheduling	Novel MILP model with improved assignment and sequencing constraints	Outperforms existing models, especially under scarce resource conditions	Increased model complexity for large-scale instances	Further optimization for large datasets and integration with heuristic methods
Peralta et al. (2016)	Time and schedule management	Analysis of Personal Software Process (PSP) time records	Provides actionable recommendations for employee and manager schedule management	Context-specific findings tied to PSP adoption	Adaptation to agile and hybrid project management frameworks

6. Conclusion and Future Work

An environment of growing uncertainty, increased project size and the desire to make critical decisions is a driving force behind the need to develop more sophisticated planning and scheduling tools. The conventional methods of project management cannot be used alone to ensure performance, particularly in dynamic and resource-based situations. The paper has done a comprehensive survey of the ML-based techniques of planning and scheduling of a project and has revealed itself to be useful in enhancing the forecasting, optimization of resources, and mitigation of risks. The literature synthesis reveals that supervised learning is a more effective predictor of costs and time, unsupervised learning uncovers concealed patterns and reinforcement learning can help in adaptive scheduling to evolving conditions. Despite the apparent opportunities of the ML-driven solutions, their use is still challenged by data quality, complexity of the model and lack of real-world validation. However, it is true that the results prove the effectiveness of the promising approach to using ML in combination with traditional planning tools to enhance project performance and operational resilience.

The research work that must be carried out in the future is the creation of scalable ML models that can work in real-time project contexts and can deal with heterogeneous data sources. The combination of ML and simulation, digital twins, and optimization models could also increase the predictive accuracy and the ability to schedule dynamically. Also, there is need to have wider empirical validation in many industries to determine generalizability. Enhancing data control, standardization and model interpretability will also be necessary to bring about reliable and industry-wide usage.

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