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“Applications of Artificial Intelligence in Project Management”

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Abstract

Recently, Artificial Intelligence has gained a wide interest to ground itself into business and commercial use. As one of the fields that will be highly impacted by Artificial Intelligence is Project Management due to the unparalleled era of continuous computerized development starting from manufacturing to utilities and transport to financial services. Rationally, Artificial Intelligence is the machine's ability to imitate intelligent human behavior and thus attempts to emulate the potential of human cognition by manipulating symbols and symbolically organized information bases. Artificial Intelligence has found its way in inventing new methods and techniques to allow project managers perform their tasks faster and more efficiently, although the inherent uniqueness of projects could hinder the automation of the complex activities . Methodologically, a literature review on artificial intelligence applications takes place and then evaluates the current use of artificial intelligence in real time projects and companies for more in depth analysis. In addition, how Artificial Intelligence is set to change project management practice, what challenges need to be overcome, and how project managers can prepare themselves to stay up-to-date in a fully integrated, automated, and predictive project management world. The goal of this study is to discuss potential implementations of AI to improve PM activities and how project managers can objectively comment critically on the issues of responsibility in action taking, accountability in decision-making and still the crucial need for human reasoning.

1. Introduction

Artificial Intelligence serves as " the designing and building of intelligent agents that receive precepts from the environment and take actions that maximise its chance of successfully achieving its goals" [1] . In recent years, AI has been among the most extensively studied and examined technological breakthroughs, where AI tools have paved their way into real life applications at an unparalleled rate. Zujus et al. figures out a strong difference of AI versus other computer-mediated techniques with respect to AI ability to use a large amount of data to modify its internal structure particularly when new data is introduced, it gets categorized in conjunction with the previous data provided [7]. The application of AI software surprisingly dates back to 1987 [2]; however, only recently it has gained a wide interest in the field of manufacturing, production, operation and delivery [3]. Indeed, according to two popular online project management think spaces [5] [6], the use of AI and machine learning has recently been described as one of the top trends in project management. AI can aid in projecting and recognizing emerging trends that may contribute to more reasonable planning as well as provides the data-driven iteration required to analyze various approaches, their consequences and timeline. Handling uncertainty and complexity have been largely key objectives and these two attributes have a direct influence on project performance and exploring solutions to reduce them. Such flourishing changes are leading into a magnificent transformation in the nature of work and as a result, in the nature of potential workforce demands.

The purpose of project management (PM) can be expressed as a dynamic practice that is infused with various challenges as non continuous planning of projects involving flair adjusmtents, dependencies and conflicts in resource allocation, management and identification of any potential threats or opportunities during project implementation, and coordination among projects and activities. There is a broader discussion on whether project management will be a distinct discipline or whether it will be integrated into broader management practice [4]. Despite the possibility that highly competent technologies can eliminate even more occupations, project management’s foundations will remain to have an indispensable human combination of leadership, integration of specialists, and ethical conduct.. The primary driver behind this thesis is to present AI as a potential ally in turning PM as a standalone function and uplifting it to a higher rank from which project managers and organizations can benefit the most. In turn,the experience of the project manager can be enhanced to cope with the various hazardous circumstances that are prone to occur during the project’s progress while also avoiding errors caused by inadequate management or planning [8].

Heukamp et al. [9] formulated ten aspects wherein AI is changing management; moreover, Noponen addressed the effect of AI systems on management over the coming decade and found that AI will supplement human decision making, especially for top-level executives [10]. It is also deduced that AI is mainly examined in computer science and operation research to achieve better understanding of how automation can influence our future, in brief, how AI can not only automate processes but also strengthen the management domain [11] Adequate PM is required for all forms of projects, with the intention of leading the project to completion while managing time, cost, scope, quality and personnel arrangements. Project managers work together with other stakeholders and track the entire workflow and focus on all aspects of the project such as labor, capital, time, equipment, material and risk to reduce the possibility of delays, budget overruns, and imminent contingencies.

Due to the rise in data and computing capacity since 2002, the research interests have steadily moved to machine learning and deep learning at a higher level of intelligence for different purposes in the industry. However, prior to 2002, most studies focused on the expert system, an early AI-enabled tool for simulating human behavior and knowledge for decision making. To examine the current reviews' deficiencies, we intend to highlight a wider and more systematic review that will encompass the development of application of AI in the domain of PM taking into account both the bibliometric analysis and qualitative one. To summarize, the main key goal of this thesis is to: (1) search the academic publications within the topic of AI and carry out scientometric analysis (Section 2); (2) summarize the activities and characteristics of PM (Section 3);(3) highlight the current use of AI in PM in different industries (Section 4); and (4)identify the project manager of the future and how the role will differ in the coming decade and what are the skills that are needed to be acquired to cope with the new technologies breakthrough ahead for the process of digitizing PM(Section 5). In the beginning, related papers within the domain of PM are gathered to prepare our database for review. The following criteria are adopted to guide the search : (1) Web of Science (WOS), Scopus, Sciencedirect , Researchgate, Google Scholar and IEEE library are defined as the adopted academic databases for selecting targeted publications. (2) Selected keywords focus on the main concepts of this review, which can be simply divided into: "Artificial Intelligence" , "Machine Learning", "Project Management" , "Risk management" and "Construction management".

2. Artificial Intelligence

Artificial intelligence is a branch of the software engineering field in which mathematical experts are attempting to establish enhanced intelligence within computer systems. Russel and Norvig described AI using a statement of "the art of creating machines that perform functions that require intelligence when performed by people" [12]. AI urges computers to understand and learn human-like inputs for cognition, knowledge representation, logic, problem-solving, and planning, enabling them to handle complex and poorly defined issues in a deliberate, insightful, and adaptive solution. Owing to the unparalleled advantages for the human-machine interconnected future, a substantial percentage of investments into the research and development within this field has been noted dramatically over the past few years . Machine learning, in specific, accounts for a huge portion of AI funding, since it learns properly strong data from diverse sources and gets insights from the data to achieve intelligent decisions dynamically. AI has a vast variety of practical solutions, from smart personal assistants to intelligent systems that enable facial recognition, for instance. Its advocates acknowledge that intelligent machines are the best way to ensure humanity's long-term existence while skeptics are doubting the unpredicted negative effects of uncontrollable AI . According to a study from Accenture company, AI is now changing every area of life, with the potential to raise labor productivity by 40% and double annual economic growth rates in 2035 [13]. To ensure that AI meets expectations, a growing number of companies are actively engaging in different AI technologies that sharpen AI focus and expand its application context [14]. Despite the fact that the volume of engineering data is increasing at an exponential rate in the project management sector, AI implementation is still lagging behind the method in other industries, leading to a high degree of automation and intelligence in both industry and commerce.

2.1. Types of AI Systems

According to [15], in terms of learning, reasoning, and self-correcting, a variety of AI systems have been mathematically classified into three known categories as follows:

Artificial Narrow Intelligence (ANI): ANI systems, also known as Weak AI, are the type of AI that are programmed to perform a definite task and can only concentrate on one functional area. On the other hand, such systems can be designed to perform hundreds of thousands calculations per second; they are limited in their performance capabilities due to pre-established specifications by their developers.

Artificial General Intelligence (AGI): also referred as Human-Level AI, that refers to AI systems which can mimic humans in every way and can do all types of human tasks. Alan Turing, who created the Turing test to test the probability, was the pioneer to suggest that these kinds of "thinking machines" existed, where it is generated by coordinating a conversational text exchange between the following parties: Human Tester, Other humans, and AI system being tested. The AI system under examination is engineered to imitate and function like a human. The AI system has not met all the requirements whether the human tester is able to discern among test participants and recognize the AI system inside the text exchange , the AI system has therefore not succeeded to pass the test and the other way around. In addition, the Turing test also known as the Imitation Game has become a well-known guideline for possible developments of AGI systems. On the other hand, not every AI advocate believes that such a test is adequate due to the speed at which computers are being developed to shift the target of developing AI with intellectual tools as opposed to intellectual statues.

Artificial Super Intelligence (ASI): ASI systems are expected to be the sort of AGI systems that would quickly progress to the point they will be able to substitute humans in nearly every field including cognitive reasoning and social skills. They reflect as well the kind of AI which will eventually "take over" humanity, resulting in singularity theory. Indeed, it is argued that humans will not notice the advent of ASI systems until after they have become a part of the daily human lives, indicating that singularity may be closer than expected

Machine learning (ML): ML is a branch of AI that supports designing and developing algorithms that primarily can learn to complete activities without being specifically told how to do so by the developer. Cleaned and appropriate data is necessary for machine learning to operate properly as diverse ML algorithms are now being used more commonly in forecasting research, which can learn vast amounts of data from a variety of sources before focusing on predicting data inputs. ML is an important step that trains machines how to identify patterns in large data and make data-driven forecasts on future tasks. For instance, it exemplifies its significant utility in structural health control for a variety of applications, including structural risk detection and diagnosis, structure strength prediction, system reliability, and durability assessment, and infrastructure maintenance[17].

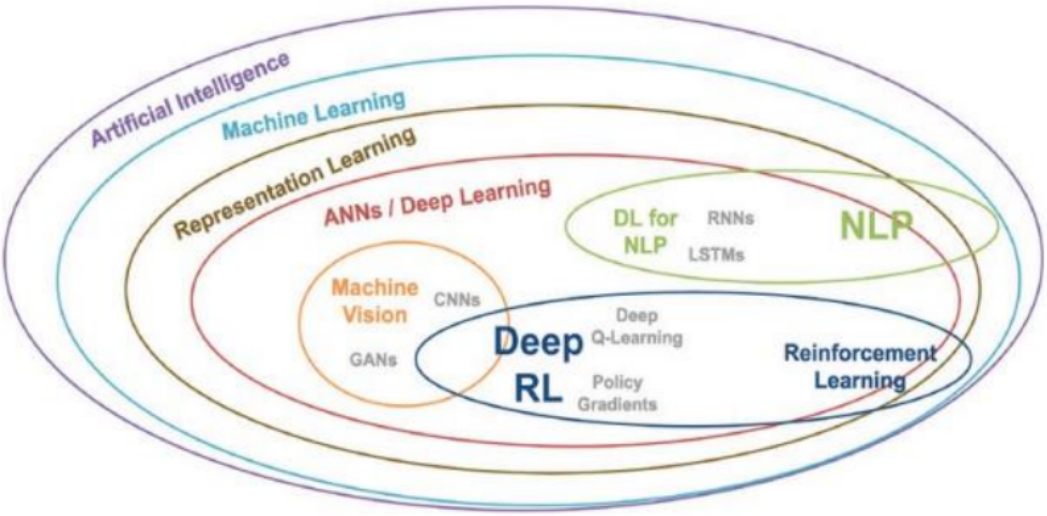

Figure 1: Venn diagram illustrating AI and its subgroups [32]

Artificial Neural Networks (ANN) :An ANN is a form of machine learning which mimics the human brain. In ANN, a neuron is a mathematical function which collects and categorizes data because of specific architecture. It is analogous to a multiple linear regression in that it contains layers of interconnected nodes, each of which is a perceptron. The signal produced by the multiple linear regression is fed into a potentially nonlinear activation mechanism by the perception; whereas, the input weightings are adjusted by hidden layers till the ANN error rate is as low as possible. As a valuable method for analyzing and solving complicated issues, the ANN potential is widely recognized in the scope of PM. ANN is inspired by biological neural networks with interconnected neurons to imitate human learning processes[16].

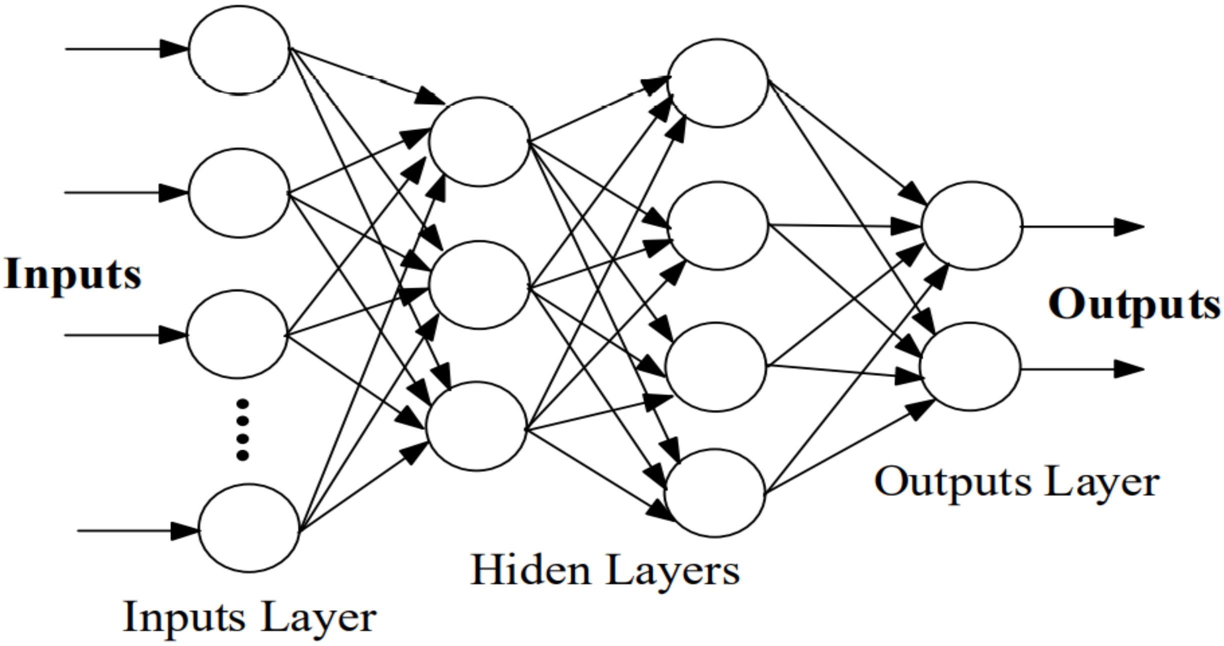

Figure 2 : Illustration of ANN Structure

Fuzzy Logic (FL): FL is essential for the growth of humanlike capabilities in software, enabling the AI system to figure out a solution in the face of an unfamiliar challenge. The capability of FL to imitate the way humans make decisions, which includes most transitional scenarios between two digital values, can be used to explain how information is stored within human brains. FL is composed of three fundamental steps; i)Fuzzification is a method of converting crisp values into membership scores for fuzzy sets in linguistic variables. Each linguistic term is given a score using the membership feature. ii) An inference engine uses rules on a linguistic level to describe a system's action. iii)Provided by fuzzy sets and correlations, defuzzification is the method of generating a measurable result in Crisp logic. It is necessary to represent the threat and uncertainties which are inherent within the projects. For instance, project managers can benefit from the fuzzy model, including faster decision-making, effective PM, and visualization of future development projects..

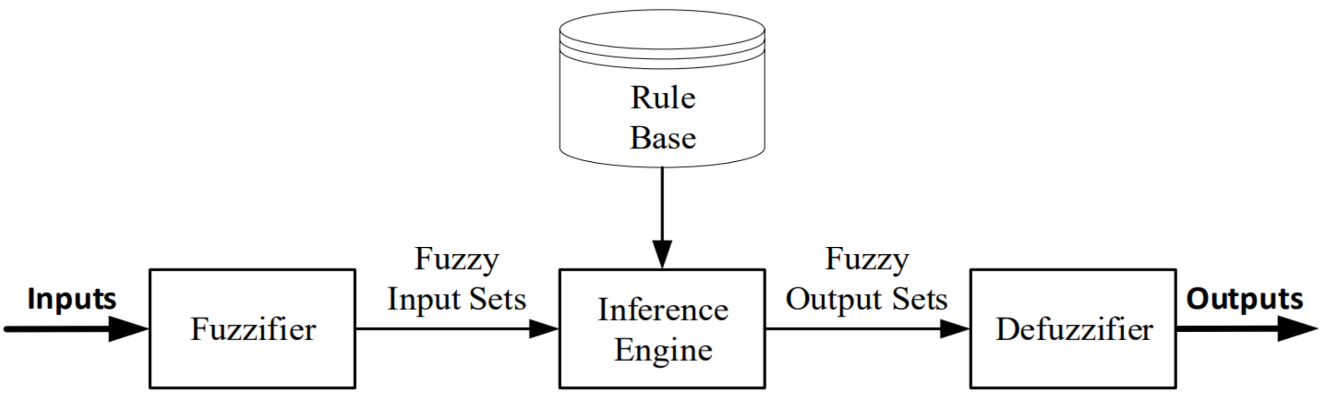

Figure 3: An illustration of fuzzy logic

FL has played critical role in modeling qualitative data evoked from professionals judgement and enabling reasoning with unclear facts, with the three stages of "fuzzifying" inputs with membership functions, combining knowledge and deducing conclusions by fuzzy set logic, and "defuzzifying" these conclusions for a final decision [18]. It has been discovered that mixing FL with the Bayesian network or analytic hierarchy process (AHP) has revealed substantial advantages in risk evaluation or multi-criteria collection particularly when the issues are marked by arbitrary uncertainty, and obscurity [19].

Another type is the fuzzy cognitive map (FCM) which is either learned from data or created via professionals' opinions. Such a fuzzy graph structure perceives complicated interactions and enables systematic casual dissemination, which can yield to immediate interpretation and recognition of root causes when a risk occurs even under difficult, unpredictable and arbitrary circumstances [20]. In addition, the hybrid FCM being integrated with other approaches, has been designed to speed up the modeling process and evaluate more precise metrics, and therefore has been widely used for risk analysis, decision making, and project complexity analysis. Surprisingly, despite their ease of implementation, the previous approaches suffer from the high computational cost in large-scale spatial and temporal datasets [21].

Fuzzy Rule-Based Systems (FRBS) and Genetic Fuzzy Systems (GFS) FRBSs show an expansion of traditional rule-based systems given that they deal with "IF-THEN" rules, the antecedents and consequents of which are made up of fuzzy logical statements, rather than classical ones. They have demonstrated their capacity for modelling, classification, and data mining problems in a large number of applications, which makes them highly useful for project management and control. A GFS is essentially a fuzzy system driven by a learning process based on evolutionary algorithms, which includes FL + GA, genetic programming, and evolution strategies, among other evolutionary algorithms .

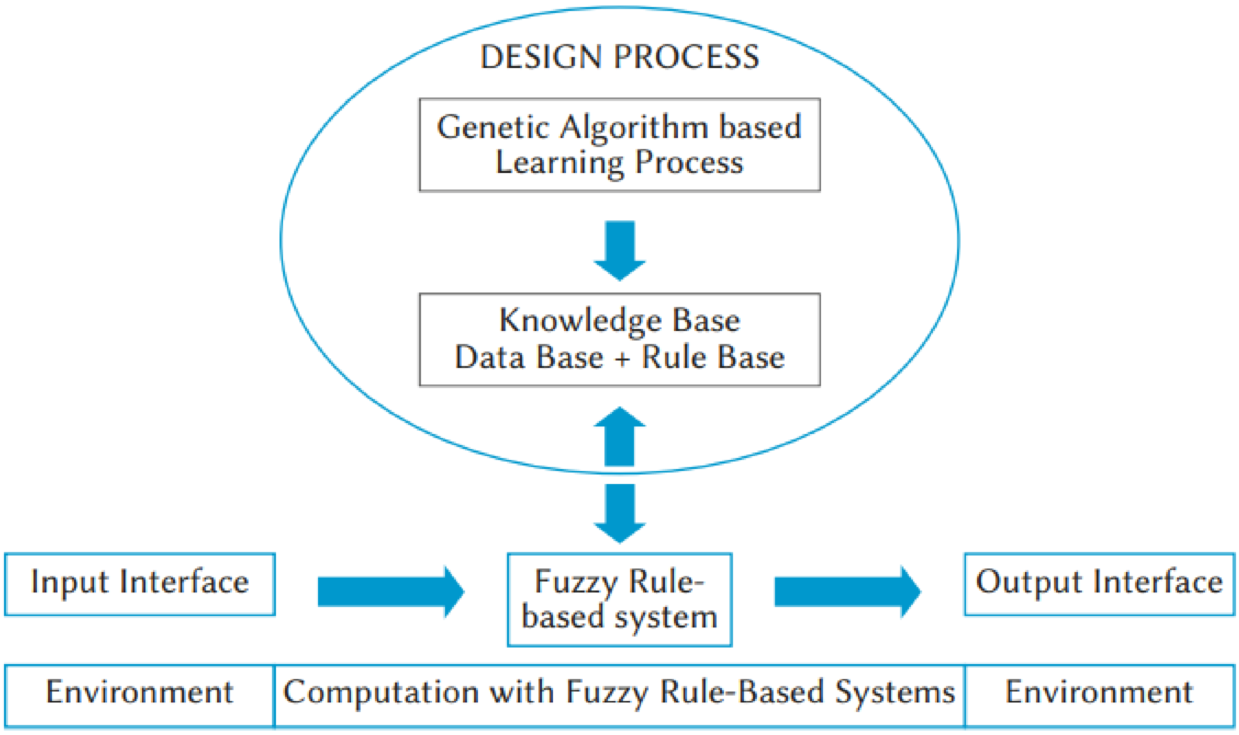

Figure 4: FRBS structure components [22]

The central aspect of using a GA for the machine learning of an FRBS is that the process can be analyzed as an optimization problem [22]

Neural-Network-Adding Bootstrap Many artificial neural network classifiers are combined in a bootstrap that adds neural networks [23]. This approach employs several ANN-based classifiers, with each classifier making a final judgment through a voting system. The cumulative weights are determined using the input and the model output is provided as a linear combination of the experts' output. Bierman suggested “packaging,” a new approach for aggregating several models utilizing boot replicas of training data. Studies reveal by using this method, the model's generalizability can be greatly enhanced. BAGNET models, or efficient neural network models, are created using the "bagging" principle. Instead of choosing a single neural network model, a BAGNET model, as seen in Fig. 10, incorporates multiple neural network models to increase accuracy and durability. A BAGNET model's total output is a weighted mixture of the outputs of single neural networks.

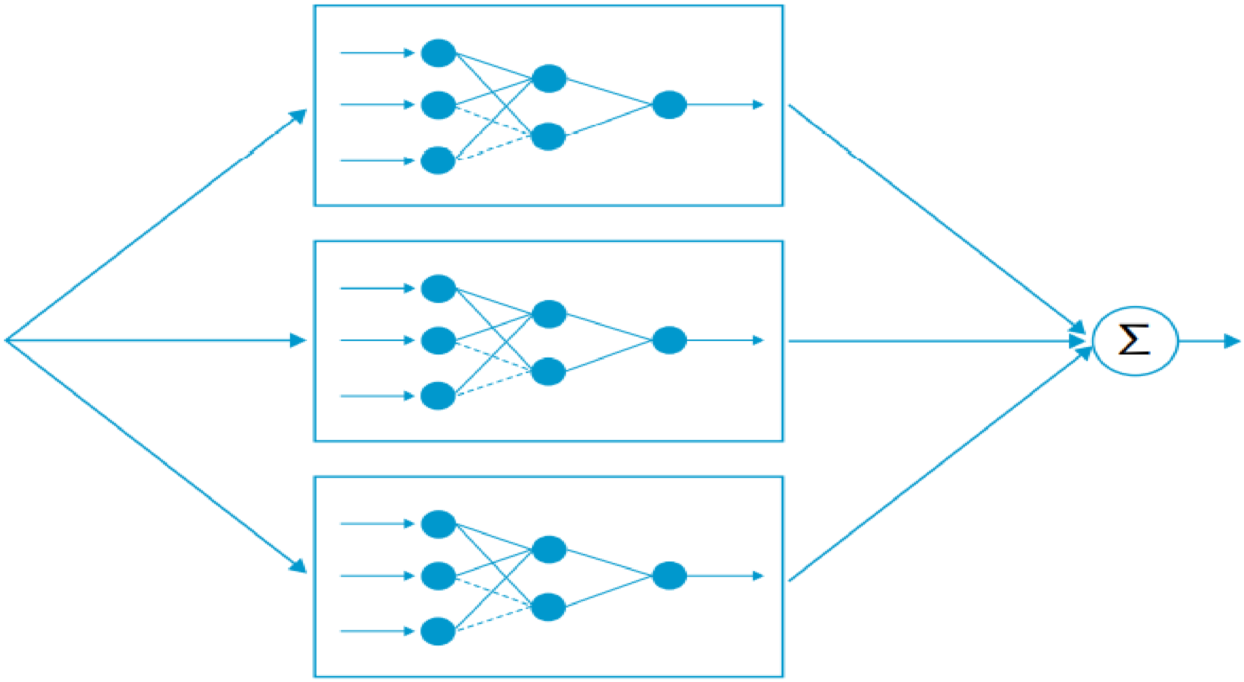

Figure 5: An illustration of Bagnet diagram [23]

Evolutionary Fuzzy Neural Inference Model (EFNIM) presents hybrid systems resolution techniques, composed of GA, FL, and NN, as shown in Fig. 6 which can be employed to handle a variety of issues. The integrated composition of its three components boosts each element's positive qualities while also attempting to substitute for their intrinsic shortcomings. The GA is used for global optimization, the FL addresses ambiguities and estimated inferences, and the NN deals with input–output visualization. The method has traditionally been used to solve issues of civil engineering [24] and proposes a hybrid system with significant capacity for assisting administrators in executing effective long-term plans and taking the appropriate measures to ensure the project's overall performance [25].

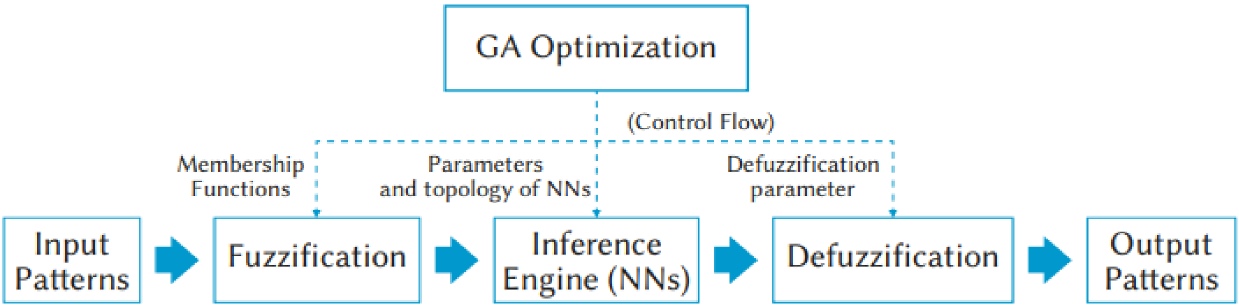

Figure 6 : EFNIM hybrid components [25]

An **Expert System (ES)** is a computer program that employs AI to mimic the actions of a person or entity that has gained knowledge and experience in a particular area. An ES's power is based on a well-organized set of facts and heuristics about the system field. An expert system is defined by the accumulation of information from which the inference engine may form opinions. The ESs will deduce a solution, expect outcomes, and propose possible solutions to a dilemma. Classification, planning, scheduling and risk estimation are all sectors where ES can be used. Furthermore, ES helps the PM to make informed decisions and decide how to address corrective steps [26]

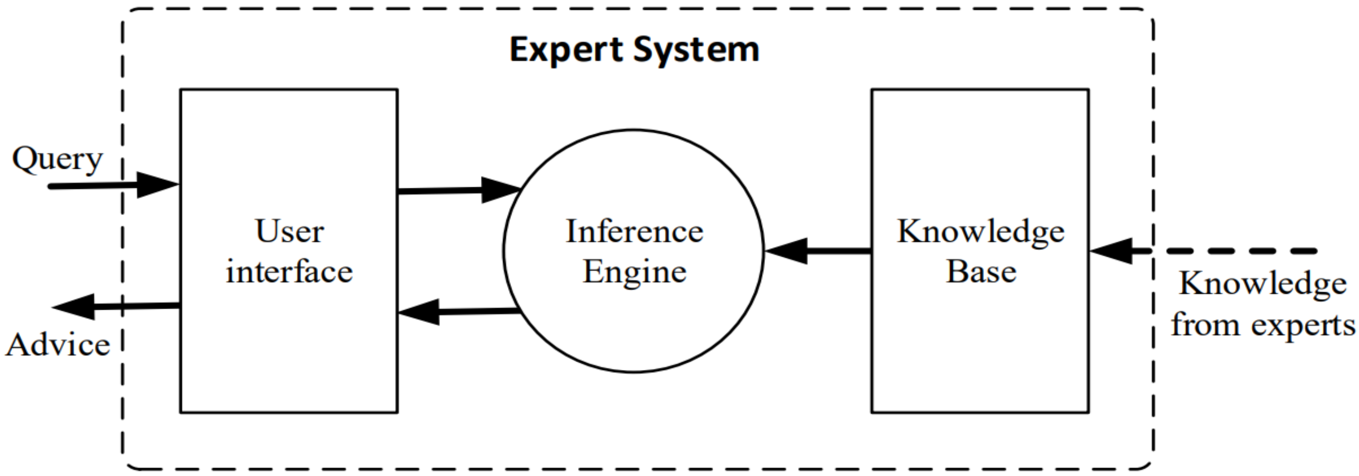

Figure 7 : An example of Expert System

Natural language processing is a method of machine learning that instructs a computer to identify characters and language. Deep learning for NLP is a more powerful way to bring AI to communicate with humans via natural language either spoken or typed. As a significant subset of AI, natural language processing (NLP) primarily stimulates computers to store, discover, and translate language-related data into text and words, leading in human-like natural word recognition. The traditional manual approach of examining free-text data has a propensity to leave a lot of useful information untapped. For this purpose, NLP is gradually being used to replace time-consuming human analysis, as it can process vast quantities of textual data at a low cost and in a short period of time. NLP has the ability to delve through a large number of text files collected in the CEM domain in order to aid in the management of construction projects and engineering data.

Beneficial and legal information can be effectively retrieved from a vast amount of unstructured textual documents using natural language processing (NLP). As a consequence, supervisors may benefit from the incident precursors in order to enhance construction safety monitoring and evaluation. For one aspect, hazardous actions and causes may be readily detected and categorized at a preliminary phase for post-event analysis, allowing for timely human action in construction sites and practices to reduce danger. It may also provide accurate assumptions about possible threats that are likely to arise in the future. It enables administrators to take preventive measures to avoid such incidents from occurring again. For example, Zhong et al [27] developed a novel platform mixing deep learning and text mining for more than just topic recognition and danger detection, which could also construct word co-occurrence networks to expose hazard trends and monitor danger dynamic evolution over time for accident avoidance

Machine vision: It's a discipline of deep learning that centers on object identification. It's used in algorithms for self-driving vehicles, image recognition, and any AI that wants to identify objects at any sort. **Representation Learning (RL):** RL is a field of ML that goes further than traditional machine learning that needs extra human interaction. RL models handle large volumes of data and learn representations, also known as features on their own.

Deep learning is another RL method. It is consisting of five or more layers of artificial neurons. A single input layer collects data, three or more hidden layers process the data and learn new functions, and a single output layer indicates the results. Computer vision has surpassed conventional computational methods as the preferred approach for extracting qualitative information from images and achieving cutting-edge success in computer vision. Deep learning-based approaches are specifically in charge of three tasks: image classification, object identification, and classification techniques. To be more precise, image classification is the method of recognizing an entire image as a whole by attaching it to a label. The classification function is often performed by the most common architecture known as convolutional neural networks (CNNs), which have three essential varieties of neural layers: convolutional layers for producing feature maps, pooling layers for minimizing the spatial dimensions of inputs, and fully connected layers for constructing 1D feature vectors.

Deep reinforcement learning: DRL is a reinforcement learning technique that involves artificial neural networks. Reinforcement learning is good at taking the appropriate decision among many options. DRL is better when it comes to processing a huge variety of data coming from an external environment.

Computer Vision: Over the last several years, there has been a wave of interest in the evolving topic of computer vision in construction-related projects. Computer vision is generally used in combination with acquisition equipment such as cameras, unmanned aerial vehicles (UAVs), LiDAR, and others to provide non-contact and remote alternatives for project tracking, and the collected image data can then be turned into actionable information in an accurate, fast, and cost-effective way [28].

Computer vision-aided technologies mostly lead to automated and robust vision-based inspection, which increasingly replaces the error-prone, time-consuming, laborious, and risky manual observation by humans. Finally, the actual state of dangerous conditions or actions in the infrastructure or construction site can be quickly detected and measured, which in turn proposes ways to minimize future dangers ahead of time. [29]. Computer vision is used in field observation to automatically monitor, identify, forecast, and evaluate construction resources such as personnel, materials, and equipment. Computer vision can offer problem-solving assistance in mitigating hazards before they emerge, significantly enhancing field-based workplace safety and health during the construction process.

Process mining is a comparatively new research branch which is a subset of AI techniques. Process mining can be thought of as a link between event logs and the operating process since it is dedicated to investigating event logs. As a consequence, it is capable of providing straightforward and fact-based information from real event logs for improved process management and tracking. Process mining analysis can be divided into three categories: process exploration, process conformance, and process improvement [30].

In other terms, event logs may be trained to automatically construct process models that are a representation of the real process and measure process metrics. The discovered process model can then be subjected to a variety of analytical approaches in order to identify potential issues such as inefficiencies, bottlenecks, and other flaws and also catch organizational characteristics in the process. As a result, process mining enables managers to easily identify main process components and make data-driven decisions for improving operations and speeding up the process.

Support Vector Machine (SVM) introduces a modern type of learning that is more effective than classical learning methods. Data regression and categorization problems can also be solved using this approach. SVM, like neural networks, relies on a training dataset for training and research. SVM features allow for better processing of uncertain data, and the method has a range of advantages over neural networks. It is commonly used in cost and project management [31]. Within the area of classification, SVM belongs to the category of linear classifiers since it induces linear or hyperplane separators (as shown in Fig. 8), either in the original space of the input examples

3. Project Management

The Project Management Institute (PMI) has defined project management as a "temporary endeavour undertaken to create a unique product, service or result." It has been argued that project management as a prominent function is mainly concerned with "creating an environment where individuals can work together to accomplish a shared objective, in order to achieve successful projects on time and on budget." In a rapidly volatile environment,the overall objective is to engage and control all stakeholders in order to create an unprecedented environment that can host teams or employees from the same or even different organizations and may not necessarily collaborate together again once the project is completed. It is uncertain who invented the term "project management" but the approach has been developed and modified over time, with early strategic implementations confined to the construction industry over seventy years ago.

Later, organizations started using and documenting specialized strategies and techniques to complex missions. Construction projects vary from each other due to differences in customer expectations, project complexity, environments and influences, and shortcomings to increase the complexity of PM. Consequently, it is quite senseless to just imitate the scheduling, design scheme, budget, and logistics of an established project to a new one. Moreover, individuals with various roles such as designers, engineers, suppliers, contractors, managers, and other service providers, require a customized project plan according to the participants' skills, knowledge, experience, and communication.

3.1. Fundamentals of Project Management

The concept and perception of the project manager role was first introduced by Gaddis [33]. The Project Management Institute's (PMI) Project Management Body of Knowledge is a standardized guide for project management that describes five main phases that form the process of project management. According to PMI-PMBOK the following process map describes how projects are currently managed starting from the Initiation, Planning, Execution, Monitoring and Controlling and ending with Closing. The PMBOK Guide illustrates 49 processes that are categorized by 10 knowledge areas. The 49 processes are divided logically into five project management process groups that aim to achieve defined objectives: (i) initiating, (ii) planning, (iii) executing, (iv) monitoring and controlling and (v) closing. The 10 knowledge areas are: (i) integration, (ii) scope, (iii) schedule, (iv) cost, (v) quality, (vi) resources, (vii) communications, (viii) risk, (ix) procurement and (x) stakeholders. Each knowledge area is defined by its knowledge requirements. As an illustration, the knowledge area "integration" is supported by; developing project charter, project management plan, project work, knowledge, monitoring, change control, and project closing, etc.

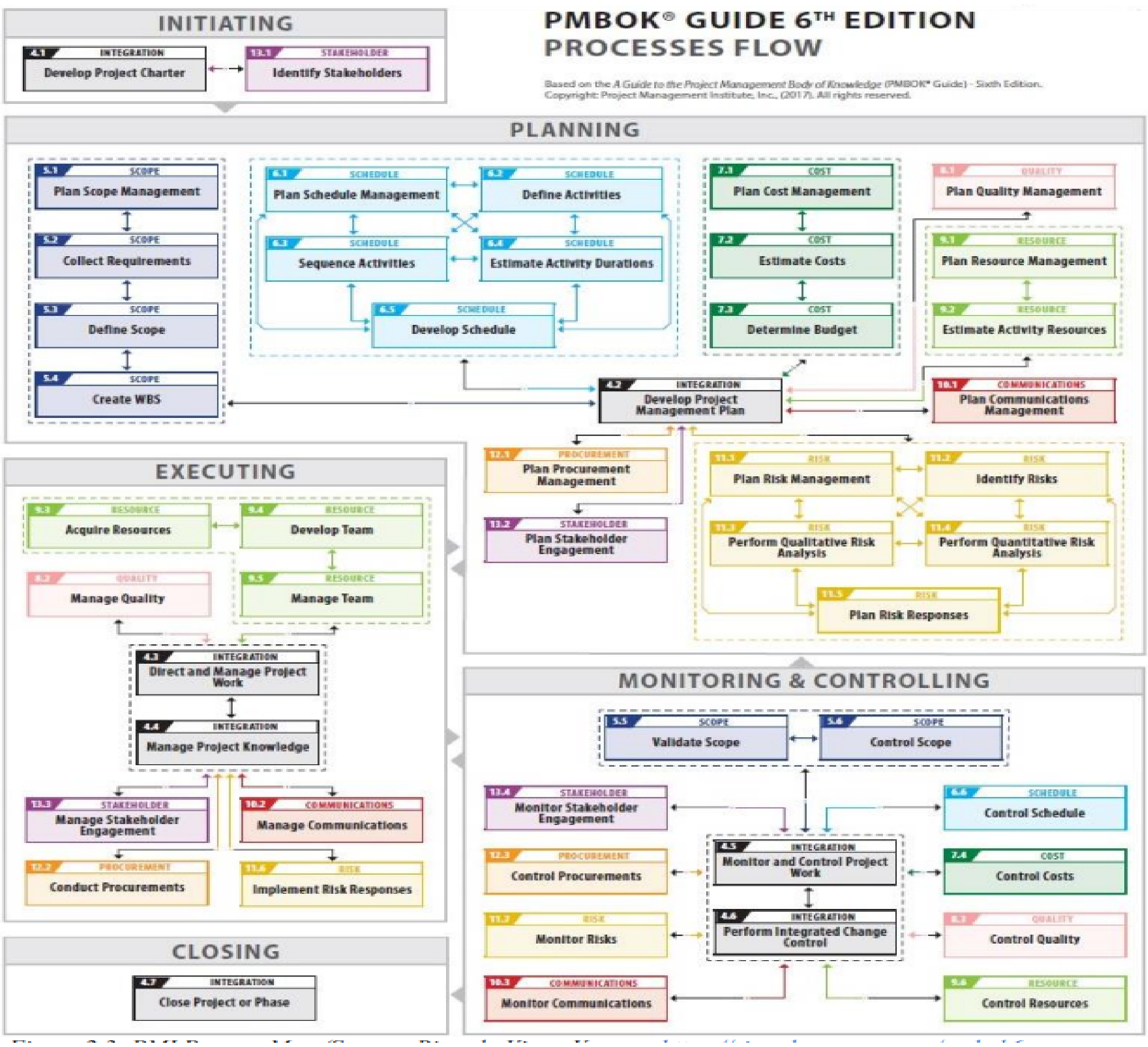

Figure 8: PMI Process Map as depicted by PMBoK v6

The phase in which the benefits of a project are admitted and the project is approved is called the Project Initiation. Followed by the Project Planning, the stage in which the basic parameters, as those illustrated by the Iron Triangle, of the project are defined, activities are planned, risks are assessed and team resource allocation is occured. It is necessary to make a detailed plan for the project development including resources, schedule, budget, and dependencies; in addition, the better prepared plans have to fit a logical time scale and workflow, which help in minimizing cost, duration, and illogical process in the real project. Particularly, the most critical issue in the planning phase is the project plan development to rationally automate the process, which can also serve to track the actual process and allow for guidance to be completed within the estimated budget.

The third stage is named Project Execution which involves that the project manager directs and manages the work while the team starts the project work.The stage of Project Monitoring and Control takes place in the fourth place where the progress of the project is monitored and assessed from the beginning of the project. Modifications are performed if the predetermined objectives can not be met as planned. The final stage is named as the Project

Closure where all the tasks of the project are concluded, the contract is resolved and the finances of the charged numbers are closed.

An important figure named as the Iron Triangle should be discussed to show the relationship among the basic parameters when a project is defined or planned. The project management constraints make a standalone set where a change to one factor influences the others and requires changes to one or more aspects within the triangle to keep the balance based on the predetermined parameters of the project. The top tip factor of the triangle is the cost, sometimes called the characterized cost, or known as the financial plan of the task. It is a vital aspect to monitor for the venture's viability and could be regarded as a success measure of completing a task inside or underneath the agreed-upon financial plan. Cost estimation is the process of expecting the needed funds and resources for performing a project within a determined scope. Prediction plays a major role in developing the financial plan to decide if a task has the permission to continue against the planning stage.

The left-side of the triangle has time on its leg. It is associated with the predefined termination period of the undertaking and categorized as an untracked component of PM. Contrarily related to cost, for instance if the predetermined period of the undertaking is reduced, the costs to complete the project will increase . For a project manager, it is vital to keep the project going on track since lost time can not be recovered. The right leg of the triangle has the scope of a project, occasionally referred to the business case or specification, which determines the shortcomings of the project to explain what is included or not in the project. It is the aspect which is prone to change and therefore needs continual adjustments of the other critical elements of the project. In the heart of the triangle resides the quality that can be classified into two kinds: i) Product Quality: deals with the quality of the deliverable of the project which necessitates constant inspection to maintain a decent output. ii) Process Quality: deals with the quality of the PM process and concentrates on how well-executed the process has been historically, and how it can be refined based on holding a level of stakeholders satisfaction who can have different opinions regarding the success of a project.

Figure 9: The Iron triangle of PM

According to Kerzner, effective PM warrants the customer's approval of the end-result as well as completion on schedule, under budget, and at the optimal level of quality through the efficient allocation of resources [34]. Despite the fact that a project has been explicitly specified from the start till the end, the real project execution would not necessarily follow the pre-defined plan. Unavoidable modifications or adjustments due to multiple reasons will take place dynamically during the project lifecycle. For instance, the project alternatives which require updated reviews due to some human aspects such as clients' dissatisfaction, designers' and engineers' errors, unexpected emergency as unwanted lag, weather effects, financial problems from contractors and extra demands of labor, equipment, and material. Furthermore, if any adjustments are applied to the project scope, the scheduling and budget should be amended accordingly to cope with the volatile circumstances. Moreover, project managers are accountable for identifying the potential risk and the accompanied effect on the performance, schedule, or budget of projects. These defined risks must be evaluated from both the non-numerical and quantitative view, and thus timely updates can be done to proactively adhere the potential issues

3.2. Effect of AI across Project Management processes

Project managers of many companies have agreed that , in terms of new technologies as AI, the executive management must investigate how multiple tasks and functions are handled within the enterprise to find solutions for most of the corporate problems, which necessitates a systematic approach that looks inward rather than outward. As a result, PM is one of the fields which will undergo a process of re-evaluation, and activities recognition on a large scale. For instance, "Future of Project Management " shows a parterned effort by an organization called Arup, The Bartlett School of Construction and Project Management at University College London, and the Association for Project Management (APM)'s. The research looked into various aspects, one of which assessed the future via the lens of novel trends that will certainly affect the PM community as shown in the following figure .

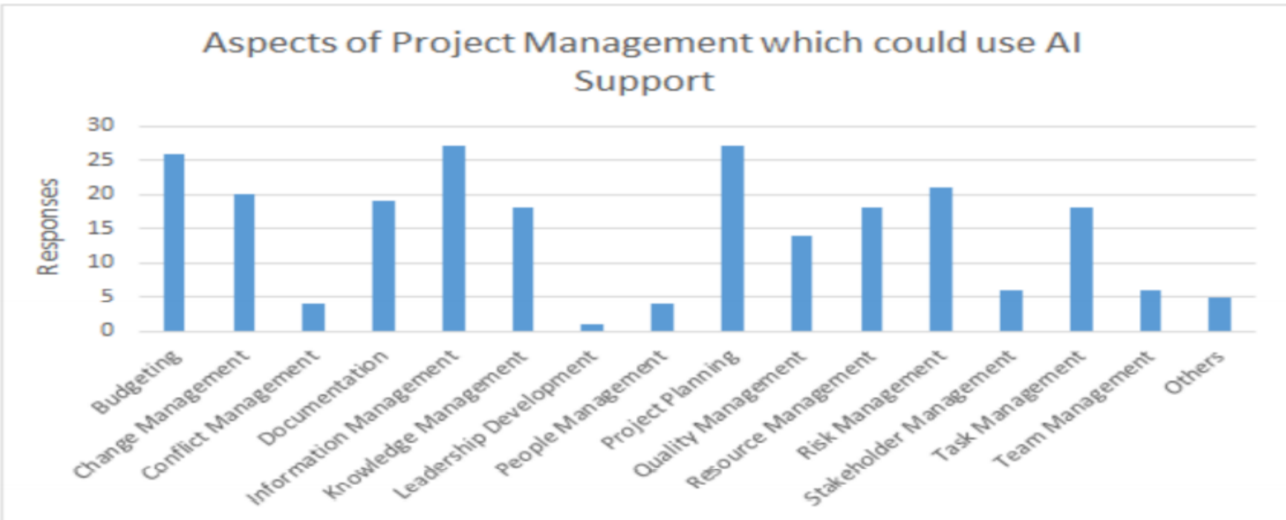

Figure 10: Aspects of Project Management which could use AI support [35]

The results have shown AI would have a huge effect in developing the planning phase, performing a project charter, and an integrated change control. Indeed, AI was believed to have the least effect on managing stakeholders, closing a project or phase, and directing and managing project work. Moreover, AI is likely to have the greatest impact on creating a work breakdown structure (WBS), 50% answered high or very high effect. 40% of participants said that AI would have a very low or low effect on defining scope, 31% on controlling scope, and 27% on validating scope. project cost management, project schedule management, and project risk management are likely to benefit most from AI. Foster discussed that AI could be used for scheduling and estimating time, cost, and risks [36].

Another study by PricewaterhouseCoopers (PwC) has ensured that AI will inevitably change PM even to a broader scale than the classical level of data integration and task automation which is generally combined with these systems. AI will bring PM into a novel period which will be associated with the use of chat-bot project assistants, machine learning based project management as well as autonomous project management. The authors declared that while AI technologies will transform how projects are managed and delivered, they will still lack the human interaction uniqueness. Such assumptions will yield to the long-term need for human project managers even in the AI-dominant future. Even if core project management methods or techniques could be replaced by AI systems, the activities which will need sloley cognitive skills such as leadership, empathy, emotional intelligence and negotiation will remain in essengence for human interference.

Multiple AI technologies have shown success in estimating project duration, with huge effect on the estimating activity duration and performing a schedule, which are the processes that mark the beginning and end dates for each activity. Other activities on which AI will have a huge impact are creating WBS, planning procurement management, and monitoring and controlling project work. Typically, AI will have the lowest effect on managing stakeholder engagement, which is the process of dealing with stakeholders to meet their requirements, expectations, and needs. The study outcomes promote the notion that there will inevitably be a necessity for project managers, and human skills will possibly be more valuable in the project manager's role in the near future.

Regarding automation and human-machine cooperation, smart user interfaces will require changes to workplace structures in order to keep up with collaboration and communication, and ensure a good environment for fostering productivity and creativity in the workforce . It is also assumed that cognitive human skills such as strategic decision-making, empathy, and communication could become even more valuable, while organizations will have to "rethink the role of people and provide training to prepare their employees for this new work environment." The report further concludes that "businesses might soon start dividing skills and reframing jobs according to, on one hand, essential human skills, and, on the other, nonessential tasks that could be carried out by machines." These results present a fascinating image for the future of project management reflecting the fact that project managers will require intensive preparation to work efficiently in the human-machine collaborative environment, and will be discussed in detail in chapter 5.

4. AI Current Use in Project Management

The introduction of AI across various industry sectors will result in unprecedented improvements in the nature of dynamicity, work-force, and uncertainty inherited in the field. AI can act as a significant role in the prediction, growth and decision making to uplift the conventional activities to keep up with the digitization and automation era. Beginning with the notion of automation, ML algorithms are used to learn the amalgamation of data that would be incorporated into PM software to assist in decision making and insights analysis instead of relying on human intuition. With a data- driven approach, these perspectives will immediately concentrate on the project problems, empowering project managers to further capture the hidden knowledge from the project experiences to be automated [41]. In addition, when on-site tracking is needed, drones and sensors can eliminate the time-consuming, error-prone manual surveillance through capturing images or videos for better data visualization.

Furthermore, computer vision can be used as a potential substitute for the dubious visual inspection in the civil infrastructure evaluation; it is primarily useful in data processing, and analytics using deep learning techniques via end-to-end understanding. According to [47], inspection and monitoring are the vital areas of consideration to efficiently boost the comprehension of complicated construction milestones. While the tracking applications can be found in the measurement of the infrastructure status, the inspection utilization can be in the shape of condition determination, automated damage detection, structural component recognition, unsafe behavior. In brief, the vision-based methods in construction management are comparatively cost-effective, simple, efficient, and accurate, which can strongly transform image data into actionable information for structural health assessment and construction safety.

4.1 Current AI tools that affect the project manager's role

According to [37], AI use cases fall into one of the following seven patterns no matter of the application of AI and the range of its implementation; therefore, these seven patterns contain Hyper Personnnalisation, Autonomous Systems, Predictive analytics and decision support, Conversational/human interactions, Patterns and anomalies, Recognition systems and Goal-driven systems. The initiating phase of PMBOK could be related to the autonomous systems and patterns and anomalies while the planning phase could interact with all of the seven patterns except Recognition systems and patterns and anomalies. The execution phase would not only be related to predictive analytics and decision support and human interaction. The monitoring and controlling phase would make use of the whole AI commonalities apart from Hyper personalissation; lastly, the closing phase would involve autonomous systems and conversational/ human interaction.

Considering AI tools such as Chatbot, Deep Learning, and NLP, their functions can be examined to different management processes. The Chatbot can schedule a meeting, organize gatherings, listen to meetings to assign tasks to people with specific dates, send out actions and follow-up, and keep track of stakeholders through collecting details from meetings. Deep Learning can be helpful in quality management by analyzing component data to predict which parts are likely to fail quality control. In addition, the NLP can eliminate the communication gap between human and computer, identify appropriate contents leading to quality output, reduce costs associated with repetitive tasks and understand customer language to provide credible output [38].

AI provides project managers with more insights into possible outputs, which will optimize the accuracy of decision-making. The system will eliminate redundant data by identifying relationships and trends in data, allowing managers to concentrate on the most important information. For instance, in the finance sector, organizations are at various levels of integrating it into their long-term corporate strategies; organizations have to reconsider their primary goals, capabilities and shortcomings. As a result, businesses are encouraged to employ the support of corporate management experts. McKinsey's QuantumBlack is an indication of such a firm wherein project planning could be made more reliable by allowing auto-scheduling through means of programmed logic and principles. In fact, progress and activity status can be monitored automatically and notifying the project manager in irregular scenarios.

The application of AI to project management, especially machine learning, will result in novel solutions by famous project management software companies. Atlassian, a well-known project management provider also offers a plug-in to Jira which promises to detect and fix minor nuisance bugs, eliminating the work of planning and prioritizing off the project manager's shoulders as well as freeing up skilled team players for more valuable tasks [39]. Atlassian as well forecasts that "early project management AI will be a project assistant focused on a narrow area of managing a project or team such as assisting with estimates, budget and sprint management or management of team knowledge" [40].

When faced with ambiguity and complexity, the mixture of AI and raw human intelligence will provide the most benefit. For instance, Accenture performed a study of over thousand companies to explore the interaction between machines and humans. They learned that organizations which used AI methods in combination with human learning had a much greater improvement in the value added from AI programs. Consequently, they implemented a model which the consulting firms called MELDS. It consists of five key principles of integration between AI and humans, that counts for the right Mindset, have championed Experimentation, Leadership role in setting goals and directing AI, and have incorporated DATA as an crucial part of their AI strategy [43]. Wauters et al. concentrated their work on project duration forecasting and AI techniques to improve earned value management (EVM) with an AI technique called k-Nearest Neighbors. By using the Nearest Neighbor, the researchers seek to improve the accuracy and stability of the EVM method in addition to test the benefit of adopting a hybrid AI method.

Another significant use of AI technologies lies in the optimization issues, which seek to make projects run smoothly and effectively. It is anticipated that needless initiatives to avoid unnecessary steps, reworks and disputes, inevitable delays, and insufficient coordination. As a result, strategic decisions can be taken for testing and fixing at an early stage, motivating the refinement of operational efficiency. For example , process mining is a novel AI-enabled method to generate meaningful insights into the complicated nature of the procedure, such as to monitor key workflows, anticipate anomalies, detect hidden blockages, and extract collaboration patterns [45]. Other kinds of optimization algorithms are also a robust tool for yielding reasonable plans under the maximal tradeoff among time, cost, and quality, as well as effective in preventing costly correction at the remaining stage [46].

According to [44], some tools are introduced to provide support to project managers in the context of AI-powered agile PM. The importance of such tools is to allow for forming the team and assign the projects to specified resources and to manage the deadlines in an efficient way. For instance, “Stratejos”, an integration of Slack in the Agile software teams , while the “ZiveBox” can specify when the task will be delivered and can analyze the productivity of each resource, ordering through the communication databases at enterprise level. Another tool named “Polydone” helps in the automation of budget and time in a precise way.

Moreover, “Rescoper” , which handles the repetitive work that the team focuses more on the solutions, can give notifications if the project will run out of schedule or budget; “Clickup” helps in anticipating the best team member for some specified task. It helps in tagging users in comments related to the most common context and expect deadlines that can be met , whereas “Clarizen” ,based as a cloud-based platform, has the ability to access the information for making different decisions in customized workflows . In general, AI can provide a solution to repetitive tasks that burden project managers such as data entry and management, project plan preparation, and so on. These tasks can be performed automatically.

4.2 AI impact on Project Risk Management and Resource Allocation

One of the areas that is expected to be highly enhanced with the introduction of AI based on the studies mentioned above is risk management where AI is capable of detecting correlations in data that are not so obvious even to the finest human eye. For instance, AI can assist project managers in finding value and resolutions as risk estimation and management. Whereas risk management encompasses risk recognition, analysis, planning, monitoring, controlling, and communication. The process of AI extracting parametric data is feasible, for example, historically scheduled start and end dates can be used to anticipate precise schedules for future projects.

Multiple AI technologies such as neural networks, fuzzy logic, and machine learning have been introduced to learn data obtained to catch interdependencies of causes and effects, calculate the likelihood of failure occurrence, and assess the magnitude of the risk from both the non-numerical and quantitative view. Facing uncertainty, AI can track, identify, analyze, and forecast potential risk in terms of protection, quality, efficiency, and cost through various teams and work environments, which has been majorly used for risk identification, evaluation, and prioritization. Moreover, the AI-based risk analysis can offer analytical and adaptive insights on risky issues, allowing project managers to easily manage imminent risks and determine constructive actions rather than those including risk mitigation, for instance, to automate operations on the job processes, adjust staff organization, and track projects on time and budget [42]. In brief, AI provides high chances to realize early troubleshooting of dynamic workflows to eliminate unwanted failure.

When the project risk management knowledge area was assessed, it stated that AI would probably have a great impact on the processes of project risk management. Out of the respondents, 63% thought that AI would have a fairly high impact on risk monitoring and 54% on performing quantitative risk analysis. The findings indicate that AI was thought to have the least impact on planning and implementing a risk response as shown in Figure 8

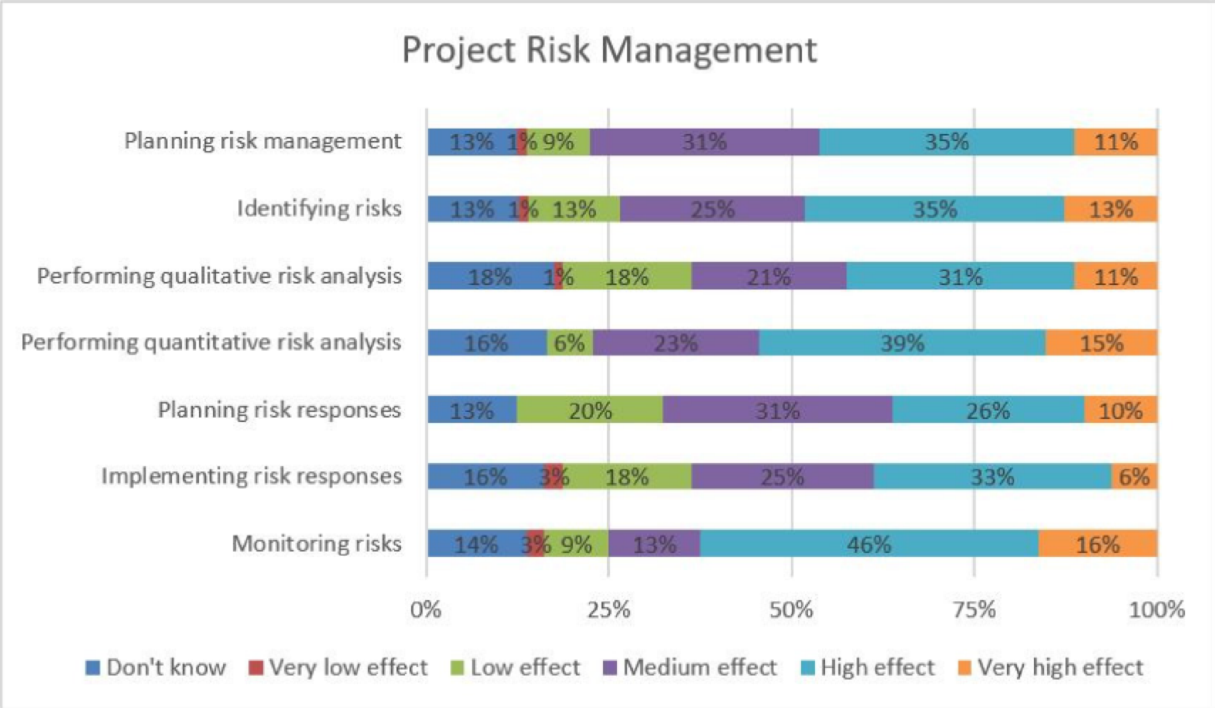

Figure 11 : AI effect on risk project management [42]

Resource allocation: or resource management ensures that the project is carried out in compliance with the scope in the planning phase. It includes the calculation of resource consumption and the distribution of the resources to achieve the project goals. The health of a project depends on assigning the best resources to the right department with the apt qualifications and ensuring that they have all the necessary tools to deliver before or by the deadline. In addition, AI has a huge potential for improving HR features such as self-service transactions, recruiting and talent acquisition, payroll, reporting, access policies and procedures. Applying AI to human resources will fasten processes and leave more time for the truly human side of the job.

In the healthcare industry, leaders can steer the next wave of progress in healthcare, by making use of advancement in data science to generate valuable insights from the large, complex data sets accruing in health systems. Machine learning algorithms can be used to provide estimates of the duration and resource requirements for project activities based on expert knowledge and lessons learned from previous projects. We also have the analysis of patient data, and patient monitoring being enabled from a Machine Learning standpoint where we have companies, such as LifeMeshAI, which are experimenting with population-level data analysis to guide Public Health professionals using probabilistic modelling. Moreover, the decision management systems innovate an unprecedented flow of steps or procedures to automate decision making while the knowledge-based systems bolster human learning and decision making through recognizing the sequence of the data being processed.

4.3 Beyond the Classical AI applications

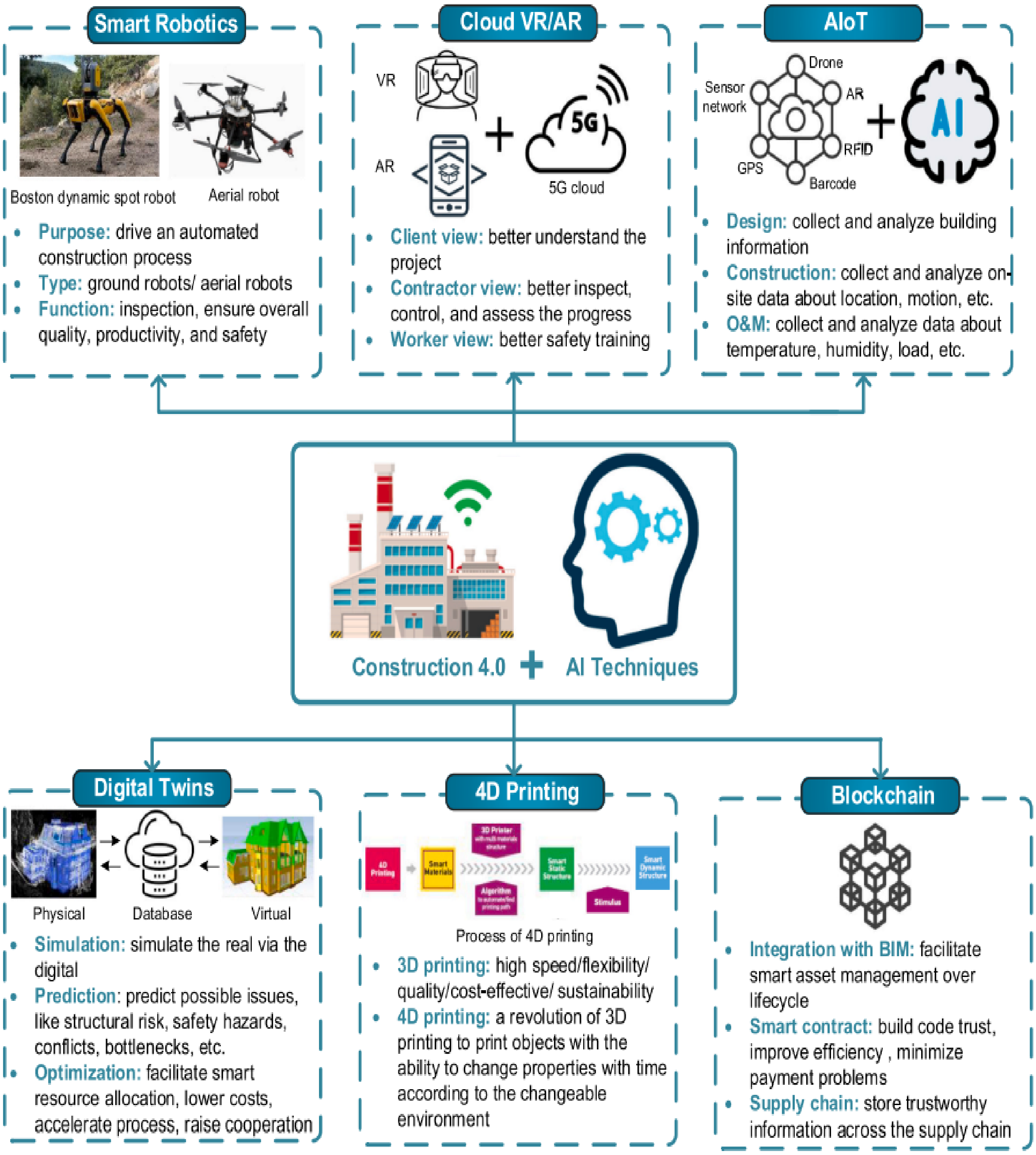

Figure 12: Future direction of AI in construction management

The previous figure tackles mainly six important directions to further grasp a variety of exhausting, complex, or even tedious tasks within the notion of construction project management domain. Our focus will be only upon only four technologies that tend to focus more on the PM process rather than construction itself so smart robotics and 4D printing will be neglected. Smart robots can be beneficial only for certain high-risk tasks to protect workers from work-related accidents. Thus, project managers can benefit from them to face the labor shortage, to reduce operation costs, to ensure overall quality, productivity, and safety. The top half of the figure has two main interesting topics, namely Cloud Virtual Reality/ Augmented Reality (VR/AR), and Artificial Internet of things (AIoT), which can be effective and extensively linked to the built environment for safety improvements and evaluation, and operational performance enhancement [47]. Furthermore, the latest development is to link them with Building Information Modeling (BIM) to build more sophisticated systems with improved automation, interoperability, and intelligence.

In addition, the evolutionary path of VR/AR, towards the cloud, is dependent on the fifth-generation (5G) networks and edge cloud technologies.Cloud VR/ AR solutions have been addressed to speed up VR/AR applications and improve users' experience. Since VR/AR functions as the information visualization technology that allows for more interactions between the physical and cyber worlds, VR copies the whole situation and AR incorporates data about the real entities with computer-generated images. Such advantage can help project managers to quickly understand possible risks and issues and then devise strategic plans to anticipate contingencies. The significant advances of cloud VR/AR root in cloud computing and interactive quality networking, which can effectively strengthen the data processing capability from the local computer to the cloud and then make real-time perception along with responsive interactive feedback. [48]

AIoT is the new-generation of IoT, which incorporates AI techniques into IoT infrastructure for more efficient IoT operation and data analysis. Instantly, IoT can be defined as a network of interconnected physical devices, such as sensors, drones, 3D laser scanner, wearable and mobile devices, radio frequency identification devices (RFID), which is attached to the resources to collect real-time data about the operational status of the project. Many studies have focused on developing some smart IoT-based sensing systems to feasibly track the progress, monitor the worksite, which are expected to support continuous project improvement and accident prevention [49].

In the meantime, the huge amount of recorded data can be shared over a network, and then be analyzed deeply by various AI methods to offer actionable insights for better supervision and decision making. Apparently, AIoT provides solutions for different industries, relying on real-time data transformation and instantaneous data analysis. Since AIoT is guided by AI, its advantage over the classical IoT lies in providing analysis and control functions for intelligent decision making. It can automate the real-time decision making at an operational level to remotely control the construction worksite, optimize the project performance, and predict future conditions for the maintenance planning, through synthesizing and analyzing data collected via IoT infrastructure in unprecedented volumes and rates[50].

Regarding the bottom research areas, we will focus only on the digital twins, and blockchain as are emerging topics from innovations of the manufacturing and financial industry. The digital twin is a realization of the cyber-physical system for visualization, modeling, simulation, analyzing, predicting, and optimizing. It incorporates three key components, namely the physical entity, virtual entity, and connection of data, to form a practical loop. Typically, there are two ways of dynamic mapping in the digital twin. On the one hand, inspection data is collected in the physical world, which is then transferred to the virtual world for further analysis [51].

On the other hand, simulation, prediction, and optimization are performed in the virtual model by learning data from multiple sources, which can provide immediate solutions to guide the realistic process and make it adapt to the changeable environment. To maximize the strength of data, various data mining and AI techniques are leveraged to make digital twins generic across the board domains to help project managers for automated monitoring of site progress, early detection of potential problems, easiness of smart resource allocation, optimization of logistics and scheduling, minimization of operational cost and value chain management of the company.

The final block of consideration is the Blockchain, which represents a powerful shared global infrastructure, which is originally utilized for simplifying and securing transactions among parties [52]. Basically, the concept of blockchain can be explained as a verified chain with blocks of information, and each block embodies data associated with processes in a trusted environment. That is to say, history data along with modifications can be saved across a network and protected by cryptographic technology. For our scope, blockchain in construction can aggregate the adaptable and scalable knowledge into a shared dashboard, and thus the project management systems can be converted into a more transparent and secure practice.

It can also be combined with BIM to collect large data from various stages of the project and share data securely among stakeholders, aiming to support life-cycle project management [53]. The BIM model can be updated timely when it receives the next block of information. Therefore, project delivery can become automated and streamlined, achieving improved productivity, trustworthiness, and cost. In addition, the creation of a smart contract written into code is another critical application of blockchain to enforce the expected behavior by itself and reduce payment fraud. The process will only be executed when the corresponding criteria are satisfied, resulting in high accuracy, compliance, transparency, cost effectiveness, and collaboration in activities, like payment, contract administration, etc. [54].

5. The Project Manager of the Future

According to research, project managers devote more than fifty percent of their time on routine activities including update control and check-in managing. With the support of AI-enabled project management systems which automate tedious tasks and procedures, project managers would be able to focus their attention on more value-added operations. AI bots are capable of embarking up and focusing on less complex tasks which will save project managers a huge amount of time by allowing them to concentrate on the conceptualization process behind their strategic management and giving their team more time for things as support and advice. According to the PwC report [55], project leaders and virtual partners will continue to collaborate together to deal with the upcoming digital transition, which will bring value to the profession and lead to more exclusive recognition and respect for project managers as shown in figure 13. PMI acknowledges that project managers will need digital skills to keep up with the emerging technology [56]. However, human interaction is unavoidable, particularly when dealing with stakeholder management

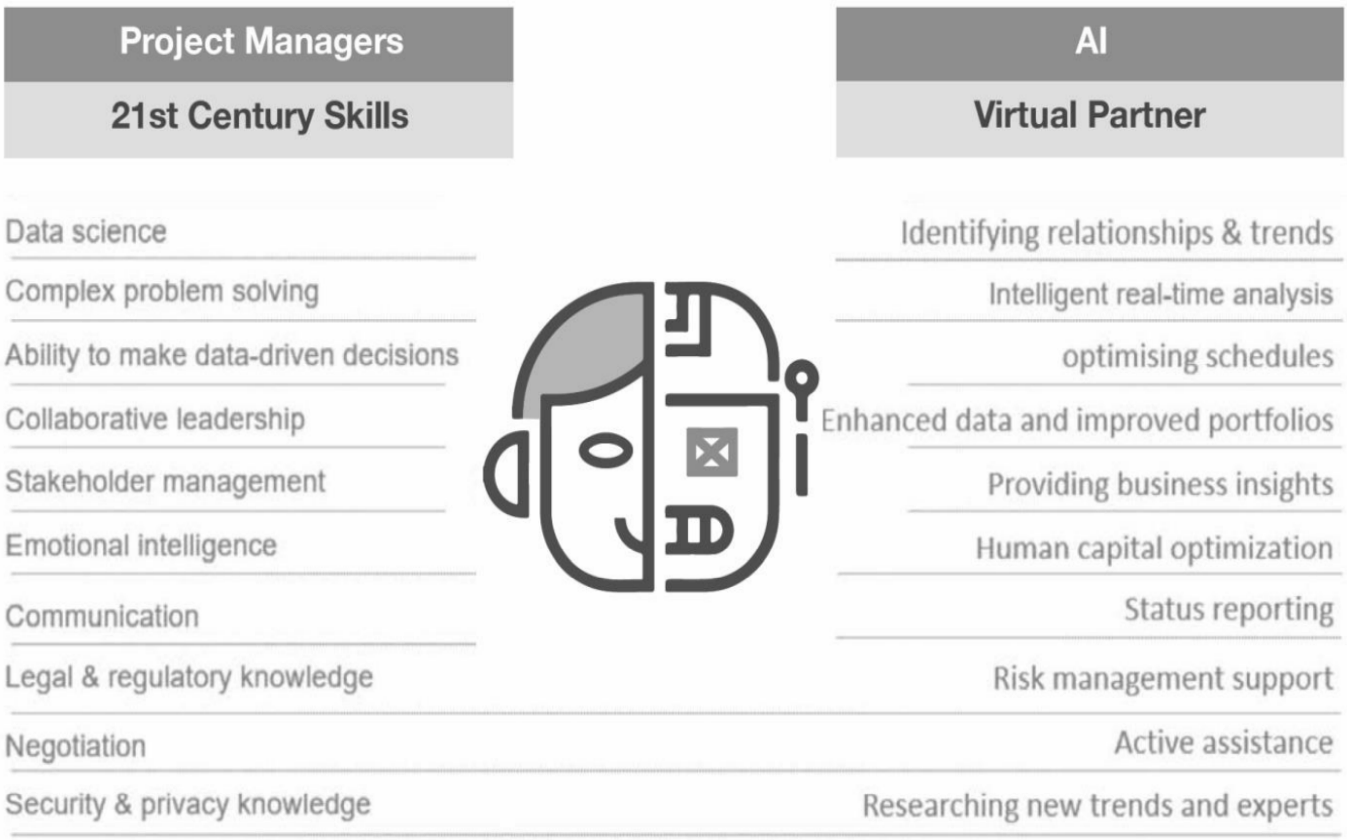

Figure 13: The relationship of project managers and virtual AI-partners

Moreover, Al supports project managers with perspectives and techniques that warn them to take extra precautions when working with difficult tasks. It also boosts project managers' effectiveness by enhancing their creativity and emotional intelligence. Valuable perspectives for the recommendation process are retrieved to make project-related decisions and to show the team's insights. The potential to align the best kind of resource to the required task using AI capability is a huge benefit. HR leaders are devoting more resources to improving the recruiting process; in turn, an increase in revenues has been estimated by 4 percent increase and the rate of turnover has decreased by about 35 percent which yields to a decrease of the ideal time for individuals [57].

The intonation of team member's productivity should be learned so project managers would have an easier time assigning daily work based on individuals skills. When working on the project, AI will sense the unseen warning red flags that impact the risk of emergencies, resulting in a stable atmosphere of the ecosystem, for instance, when it comes to smooth construction project management, equipment efficacy, unsafe workplace, air quality and paying attention to the facial expressions of workers to highlight the performance and minimize risks.

AI will assist project managers in strategic and business management by fitting metrics and performing predictions. Also, project managers can gain more assistance, productivity and control by incorporating AI into their programs. If organisations and project managers are diligent about the availability and appropriability of use of AI systems, it could make a significant difference in value delivery. AI programs can help in cost forecast, manage plans, track progress, send flags, updates and follow-ups and manage resources, in turn project managers can focus on team members and more complicated tasks [58]

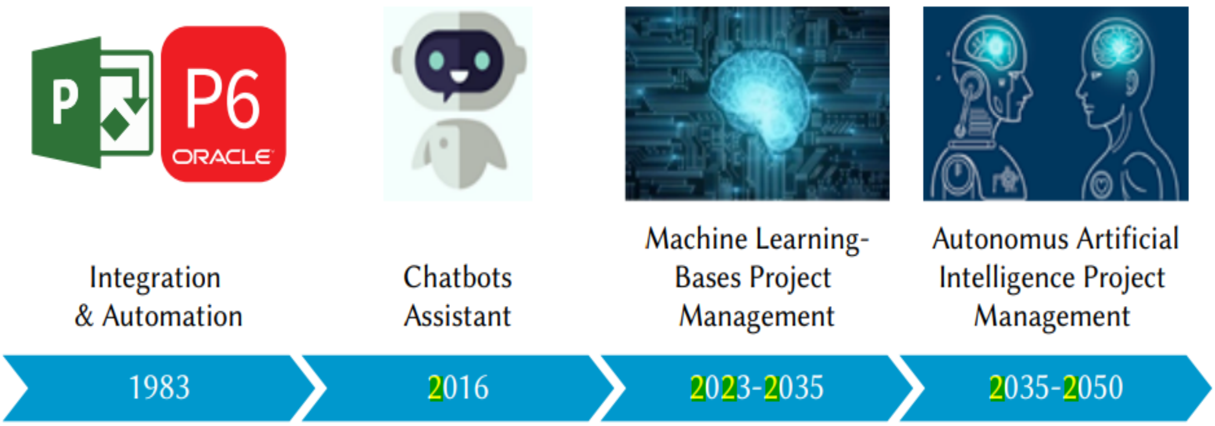

Figure 14 : Timeline of evolution of AI in PM [52]

When investigating the PMI talent triangle, the technical PM skill group is regarded as the one with the most potential to be reinforced by AI functions. Certainly, AI chatbots, introduced by 2016, assistants, and algorithms can provide project managers with support in their daily activities by examining the project status and yielding insights and forecasts of the data. The third stage, as shown in figure 14, which is our focus in the time-line, has started with the most simple definition of AI; machine learning has been applied in the field of PM to enable analytical and predictive analysis intended to supply project managers with data for decision-making process in terms of how to schedule and handle project resources under such requirements and constraints or how to cope with challenges and risks in the field [59]. In less than a decade, AI could use the insights learned from previous and historical data sets of projects to propose new schedules which can respond in rela time to the output of the resources and the project's success. Via the use of real-time project data gathering, an AI system might also alert the project manager for any future threats or potential opportunities or trends. When it comes to managing projects by reducing the uncertainties associated with decision-making, a new vision of project management will emerge. Surprisingly, an AI system may finally be able to make decisions for itself, ushering in a new period of AI and the fourth step evolution of PM will start.

In spite of AI high-paced adoption, there are still some fundamental obstacles to overcome at least in terms of comprehension as shown in figure 15. A study has been held by [60] to show that the largest portion of survey respondents (around 70 percent), when asked about the existing obstacles to using AI technologies in PM, revealed that a lack of knowledge of AI technology is the most significant challenge, followed by 62 percent who have issues in selecting the best AI applications due to limited experience. The third hindrance is the data privacy, data ethics and security risks, holding 60 percent, and the limited IT capabilities such as IT technical skills, standard IT processes or procedures holds the fourth position among the limitations with 58 percent as were mentioned in the responses. The fifth barrier is the fact of immaturity of a vast number of AI solutions, typically not enough for full deployment.

Figure 15: The major obstacles in adopting AI in PM [54]

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Generally, leadership may not be taken into consideration in AI systems but maybe in the future. for instance, it could generate a ranked list of nominees for a team based on criteria [61]. Even though AI will apparently have a high impact on project management, AI is not human and there will still be a need for flesh and blood project managers. Human skills such as empathy, emotional intelligence, negotiation, decision-making, and human resource management will be valuable in the near future—perhaps more than ever [62].

Conclusion

To conclude, AI is anticipated to categorize, quantify, and forecast potential risks associated with project performance and their relevant effects, in order to perform reliable investigation and analysis ahead of time concerning broad aspects of the project management. The predicted outcome can serve as the baseline knowledge to guide proactive management, and to ensure the effectiveness and reliability of the project towards its goals. In addition, the promising AI is robust in dealing with complex and dynamic problems under vast uncertainty, which is more likely to return accurate and convincing results for tactical decision-making. For instance, since undesired delays will inevitably lead to low efficiency, cost overruns, and other negative effects, the prediction of possible delays can help in uncovering key factors related to bottlenecks and pursuing high-accuracy estimation in project duration.

AI tools are highly beneficial for the project manager in terms of controlling and monitoring the project; however, many of the reviewed models involve weaknesses and limitations, which indicates that project managers should continue to use their experience when making evaluations according to the results especially when it comes to stakeholder management or leadership for instance. The trend of merging different AI tools continues to spread, wherein the strengths of one tool can compensate for the weaknesses of another as indicated in chapter 2 hybrid techniques. In this work, we studied the AI techniques and the possible applications in the field of project management. In the near future, a hybrid computational model that could fully ascertain the potential of AI in the field of project management may be the next step under the expectation of requiring only a partial supervision of a human project manager.

The contributions of this review are: (1) To provide a basic understanding of artificial intelligence and reveal the potential value of AI in supporting and improving project management. (2) To capture and discuss the state-of-the-art researches related to AI applications in PM, which provide strong proof to highlight the benefits of AI techniques in providing intelligent solutions by learning from previous data even with incompleteness and uncertainty in an automatic, efficient, and reliable manner. (3) To depict the evolution of research trends in the future such as AIOT & Cloud VR/AR which help researchers to appreciate these prominent future works in AI-enabled PM (4) to provide an image of the future project manager role in the future, the skills that should be acquired and insist on the fact of there will always be a need for project managers, and human skills will possibly be more valuable in the project manager's work in the future.

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