ABSTRACT

This research aims to shed light on the use of machine learning in improving, developing and automating the critical path method, solving its problems, studying this effect and its dimensions, and discussing that from many aspects.

The research is divided into two theoretical and practical parts. The theoretical part is concerned with studying the critical path method and its advantages, problems and challenges, as well as studying machine learning and artificial intelligence and its dimensions, reviewing materials and sources related to this, and then presenting suggestions and future solutions based on this study. As for the practical section, it is a questionnaire that targeted a segment of engineers, in particular, and others who have sufficient experience in both the critical path method and machine learning, and seeking their opinions on both topics.

The result of the theoretical research was 14 theories or proposals that were presented based on the foregoing study. As for the practical questionnaire, a sample of 127 was taken. Through statistical analysis, the results were analyzed and discussed separately, and then a conclusion was drawn regarding them.

Keywords— Critical Path Method, Machine Learning, Artificial Intelligence

I. INTRODUCTION

Before starting to discuss the Critical path method, it is important to understand the way project management process, like planning, scheduling, monitoring, and controlling along with corrective actions. The main goals of any project are to finish a project before the estimated time and cost to the desired quality. To attain these goals, project planning, scheduling, monitoring, and controlling are a cycle process [1]. There are different project management methods and tools, that can be used for every one of these stages according to the type and the size of the project. For the planning stage, there is a significant number of methods such as Critical path Method (CPM), Bar Charts, Program Evaluation and Review Techniques (PERT), Linear Scheduling Method (LSM), Line of Balance (LOB), Work Study technique and operation techniques [1]. The Critical Path Method is a powerful tool for planning and management of all sorts of projects. It offers an accurate mathematical policy for planning, scheduling and control and permits evaluation and comparison of substitute work programs, construction methods and kinds of equipment through changing activity durations individually, resources or bonds between activities [1]. CPM is a quite important and effective tool in the project management and hence, should be included in the project management software packages. There are different project management techniques based on critical path method. They are needed at different stages of a project. Despite the fact that machine learning is a branch from computer science, it varies from classical computational methods. In classical computing, algorithms are collection of frankly coded directions employed by computers for calculating or solving a problem. Machine learning algorithms on the other hand, let computers train using data inputs then analyze them statistically in order to extract output values that are falling in a particular range. Because of this, machine learning facilitates computers in building models from sample data in order to automate decision-making processes based on data inputs. Machine learning is a continuously developing field. Because of this, there are some considerations to be kept in mind as working with machine learning methodologies, or analyze the impact of machine learning processes [2]. Investing in this field to solve different problems and challenges is the new trend for researchers and scientists around the world.

II. METHODOLOGY

The goal of this research is to make the first step and the first research that focuses the lights on the investment in the capabilities and enhancements that ML can contribute and make in the improvement journey of CPM, and this was done by dividing the research into two parts:

- The first part is about collecting information about the CPM through previous articles and researches and also collect information about ML and its capabilities and branches and try to make a
The combination of the two and summarize that into practical and solid ideas and thoughts that can possible be implemented in further researches and discuss each of them separately.

- The second part is a survey that is made for a wide slice of engineers collecting information about several aspects:
  - Engineers’ awareness of ML and its abilities.
  - The aspects that need to be reconsidered in developing CPM.
  - Automation of CPM and what are the aspects that are most needed to be automated than others.
  - Is the automation in CPM really needed?
  - What other improvements that ML can contribute in developing CPM?

The results after that would be analyzed and discussed one by one.

### III. CRITICAL PATH METHOD

The Critical Path Method (CPM) which was introduced in 1956 has proven that it is an effective useful tool for planning and controlling construction projects. CPM enables project managers to evaluate the early and late starting and ending time of each activity, and then being able to calculate the float (slack) time of the activities if available, to define critical activities, and to evaluate the impact of changing the durations and the logical relations on the overall duration. The use of the critical path method (CPM) in all industries including construction in the last three decades has dramatically increased because of its benefits and the huge advancement that has been made in computer hardware and scheduling software [3]. In construction projects, CPM is a very important method because it helps the contractor to determine and calculate when and how many resources are needed, also enables the vendors to estimate when they can deliver materials, and the subcontractors to determine when exactly they can start their work. Though, the critical path method has a lot of serious limitations that haven’t yet been overcome. The computing efficiency and the analytical capabilities of the critical path method also need to be enhanced in order to meet the changing requirements of the construction industry [4]. Construction involves unique environments, challenges, and project management needs, which are not found in other industries. Although the industry includes many large companies, statistics indicate that more than two-thirds of construction companies have less than five employees [5]. The majority of these small companies are specialist subcontractors working with a general contractor. This type of companies experiences the highest number of failures, as reported in a survey [6]. The survey shown the factors that contribute in failure, such as insufficient cash flow, underbidding, lack of experience in estimating and monitoring costs, and external difficulties. These factors, indicate a lack of efficient project management, which is in part due to the drawbacks associated with critical path method, particularly the lack of direct mathematical formulation for satisfying project constraints such as resource limits and deadlines. Despite the many practical insights provided by commercial software and professional organizations, for many construction professionals, particularly small contractors and trades, the use of critical path method and project management tools does not go beyond creating a schedule with a neat appearance in order to satisfy contract requirements [7].

The critical path method (CPM) was developed in the late Fifties by researchers at the E. I. Du Pont de Nemours Company. When firstly developed, the traditional form of Critical path method networks was named as AOA or “activity on arrow” diagram, which allows only Finish-to-Start relationship among the activities. This means that activities cannot overlap and that all preceding activities must be finished before a current activity can start. With the start of the Precedence Diagram Method (PDM), more flexibility in activity relationships has been added while the schedule calculations still use CPM analysis. In precedence networks, an activity can be connected from either its start or its finish, which besides the traditional Finish-to-Start relationship, allows the use of three additional relationships between project activities: Start-to-Start, Finish-to-Finish, and Start-to-Finish. Another characteristic of Precedence Diagram Method is that the periods of time that can be assigned between the start and/or finish of one activity and the start and/or finish of a succeeding activity. These periods of time between the activities are called leads and lags. A lead is the amount of time by which an activity precedes the start of its successor(s), while a lag is the amount of delay between the completion of one task and the start of its successor. Most of commercial software, like Primavera, Project Planner and Microsoft Project permit the use of non-traditional relationships with lags. Several surveys showed that over the years, CPM use has been increasing in the construction industry. [8] analyzed data from three surveys done in 1974, 1990, and 2003 which investigated whether Engineering News Record’s (ENR) top 400 contractors are using CPM. The study revealed an increasing CPM use that reached 98% of the respondents in 2003. By surveying a mix of both large and small contractors, a recent survey by [9] shown that it is not only the large ENR 400 firms who use CPM to manage their projects, but also small and mid-size construction companies. All the respondents said that they used CPM scheduling some of the time at least, with 45% reported that they used it all of the time.
and another 40% reported that they used CPM most of the time. The primary uses of CPM were reported as planning (before construction), control (during construction), and claim analysis. The disadvantages of CPM were also reported as implementation requiring excessive work, logic abuse, too much specialist dependent, and lack of responsiveness to the needs of field personnel. These findings agree with the results of a survey [10]: CPM did not gain the trust of the construction industry as a project control tool. This is true because in spite of the reports by contractors that they used CPM for project control, as in [8] survey. They may find it useful for analyzing progress status and updating activity data but not as beneficial method in supporting different important aspects, such as recovering execution problems and corrective actions.

IV. MACHINE LEARNING

Since their creation, human beings have been using many different types of tools to accomplish various tasks. The creativity of human’s brain led to the invention of different machines. Those machines made the human life much easier by enabling people to meet different life needs, including constructions, travelling, computing and industries. In spite of the rapid developments in the machine industry, intelligence has remained the essential difference between humans and machines in accomplishing their tasks. Human use his senses to collect information from the surrounding environment; the human brain works on analyzing that information and takes suitable decisions based on that information. Machines, on the other hand, are not intelligent by nature. A machine does not have the ability for analyzing data and taking decisions. For example, a machine is not expected to understand the story of Sinbad, fall in love, or contact with other machines through a common language. The era of intelligent machines began in the mid-twentieth century when Alan Turing thought about the possibility thinking ability for machine. Since then, the artificial intelligence (AI) branch of computer science has developed fast. Humans have had the aspirations for creating machines that have the same level of intelligence as humans. Many science-fiction movies have expressed these dreams, such as Artificial Intelligence; Her; I, Robot; The Terminator; and Star Wars. The history of Artificial intelligence started in 1943 when Waren McCulloch and Walter Pitts invented the first neural network model [11]. In 1950, Alan Turing introduced the next noticeable work in the development of the AI when he asked his famous question [12]: “can machines think?” He introduced the B-type neural networks and the concept of test of intelligence. In 1955, Oliver Selfridge suggested the use of computers for pattern recognition [13]. In 1956, Marvin Minsky, John McCarthy, Nathan Rochester of IBM, with Claude Shannon organized the first summer AI conference at Dartmouth College, United States [14]. In the second conference, the term “artificial intelligence” was used for the first time. Cognitive science term was originated in 1956, during a symposium about information science at the MIT [15]. In 1957, Rosenblatt invented the first perceptron. After that in 1959, John McCarthy invented the LISP programming language [16]. In 1962, David Hubel and Torsten Wiesel proposed using neural networks for the computer vision. Joseph Weizenbaum developed “Eliza” the first expert system that could diagnose a disease through its symptoms [17]. The National Research Council (NRC) of USA created the Automatic Language Processing Advisory Committee (ALPAC) in 1964 to expand the research in the natural language processing. But after many years, the research was terminated because of the low progress and high expenses. The book Perceptrons written by Marvin Minsky and Seymour Papert was published in 1969 [18], which was talking about the limitations of neural networks Resulted in stopping organizations’ funding for research on neural networks. The period from 1969 to 1979 witnessed an increase in the research of knowledge-based systems. The programs Dendral and Mycin are examples of this research. In 1979, Paul J. Werbos suggested the first effective model for neural network with backpropagation [19]. In 1986 Geoffrey Hinton, Ronald Williams, and David Rumelhart discovered a method that allows a network to learn how to distinguish between nonlinear separable classes, and they gave it the name backpropagation [20]. In 1986, Terrence Sejnowski and Charles Rosenberg developed a speech recognition artificial neural network called “NETTalk”. In 1987, Arthur W. Burks and John H. Holland created an adapted computing system that has the learning capability. In 1989, Dean Pomerleau proposed a three-layered neural network named ALVINN (autonomous land vehicle in a neural network), designed for road following. In the year 1997, Garry Kasparov the world chess champion was defeated by the Deep Blue chess machine which was designed by IBM. In 2011, a computer developed by IBM named Watson defeated Ken Jennings and Brad Rutter, the champions of the television game show Jeopardy! The period from 1997 till nowadays witnessed and witnessing rapid developments in natural language processing, reinforcement learning, computer vision, computer hearing, emotional understanding, image processing, pattern recognition, cognitive computing, knowledge representation, and so on. These trends aim to provide machines that have the ability of gathering data through senses similar to the human senses and then processing them using machine learning methods and the computational intelligence tools to make predictions and decisions at the same level as humans. The term machine learning means enabling machines to learn without
programming them exactly. Generally, there are six machine learning methods:
- Supervised learning.
- Unsupervised learning.
- Semi-supervised learning.
- Reinforcement learning.
- Deep learning.
- Deep reinforced learning.

V. CONCLUSION

After a detailed study of both the critical path method and the machine learning technique, and a review of their sources, previous studies and expert opinions, some theoretical proposals that could be achieved in the future were made regarding the use of machine learning to improve and develop the critical path method based on the capabilities that this technology possesses, which are as follows:
2. Using machine learning for the auto-suggestion of any substitutes.
3. Using machine learning for the auto-detection of the critical path.
4. Using machine learning for the auto-suggestion for different scenarios.
5. Using machine learning to auto-suggest different and best crashes or fast tracking have to be made.
6. Solve resources limitation by processing both resources and project duration and tasks at the same time.
7. Use the clustering technique for the auto-sorting of tasks, after that decision tree can be helpful for the arrangement of the tasks based on their features.
8. Feeding deep learning with many different modifications suggested for the improvement of CPM and try to conclude the best model of them: theoretically this can be efficient method.
10. Auto-check and alarm in case any problem is made while programing the CPM.
11. Logical abuse solving.
12. Reduce specialist’s dependency.
13. Simplifying implementing CPM.

REFERENCES