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A new perspective in construction management; the metaverse

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Abstract: A conceptual construction management model can be applied to the metaverse 3D technology in this study, which demonstrates how accelerated back-and-forth replays of the construction process can be used to evaluate the impact of new decisions on the project. Participants in the proposed model will be able to see exactly how their decisions during construction affect the progress of the project. In order to develop this model, three phases are required: 1) Analyzing the problem and planning the algorithm, 2) collecting data and designing the hybrid model utilizing artificial intelligence and construction network scheduling techniques, and 3) coding the algorithm. The design-based research will contribute to the development of new meta-models for construction management, present innovative ideas for students, engineers, and managers working in the field of construction management.

Keywords: Artificial intelligence, neural networks, fuzzy logic, CPM, PERT.

1. Introduction

Construction management coordinates a comprehensive process that includes the harmonious work of various engineering disciplines starting from the feasibility study to the procurement phase. The success of a construction project is measured by completing the construction in the shortest time with the expected quality at the lowest cost. Competent construction managers and skilled workers are needed to achieve this goal. Construction work involves interrelated and complex relationships that need to be well managed, as well as limited resources may put a lot of pressure on construction managers. Although work planning is done in detail, unpredictable events may occur during construction because of the dynamic nature of the construction site; therefore, new ways have been investigated to minimize unexpected actions; new technologies have been always needed to predict and take steps during construction. The concept of the metaverse was first introduced into novel "Snow Crash" in 1992 by Neal Stephenson, who described 3D (three-dimensional) virtual worlds (VWs) where people interact with one another and their surroundings without the physical limitations of the real world (Benedikt, 1970). It's an open, shared, persistent virtual world that uses 3D sandboxes, solutions, and environments created by users. There are no consequences for actions in virtual reality (VR). It usually requires a full 6DOF headset and controllers (sitting or room-scale). The metaverse, on the other hand, is an immersive experience and lets you live your life in the virtual world. There are also differences between VR and the metaverse in terms of ownership, VR and ownership (Narin, 2021). Augmented reality (AR) and VR have come to the spotlight through wearable technology such as Google Cardboard, Microsoft HoloLens, Oculus headsets, etc., which are very popular today (Ledbetter, 2001; Park & Kim, 2013). This new technology that introduces AR and VR is mostly used in security and education in Construction Management, and its effects are often evaluated through virtual interaction (Le, Pedro, & Park, 2014; Wu et al., 2018). Although recent studies have shown that AR and VR technologies are used in the construction industry as in many other sectors, no study has been found in the literature on the use of the metaverse in construction management.

In this study, a conceptual simulation model is developed to demonstrate how metaverse 3D technology can be applied to construction management. Construction management can benefit from this new technology in all phases, including risk assessment, design, work planning, resource management, constraints, and supply management. By using this model, the construction process can be evaluated using accelerated back-and-forth replays, and the impact of new decisions can be evaluated.

2. Literature

Unlike traditional social media or computer games, the metaverse offers new platforms for digital innovations (Schöbel & Leimeister, 2023), a parallel three-dimensional (3D) virtual world that maps to and interacts with reality (Zheng & Yuan, 2023; Huynh-The et al., 2023; Wu & Hao, 2023). The metaverse allows anyone to create a virtual avatar to walk around and work freely in the virtual space of the metaverse (Huynh-The et al., 2023a; Monaco & Sacchi, 2023). Using various technologies, the metaverse offers users personalized 3D experiences (Gu et al., 2023; Huynh-The et al., 2023a), such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Artificial Intelligence (AI), Cloud Computing (CC), the Internet of Things (IoT), blockchains, and digital twins (Zheng & Yuan, 2023; Huynh-The et al., 2023a; Wu & Hao, 2023; Shao, Tang, Zhang, & Chen, 2023). Extended reality technologies, such as AR and VR, are of the utmost importance. In the metaverse, these two elements play an essential role in creating a digital space in which users can interact as they would in the real world (Koutitas, Smith, & Lawrence, 2020). Second, the digital twin has become an important technology to create a virtual twin of a real-world object to predict its expected behavior; a digital twin can mirror the real world into the virtual world (Huynh-The et al., 2023a; Ramu, 2022). Third, the blockchain provides a complete economic system to connect the virtual world of the metaverse and the real world, providing users with a repository for storing data everywhere in the metaverse (Jeon, Youn, Ko, & Kim, 2022). Additionally, metaverse and IoT have been combined in recent years to give users 3D virtual experiences (Li, 2023).

The metaverse has great potential for AI-based methods and big data processing has demonstrated the importance of enhancing the immersive experience and enabling virtual agents with human intelligence (Huynh-The et al., 2023b). However, the metaverse is still at an early stage of development (Monaco & Sacchi, 2023; Chow, Susilo, Li, Li, & Nguyen, 2022), but they have become increasingly popular and are gradually developing (Gu et al., 2023; Seo, Seok, & Lee, 2023); people's demand for the metaverse is increasing (Zheng & Yuan, 2023). There is therefore an increasing amount of research on the metaverse in various fields today but very few real applications exist (Huynh-The et al., 2023a). One of the most popular applications is online videoconferencing; body language or eye interaction can be used to communicate with a working partner from different angles, which will greatly improve telecommuting (Huynh-The et al., 2023a). Another popular application is Digital Real Estate, which allows users to buy, rent, and sell land and buildings for living, or investment, as well as organized art exhibitions, music festivals, and gaming competitions (Huynh-The et al., 2023). There is also the Digital Arts application, where users can view 3D images from all dimensions in a virtual gallery placed in the metaverse (Huynh-The et al., 2023a). Second Life, VRCha, Roblox, Horizon Worlds, and Minecraft are some of the most popular gaming platforms that allow access to the metaverse (De Felice, Petrillo, Iovine, Salzano, & Baffo, 2023). It is evident from the studies that metaverse technologies are evolving every day; whatever you can imagine in the real world, you can create virtually in the metaverse (Dizaji & Dizaji, 2023); however, there are some common concerns about governance, ethics, privacy protection, and reliability and accuracy of data (Monaco & Sacchi, 2023).

Research on the metaverse has been utilized so far in education and health, security, and design or construction, but it is still in its infancy in tourism and hospitality, transportation, and fitness and consulting (Tlili, Huang, & Kinshuk, 2023). Aside from healthcare education, online education, industrial training, aircraft maintenance training, marine maintenance training, military training, art upskilling, and gaming expertise, the metaverse offers education, training, and skill development in a variety of fields (Sá & Serpa, 2023). Students can gain new educational opportunities and innovations through metaverse technologies (Asiksoy, 2023), especially in areas where hands-on experience and practical training are required (De Felice, Petrillo, Iovine, Salzano, & Baffo, 2023). A key barrier preventing students' adoption of the metaverse technology is cyber risk, so some mechanisms are needed to reduce privacy and security risks (Al-Adwan et al., 2023). As a result of Wu & Hao's study (2023), an Edu-Metaverse ecosystem architecture and teaching method has been developed for offline and online education and stated that by utilizing Edu-Metaverse, educational content is not only broadened and deepened but also costs are reduced and education quality and efficiency are improved. An integrated metaverse and deep reinforcement learning system developed by Gu et al. (2023) assists evacuees in choosing the most effective evacuation route to leave the building as quickly as possible. Alvarez, Del Angel, and Martínez (2023) examined how a virtual campus metaverse affected active learning, school motivation, and learning issues in engineering courses and concluded that it increased interest in learning and attending lectures. Said (2023) identified five challenges for metaverse learning: (1) Simple and comprehensive 3D design, (2) Cybersecurity vulnerabilities and the privacy of data, (3) Cost-effective access to the metaverse, (4) Health issues (physical and psychological) due to excessive use of the metaverse, and (5) Governance. The research of Said (2023) also identified three opportunities to overcome these challenges: (1) Hands-on training and learning, such as flight simulation training, or surgical experiment (2) Game-based metaverse learning in virtual worlds, and (3) Collaborative knowledge creation.

There are many types of applications of the metaverse in health sciences, medicine, anatomy and physiology (Moro, 2023) as well as opportunities for new and challenging research in the field of health care (Nuñez, Krynski, & Otero, 2023). There are various ways in which the metaverse can be utilized (Massetti & Chiariello, 2023); it has a variety of application potentials and will greatly enhance medical research and standards (Shao, Tang, Zhang, & Chen, 2023). It can be used to diagnose, educate, and treat patients effectively (Shao, Tang, Zhang, & Chen, 2023; Ahuja, Polascik, Doddapaneni, Byrnes, & Sridhar, 2023), visualize patient clinical data in real-time, observe treatment effects in avatars that are clinically similar to patients, and simulate surgeries on virtual patients (Massetti & Chiariello, 2023). Research in tourism can be also advanced through the metaverse in the future. In the study of Monaco & Sacchi (2023), potential benefits and challenges of the metaverse were explored in the food marketing and tourism industries. By eliminating travel by plane, train, and personal transport for activities that were previously only possible in person, the metaverse can help reduce carbon emissions.

The metaverse has also been the subject of studies in other fields. It was proposed by Liu, Chen, Li, Ren, and Wang (2023) that a virtual mining system could be used to improve the safety and efficiency of a physical mining system, which could be used to test, correct, and optimize the proposed methods. The metaverse office offers some special advantages, such as peer interaction and enhanced teamwork; however, privacy, security, addiction, equity, and usability are some of the problems that metaverse technology may create (Chen, 2023). Coded Distributed Computing and blockchain were used in Jiang et al.'s (2023) framework for the vehicular metaverse to compute reputation values for vehicles for choosing reliable workers. A study conducted by Jiang, Kim, Ko, and Kim (2023) examined the consumer experience in a metaverse environment and its impact on consumer happiness in luxury brands, concluding that it had a positive effect on consumer happiness. Last but not least, Zainurin, Haji Masri, Besar, and Anshari (2023) defined metaverse banking as the integration of the metaverse and online banking services and stated that metaverse banking will be marketed intensively yet effectively in the near future.

Construction management has not been studied in the metaverse despite recent studies in various fields. The purpose of this study is to fill this gap in the literature by integrating the metaverse, AI and construction network scheduling techniques such as the Critical Path Method (CPM) or the Project Evaluation and Review Technique (PERT) to shed light on future research in this field.

3. Project risk analysis

In the success of a project, owners, contractors, and workers play a crucial role; however, risks can adversely affect the cost, schedule, and quality of construction (ALSaadi & Norhayatizakuan, 2021). Furthermore, risks have a greater impact on the operation of a construction project since they are influenced by many factors that make it difficult to achieve the expected construction time, cost, quality, safety, etc. (Xie & Yang, 2021). The implementation of risk management in construction projects not only increases profitability and productivity but also improves the performance of the project (Siew, 2015).

Many construction projects employ a variety of risk management methods, but the main method involves four steps: (1) identifying and classifying risks, (2) analyzing risk assessments, (3) developing a risk management response, and (4) monitoring and controlling (ALSaadi & Norhayatizakuan, 2021). The classification of project risks is a critical step in the risk assessment process. Construction projects differ in risk levels, so each must be treated independently (Tah & Carr, 2000). A risk can be classified as internal or external, depending on its source. The external risks, including economic, physical, political, and technological change, are relatively unpredictable, so continuous scanning and forecasting are required; however, it is relatively easier to control internal risks, some of which are local, such as labor, materials, plants, sites, and subcontractors, while others are global, including client, construction, contractual, design, environmental, financial (company or project), location, management, pre-contract, and timeframe (Tah & Carr, 2000).

Project risk analysis and management have been the subject of several research studies. A study conducted by Yousri, Sayed, Farag, and Abdelalim (2023) examined the likelihood of risk occurrence and its consequences; extreme risk factors included funding, price fluctuations, duration of project activities, shortage of construction materials, changing laws, currency exchange rates, and changes in contractual requirements during construction. In another study, researchers investigated the root causes of risks and found that several of the causes were critical for the project, including contract, design and execution, subcontractors, software, systems, and equipment (Khairullah, Hilal, & Mohammed, 2022). As a result, risk management plays a key role in solving various unfavorable factors that affect the normal operation of construction projects (Xie & Yang, 2021; Siew, 2015). Construction projects become more successful when managers make the right decisions the first time (Șerbanoiu, Verdeș, Șerbănoiu, Șerbanoiu, & Munteanu, 2017); minimizing risks increases the output of construction projects (Siew, 2015).

This study will use risk management techniques and fuzzy inference systems to evaluate the success of construction projects on CPM.

4. Materials and methods

The research will consist of a 3D simulation model of a construction project in a 3D metaverse. With this concept, participants can accelerate, slow down, and pause the construction simulation in order to observe how construction decisions affect the process, and rewind time to change the decisions.

4.1. *Modeling with a fuzzy approach*

When planning construction projects, construction managers often face the difficult task of striking a balance between the limited resources available, which can affect key project objectives such as time, cost, and quality (Wang, Abdallah, Clevenger, & Monghasemi, 2019). A successful construction project must meet the owner's quality requirements, be delivered within the specified budget, and be on time (Wang, Abdallah, Clevenger, & Monghasemi, 2019). Various risk factors, which vary from project to project, have an impact on these three project objectives (ElBassuony, 2010) that can be used to measure the performance of construction projects (Wang, Abdallah, Clevenger, & Monghasemi, 2019). Project risk management can be effectively handled with fuzzy logic in the risk analysis process (Chaher & Soomro, 2016), and Fuzzy Inference Systems have been successfully applied to risk management in various industries (Bhowmik, Udgata, & Trivedi, 2022) since they allow for subjective judgment to be handled (Nieto-Morote & Ruz-Vila, 2011). Therefore, several studies have focused on analyzing and optimizing the tradeoffs among time, cost, and quality (Wang, Abdallah, Clevenger, & Monghasemi, 2019). An optimization model was proposed by Zhang and Xing (2010) for solving the time-cost-quality trade-off (TCQT) problem using a fuzzy multi-objective particle swarm optimization model; cost and quality were defined using fuzzy numbers, and particle swarm optimization was used to evaluate the construction method using the fuzzy multi-attribute utility method. Nieto-Morote and Ruz-Vila (2011) and Chaher and Soomro (2016) employed a fuzzy risk assessment technique for construction projects, categorizing the risk according to probability and severity, allowing for linguistic variables to be assessed. Nieto-Morote and Ruz-Vila (2011) also introduced a method for assessing engineering, execution, supplier, and project management risks. According to Chaher and Soomro (2016), a fuzzy risk assessment model for construction projects can be used to prioritize and rank all risk factors by taking into account cost, time and quality considerations, and the severity of risk is based on the likelihood multiplied by the impact of the risk. The authors of Dikmen, Birgonul, and Han (2007) have proposed a fuzzy risk assessment methodology that utilizes influence diagrams and fuzzy sets to estimate the cost overrun risk rating, stating that using the tool, it is possible to calculate the actual cost value as well as the risk level at the start of a project. The authors of Nguyen, Le-Hoai, Basenda Tarigan, and Tran (2022) developed a model that utilized fuzzy logic as well as an algorithm for multi-objective Symbiotic Organism Search to assess the impact of uncertainty on the project's time, cost, and quality and to propose a number of actions that can be taken to implement it. The authors of Banihashemi, Khalilzadeh, Antucheviciene, and Šaparauskas (2021) proposed a model which utilized fuzzy logic and multi-criteria decision-making (MCDM) methods to evaluate the best mode of activity execution depending on fuzzy duration, cost, and quality. A study by Banihashemi, Khalilzadeh, Antucheviciene, and Abarauskas (2021) showed that the projects could be completed with higher quality in fewer durations and costs; the cost of each activity is closer to the lowest cost, the activity duration is also closer to the most likely duration, and the quality is closer to the high-quality level.

Although various studies on this topic have been conducted in the literature, this study also uses a fuzzy risk assessment system is used in this proposed model (see Figure 1) to measure the impact of project risks on the project's performance. CPM or PERT is used to plan, schedule, coordinate, and control construction activities.

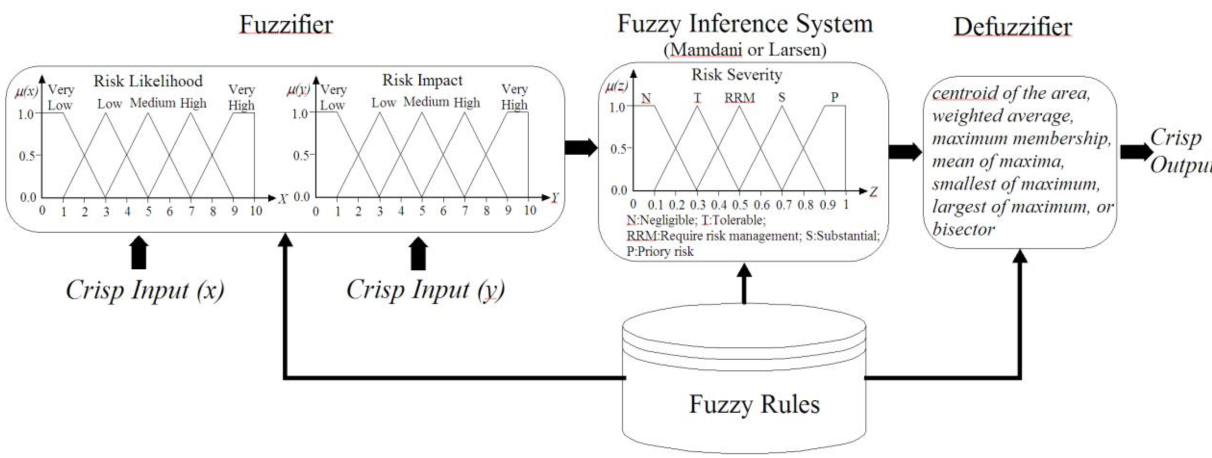

Figure 1. A typical fuzzy risk assessment system adapted from (Zeng, An, Chan, & Lin, 2004).

4.2. *Resource leveling*

The resource leveling process involves allocating resources to project activities in a way that will increase productivity and efficiency (Stevens, 1989). The goal of resource leveling is to optimize your resources, minimize deficits, and ensure quality. Construction companies use CPM to level resources and schedule projects (Liu, 2013). PERT is another network scheduling technique commonly used in planning and design applications. In comparison with CPM, PERT is a probabilistic method. PERT uses probability distributions for durations of activity rather than fixed values as in CPM (Stevens, 1989). A third technique, the Monte Carlo simulation method, utilizes simulation to estimate the duration of a project by assigning probable durations to activities and solving the CPM algorithm (Stevens, 1989).

Farida and Putri Anenda (2022) determined the optimal completion time for road construction projects by using PERT, CPM, and the crashing method. In Liu (2013), risk assessment of construction schedules was performed using the PERT approach. An optimization model based on PERT was developed by Hosny & Elbassuony (2018) in another study to take uncertainties into account during construction planning by assigning three possible estimates (pessimistic, most likely, and optimistic) for the time, cost, and quality of each activity, which identified the optimal schedule for minimizing project duration and cost while maximizing project quality simultaneously. A Monte Carlo analysis is the most effective technique for the construction of megaprojects, according to Dizaji and Dizaji (2023). Monte Carlo analysis is also widely used to assess risk in programming and budgeting (Bhowmik, Udgata, &Trivedi, 2022). A wide range of problems can be solved by using fuzzy

CPM and fuzzy PERT in many fields. A major bridge project was analyzed by Soni, Ramesh Kumar, and Shrivastava (2022) using Fuzzy CPM and Fuzzy PERT to optimize its duration.

Time and quality, however, cannot be represented by a general relationship. As an example, applying poor quality control procedures to an activity can reduce its duration, but using advanced construction methods can also reduce its duration and increase its quality (ElBassuony, 2010). If the project's duration is extended or shortened beyond its optimal duration, the total project costs increase; when the project is accelerated, the total project direct costs increase, while when the project is shortened, the total project indirect costs decrease. Figure 2 shows duration-cost and quality-cost relationships for projects with varying levels of quality. It is theoretically possible to maintain a higher constant quality at a higher cost, and there would still be a similar time-cost tradeoff curve above the original. In the case of several levels of quality, there would be a family of level curves (Pollack-Johnson & Liberatore, 2006).

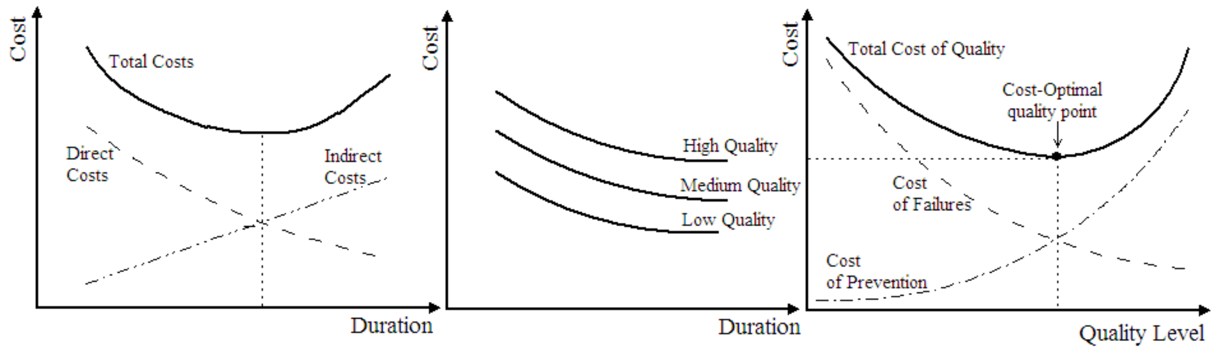

Figure 2. Cost-duration and cost-quality relationships with different quality levels adapted from Pollack-Johnson and Liberatore (2006) and Cebeci (2013).

Selecting critical activities requires identifying their normal duration and crash duration, as well as their associated costs; an activity's normal duration represents efficient, low-cost, realistic methods for completing the activity under normal circumstances; crashing is the action of reducing the duration of an activity to the shortest possible period; an activity's crash cost is the direct cost of completing it in its crash duration (Gray & Larson, 2020). A hypothetical graph of a cost-duration relationship for an activity is shown in Figure 3.

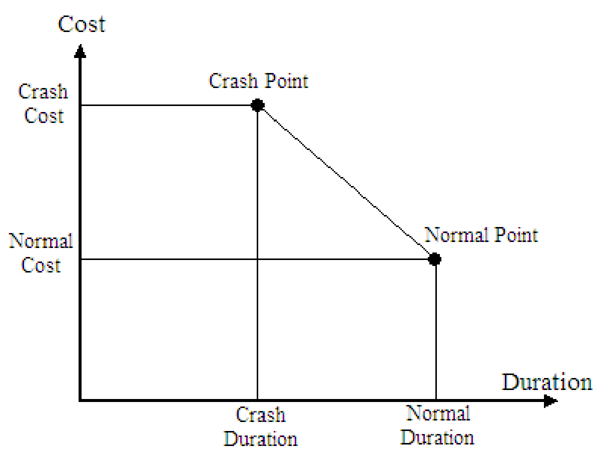

Figure 3. Duration-cost graph for an activity (Gray & Larson, 2020).

The following equation (Gray & Larson, 2020) calculates the cost per unit of time or slope for any activity under some assumptions:

$$Crash\ cost\ per\ period = \frac{Crash\ cost - Normal\ cost}{Normal\ time - Crash\ time} \quad (1)$$

In the proposed model, daily progress for each activity will be measured using CPM, risk assessment will be made using fuzzy logic, and project success measures of risks will be evaluated by analyzing the DNN performance surface.

4.3. *Neural network design*

This model will use dynamic networks to train, in other words, to map the model's inputs to the output. In the book of Hagan, Demuth, Beale, & and Jesús (n.d.), the general equations for the computation of a dynamic network are presented. Dynamic networks contain delays and operate on a sequence of inputs. At any given time, their response will depend not only on the current input, but also on the history of the input sequence. Since dynamic networks have memory, they can be trained to learn sequential or time-varying patterns (Hagan, Demuth, Beale, & De Jesús, n.d.).

$$\mathbf{n}^m(t) = \sum_{l \in L_m^f} \sum_{d \in DL_{m,l}} \mathbf{LW}^{m,l}(d)\mathbf{a}^l(t-d) + \sum_{l \in I_m} \sum_{d \in DI_{m,l}} \mathbf{IW}^{m,l}(d)\,\mathbf{p}^l(t-d) + \mathbf{b}^m \quad (2)$$

Where $\mathbf{n}^m(t)$ is the net input for layer m, $\mathbf{p}^l(t)$ is the l^{th} input vector at time t, $\mathbf{IW}^{m,l}$ is the input weight between input l and layer m, $\mathbf{LW}^{m,l}$ is the layer weight between layer l and layer m, $\mathbf{b}^m$ is the bias vector for layer m, $DL_{m,l}$ is the set of all delays in the tapped delay line between layer l and layer m, $DI_{m,l}$ is the set of all delays in the tapped delay line between input l and layer m, l_m is the set of indices of input vectors that connect to layer m, L^f_m is the set of indices of layers that directly connect forward to layer m.

$$\mathbf{a}^m(t) = \mathbf{f}^m\big(\mathbf{n}^m(t)\big) \quad (3)$$

Where **a** is the output vector of layer m, and **f** is the transfer function of layer m.

5. Results

The conceptual model will be developed in three phases as shown in Figure 4: 1) Analysis of the problem and planning of the algorithm, 2) Data collection and design of the hybrid model using AI and CPM or PERT, and 3) Coding of the algorithm.

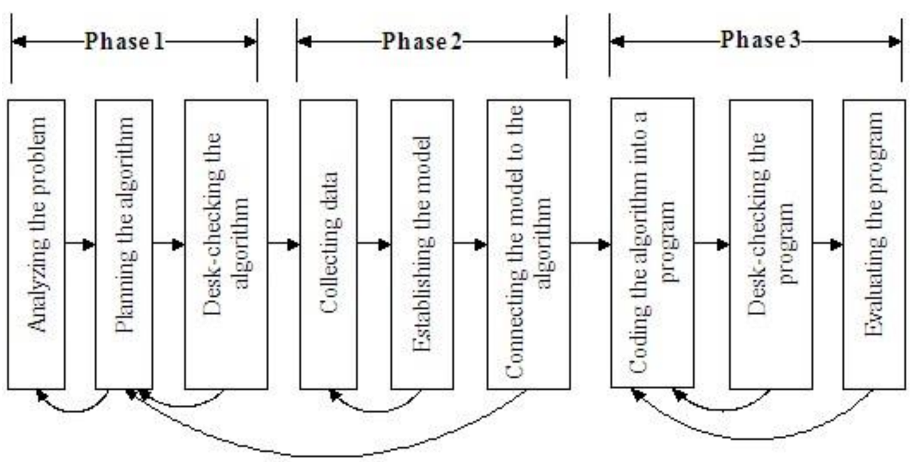

Figure 4. Model development phases.

5.1. *Analysis of the problem and planning of the algorithm*

It is possible to simulate large construction projects such as Istanbul Airport and the 1915 Canakkale Bridge using various phases of the construction, or include diverse challenges according to their difficulty levels. Users can be asked to overcome these challenges and the impacts of their actions can be evaluated using accelerated back-and-forth replays. A new construction project can also be modeled to observe its progress and evaluate its outputs according to the new decisions made.

The model will use fuzzy logic to convert inputs (risks that influence the project's success in terms of time, cost, and quality) such as inaccurate construction plans, bad weather conditions, natural disasters, inflation, health and safety hazards, subcontractor problems, inexperienced or unskilled labor, change order effects, and equipment damages. During construction, these values can be updated based on changing conditions. Other issues, such as shortages of materials, equipment, or finances, along with labor shortages or inefficiencies will be updated with the CPM or PERT. These risks will be also converted between 0 and 1 using fuzzy logic. One represents the most desirable situation and zero represents the most unfavorable situation. This model will produce time, cost, and quality parameters that define the success of a project. It is intended to train the network based on the desired output values.

5.2. *Data collection*

Two different methods will be used to obtain data for the proposed model. Data for the proposed model will be obtained using two different methods. The first is to interview the construction experts and obtain data from real-life constructed projects or the second is got from the literature and the experiences of some construction managers.

5.3. *Design of the model*

A proposed model will be based on AI and CPM or PERT. An illustration of the conceptual model process can be seen in Figure 5. The inputs for the model will include risk, resource, and constraints; and the outputs will include time, cost, and quality measures of the project's success.

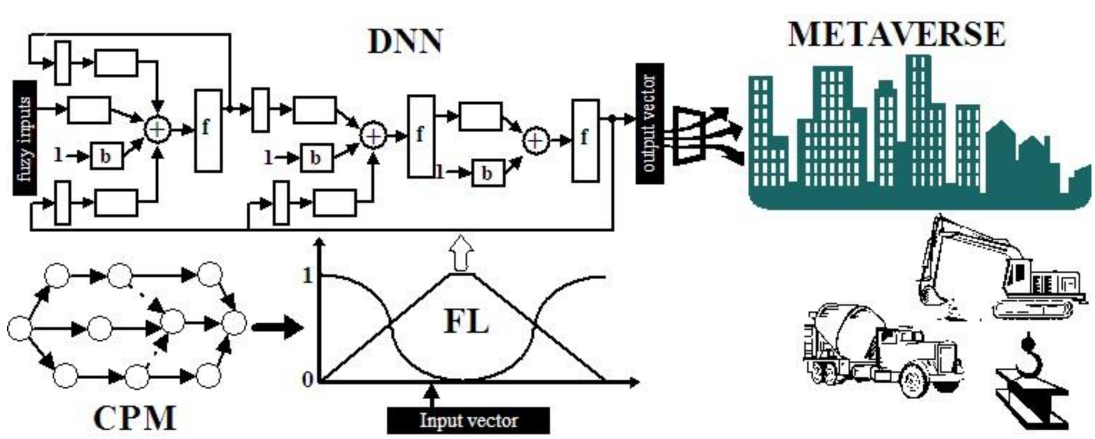

Figure 5. The analytical concept of the model.

There will be two versions of the model, one for educational purposes and one for professional purposes. There are more features in the professional version than in the educational version, as can be seen in Table 1. Predefined constructed real projects can be run in the educational version, and users can only assign risks and adjust risk levels, but in addition to the education version, users can create their own construction projects using CPM or PERT and can have full control over the project in the professional version.

Table 1. Comparison of versions.

Version	Single - user	Multi- user	Upgrade with new completed projects	Real-case project simulation	Creating new project	Assigning risk and adjusting risk levels	Calculating network scheduling	Updating network scheduling	Resource allocation	Cost control	Cash-flow analysis	Progress payments control	Conflict control
Education	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No	No
Professional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Users will be able to select one of the simulated construction projects and determine the risks and risk levels in the education version. Throughout the metaverse environment, users will be able to watch all phases of construction as if they were living it. A user can speed up, slow down, and pause the process to focus on a particular issue, rewind the model, re-adjust risks and risk levels, and simulate the process repeatedly as shown in Figure 6.

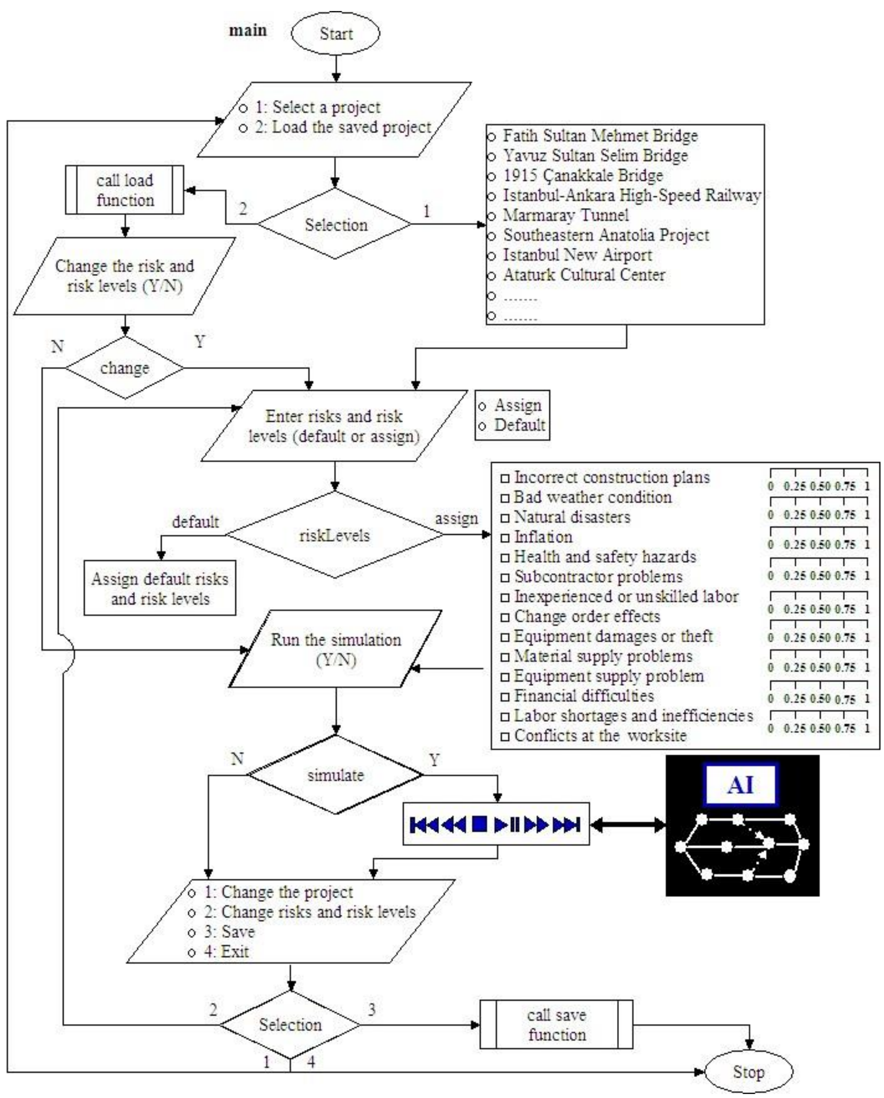

Figure 6. Main function of the education version of the model.

A professional version can also be used by one or many users, as well as define a position such as general manager, project manager, site manager, or field engineer. Such positions will be defined within the model along with their job descriptions and decision-making levels. Using CPM or PERT, the user(s) can plan and schedule construction work within the scope of the job description of the positions they have chosen. It will be possible for them to identify risks and their levels. Figures 7, 8 and 9 show flow charts of the main function and two other functions.

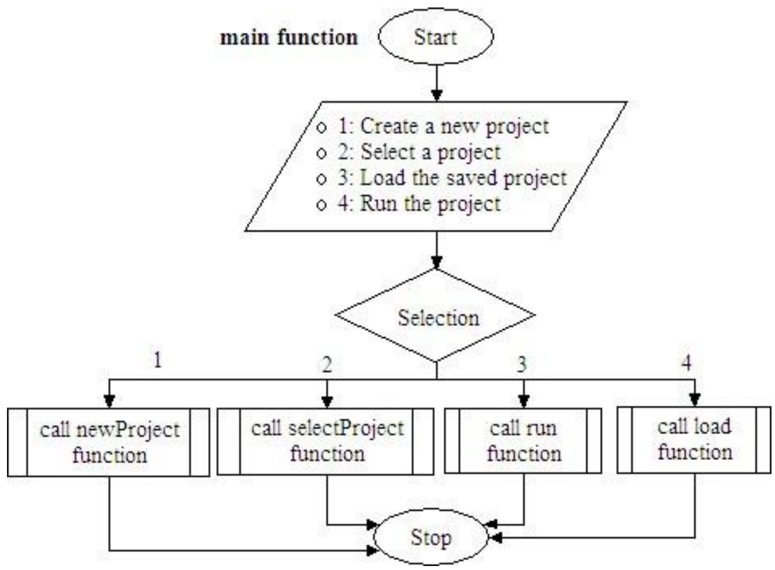

Figure 7. Main function of the professional version of the model.

The users can plan new construction projects according to the job descriptions they choose, with CPM or PERT, defining risks, determining risk levels, and simulating the project, as depicted in Figure 8.

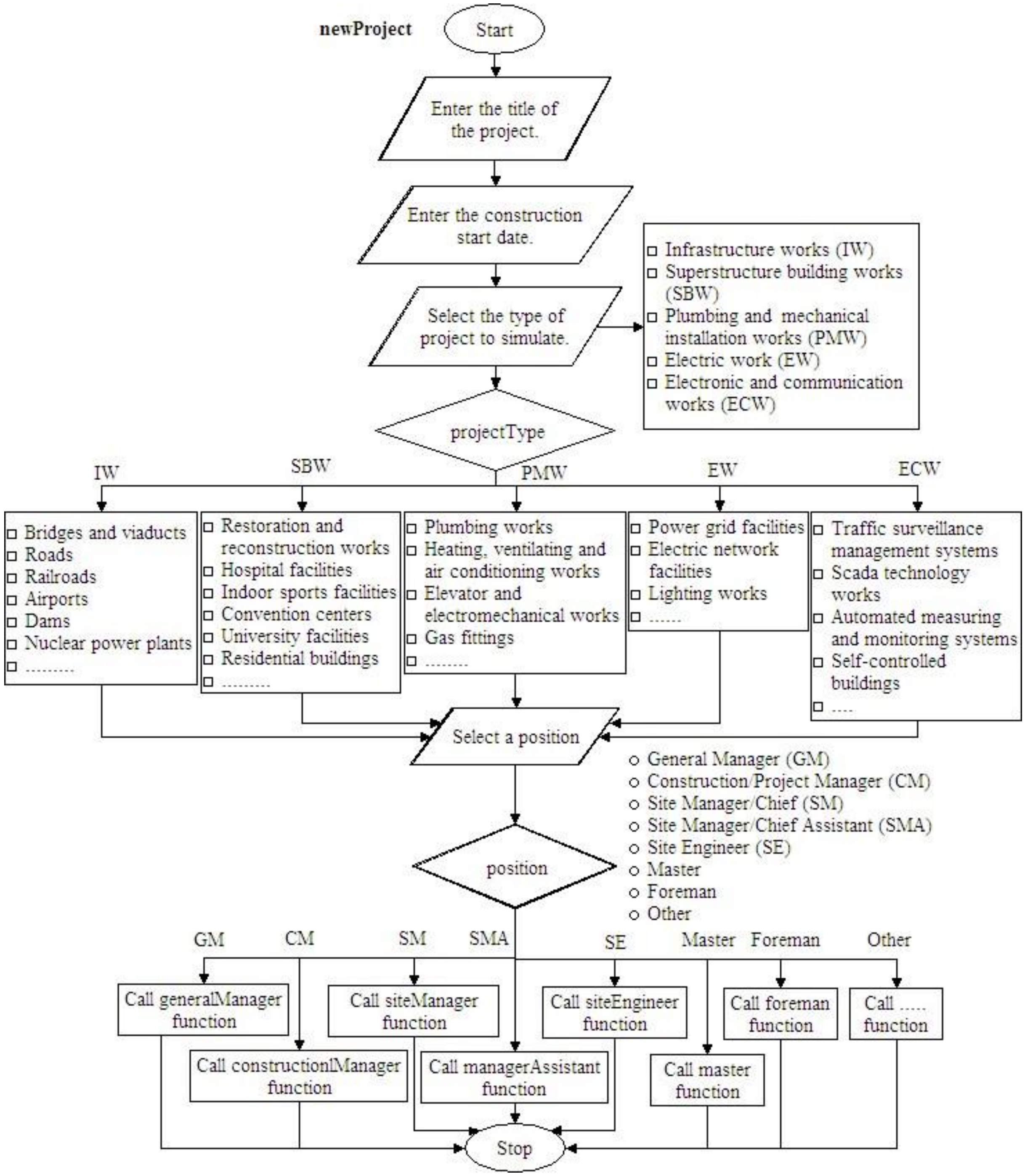

Figure 8. New project function of the professional version of the model.

There are several users of the model, including general managers, project managers, site engineers, foremen, and masters. The model defines the job descriptions for users, and users can only perform the tasks defined in the model, for example, only the general manager or project manager can define new construction projects and plan using CPM or PERT. The construction manager function of the model is shown in Figure 9.

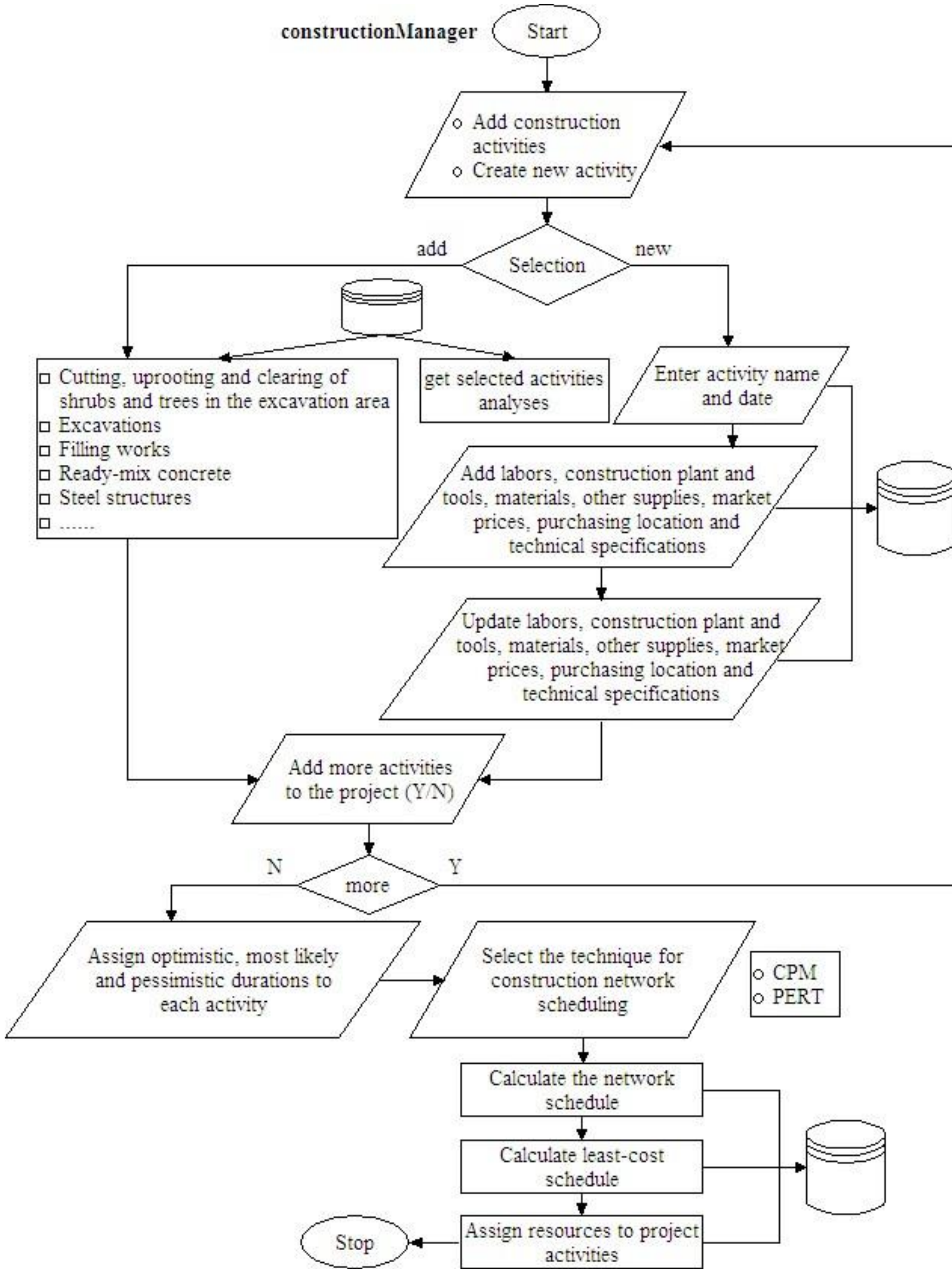

Figure 9. Construction manager function of the professional version of the model.

5.4. *Coding of the algorithm*

Developing a full-scale model requires a large budget and labor force, a wide range of real-world data, and the expertise of a large number of experts. It is also important for those who are developing the model to have knowledge of construction processes. This model will be converted into a real-life application by the software team after it has been developed and validated.

6. Conclusions and comments

Recent studies show that AR and VR technologies are used in the construction industry, as in many other industries (Shakil, 2019). VR is an application that provides 3D vision in which any visible or imaginable place can be simulated with a computer and internet environment. A study was conducted on the safety of construction equipment with AR-based wearable glasses for occupational safety and health in the construction field (Shakil, 2019). With AR and VR, not only occupational safety and health but also worker plot training are provided. Ramyani and Sparkling (2021) introduced the simulated VR world to the Construction Management undergraduates at a four-year university in the Midwest USA and evaluated the effects of this technology on both students' learning and academic performance. The fact that students gained detailed information about building systems by VR instead of using 2D construction drawings increased their motivation and attracted them to an interesting environment where they could learn. It has been seen that the inclusion of such educational tools and practices can increase the prevalence of more focused educational knowledge transfer while protecting the health of students by reducing personal contact at the same time (Ramyani & Sparkling, 2021). In another study, excavator drivers were trained with VR technology for a construction machine operator to have experience in his vehicle before working in the field (Shakil, 2019). With the rapidly developing technology in the world, project management organizations become more stable with the introduction of AR and VR technologies. These technologies provide a model for the planning and design of a construction project. Along with these changes in technology, a new concept called "metaverse" has entered the literature. A growing amount of research is being conducted on the metaverse in numerous fields and so far the metaverse has been used in education, training, skill development, health, security, design, tourism and hospitality, and transportation. The metaverse research has not yet been conducted on construction management.

Construction works are highly complex tasks involving many interrelated factors. Starting from the feasibility study, it requires different engineering disciplines to work together in the design phase and the implementation phase. Construction management starts with good project planning and work schedule and requires successful resource management, constraint management and risk management. Construction resource management is the process of planning and allocating the resources needed to meet project objectives. Proper project resource planning helps keep projects on schedule by ensuring that demands are met while maximizing the use of resources. To keep costs under control, equipment and labor must be used in the most efficient way possible. Constraints are inevitable in any construction project. These often include economic, legal, environmental and technical constraints. Rather than overcoming every constraint, it is beneficial for the construction project and team to prepare and work within these constraints. Risk management includes comprehensive planning that allows the construction manager to identify, monitor and mitigate risks and risk levels. A construction manager's experience is often constructive in managing resources and constraints and making decisions during risky situations. Project success is closely linked to decisions made on unexpected events; however, it is impossible to eliminate all the negative effects of a wrong decision by turning back the clock. It is essential to continue the work by making the most appropriate decision according to the current situation, but this may also lead to re-evaluating the expected benefits. It seems very interesting to see how the construction process is affected by changing our decision after seeing the future effects of a decision we made at any stage.

This is the first study to demonstrate that metaverses can be used in the field of construction management. This study emphasizes the importance of the subject, but only the framework of the model is presented. Aside from the new perspective presented in this study, it contains many limitations. There are a number of reasons for this, including the lack of prior research and the long-term nature of the study.

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