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Risk Prioritization in Construction Projects using AHP & Python

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Abstract - The construction industry plays a vital role in developing infrastructure such as buildings, roads, and bridges, but it is also one of the most dangerous sectors due to risks like falls, electrical shocks, machinery accidents, chemical exposure, and unsafe conditions. These hazards can lead to serious injuries, fatalities, project delays, and financial losses, making safety management essential. Traditional methods based on experience and inspections are helpful but lack a systematic way to prioritize hazards or allocate safety resources efficiently, especially as projects grow more complex. This study aims to improve construction safety management by identifying common hazards, prioritizing them based on risk, and allocating safety budgets effectively using the Analytic Hierarchy Process (AHP) and the Cost of Safety (COS) model. AHP helps rank hazards through pairwise comparisons, converting expert judgment into numerical weights that indicate risk levels, ensuring that more dangerous hazards receive greater attention.

After prioritization, the COS model is applied to balance prevention costs (training, protective equipment, planning) and accident costs (medical expenses, compensation, damage, delays), demonstrating that early investment in safety reduces overall costs. The study examines hazards such as physical, electrical, machinery, chemical, environmental, fire, ergonomic, biological, and organizational risks, and distributes safety budgets proportionally based on their priority. Additionally, a Construction Safety Application was developed to simplify this process, enabling engineers and managers to perform hazard analysis, calculate AHP-based risk priorities, and allocate budgets using COS in a user-friendly system. A case study demonstrates its practical application, showing how data-driven decisions improve safety planning and resource use.

Overall, combining AHP and COS provides an effective framework for identifying risks, prioritizing hazards, and allocating safety resources logically and cost-effectively. This approach helps reduce accidents, enhance worker safety, and improve project performance, with future potential for integration with advanced technologies like real-time monitoring, artificial intelligence, and data visualization.

LIST OF FIGURES

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NOTATIONS

W_i	Weight of hazard *i*
WSV_i	Weighted Sum Vector of hazard *i*
λ_{max} (Lambda max)	Maximum Eigenvalue of the matrix
λ_i	Eigenvalue of individual hazard
n	Number of hazards (matrix size)
a_{ij}	Matrix value comparing hazard *i* with hazard *j*
CI Formula	CI= (λ max− n)/ (n-1), formula used to calculate CI
CR Formula	CR= CI/RI , formula used to calculate consistency ratio
Weight = Cell value/Column sum	Formula used to normalize pairwise matrix
$Budget_i$ = $Weight_i$×Total Safety Budget	Formula used to allocate safety budget
₹	Symbol of Indian Rupee (Indian Currency)

ABBREVIATIONS

AHP	Analytic Hierarchy Process
COS	Cost of Safety
CI	Consistency Index
CR	Consistency Ratio
RI	Random Index
PPE	Personal Protective Equipment
WSV	Weighted Sum Vector
UI	User Interface
HTML	Hyper Text Mark-up Language

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CHAPTER 1 - NTRODUCTION

1.1. GENERAL

The construction industry plays a pivotal role in national development by delivering essential structures such as buildings, roads, bridges, and utilities. It remains one of the most dangerous sectors to work in due to the combination of heavy machinery, electrical systems, elevated work, and dynamic environmental conditions, making safety management both a technical and human challenge. Construction projects are inherently complex and risky, characterized by constantly changing site conditions, simultaneous activities, and a workforce with varied skill levels all of which amplify the potential for accidents. According to Aminbakhsh, Gunduz, and Sonmez (2013), these factors contribute significantly to construction accidents, which, beyond harming workers, also disrupt project timelines, increase costs, and can lead to regulatory and legal consequences.

Accidents not only impede progress but also burden companies financially through medical costs, compensation claims, equipment damage, and reduced productivity. Prior research shows construction accidents can increase total project costs significantly reportedly by up to 15%. Moreover, workplace incidents negatively impact corporate reputation and workforce morale. To mitigate such outcomes, systematic risk assessment and budgeting have become central to modern safety management.

One of the core reasons construction projects remain high-risk is the rapid change in working conditions. Hazards such as falls from height, electrical shocks, malfunctions, and unsafe structures persist as leading causes of serious injuries. Traditional safety management often based on experience and sporadic inspections is insufficient because it lacks robust methods to prioritize risks and allocate safety resources objectively. As Fung, Tam, Lo, and Lu (2010) argue, without clear risk quantification, decision makers may misallocate attention to less critical hazards, resulting in inefficient safety investment and higher accident exposure. This issue is compounded when companies, under pressure to save time and reduce costs, deprioritize safety protocols in favour of schedule and budget targets.

To balance safety and cost, Chalos (1992) proposed the Cost of Safety (COS) model, which distinguishes between prevention costs (training, PPE, planning) and accident costs (medical treatment, compensation, downtime). According to Manuele and Main (2002), eliminating all risks is impractical due to prohibitively high costs; instead, organizations should seek to minimize the combined cost of prevention and accidents through optimized investment.

However, a key limitation of the COS model is that it does not inherently prioritize which risks should receive attention first, especially in resource-constrained projects. A structured decision-making tool is therefore essential. The Analytic Hierarchy Process (AHP), developed by Saaty (1990), addresses this gap by enabling experts to make pairwise comparisons among risks based on severity, probability, and other criteria generating a prioritized ranking. AHP is widely recognized for its ability to incorporate expert judgment in qualitative risk environments and to verify consistency in subjective evaluations.

Recent studies continue to affirm the relevance of AHP and its extensions in construction safety. For example, Zeibak-Shini et al. (2024) expanded the application of AHP to safety resource allocation, integrating both risk and cost considerations to optimize investment decisions a direct enhancement on the traditional safety budgeting frameworks. Additionally, Sunar and Handani (2026) applied AHP to systematically rank construction site risk levels based on expert prioritization of critical activities and simultaneous operations, demonstrating how structured prioritization can guide effective safety supervision.

Parallel research has also focused on comprehensive cost risk evaluation in construction by combining AHP with quantitative weighting techniques , highlighting how cost-related risk factors can be identified and ranked for better project budgeting and control a promising direction for integrating risk and cost analysis.

Despite these advancements, most studies emphasize risk ranking or resource allocation independently, with limited frameworks that jointly address risk prioritization and cost budgeting in a unified manner. Aminbakhsh et al. (2013) highlighted this limitation, noting that risk ranking alone cannot fully guide safety planning without financial integration. The AHP–COS framework, which first ranks risks using AHP and then applies COS for budget decision making, offers a practical solution. In recent applications, AHP has been adopted in case studies to include mitigation cost criteria alongside severity and likelihood bridging the gap between risk ranking and budgeting.

The present study adopts and extends this integrated approach by combining expert-based AHP risk analysis with cost evaluation models, providing a systematic, transparent, and financially informed method for safety planning in construction projects. The goal is to support project managers in making more informed decisions that not only reduce the frequency and severity of accidents but also ensure safety budgets are allocated in a way that maximizes risk reduction per unit of cost.

In conclusion, effective construction safety management requires more than reactive inspections and compliance checklists. It demands scientific tools, structured evaluation, and financial reasoning. By integrating AHP with cost analysis frameworks such as COS, managers can achieve a balanced,

efficient, and economically justified safety strategy leading to improved worker protection and optimized project performance. To help solve this, we created a Construction Safety Application. This tool uses data and math to help safety managers stop guessing and start making better decisions. Instead of just checking boxes, it helps them figure out which risks are the most dangerous and how to spend their safety budget in the smartest way possible

1.2. Objective of the study

- To identify common safety hazards on construction sites.
- To prioritize safety risks using the Analytic Hierarchy Process (AHP).
- To apply the Cost of Safety (COS) model for budgeting.
- To integrate AHP and COS into a single framework.
- To assist project managers in making better decisions.
- To reduce accidents and improve worker protection.
- To demonstrate the framework using a real construction project.
- To give project managers a single tool that handles both risk assessment and budgeting.

1.3. Scope of the study

- This study focuses only on health and safety risks in construction projects.
- The study applies only during the planning and budgeting stage of construction projects.
- Expert opinions are used to compare and evaluate risks through the AHP method.
- The COS model is used to link safety risk levels with cost planning.
- The tool is designed to be used during the planning and budgeting phase of a project, before the heavy work begins.

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CHAPTER 2 - LITERATURE SURVEY

The construction industry has been the focus of extensive research due to its high accident rates, unsafe working conditions, and complex project environment. Safety management in construction is not only about protecting workers but also about ensuring smooth project execution and cost control. This section reviews past studies related to construction safety, risk assessment techniques, the Analytic Hierarchy Process (AHP), the Cost of Safety (COS) model, and attempts to combine safety analysis with financial planning.

Construction remains one of the most dangerous industries worldwide. According to Aminbakhsh, Gunduz, and Sonmez (2013), construction sites are exposed to risks due to multiple activities taking place simultaneously and due to unpredictable environmental conditions. The authors stress that safety failures lead to poor project performance, increased financial burden, and loss of life.Further supporting this view, Pinto, Nunes, and Ribeiro (2011) explained that safety problems reduce productivity and discourage skilled workers from staying in the industry. They emphasized that accidents create emotional stress among workers and negatively affect teamwork and site morale.

The economic impact of construction accidents has also been extensively studied. Everett and Frank (1996) found that accident-related costs may account for up to 15% of the overall project cost. Similarly, Manuele and Main (2002) stated that poor safety management increases insurance premiums and legal risks, making companies less competitive in project bidding.

Several traditional risk assessment techniques have been proposed to assist construction managers in predicting and managing project risks. Howard and Matheson (1981) introduced influence diagrams for analyzing decision problems under uncertainty. Norris (1992) applied sensitivity analysis to understand the impact of uncertain variables on project performance.

The Project Management Institute (2004) recommended the use of Monte Carlo simulation and decision tree analysis to model project risks mathematically. However, these methods require technical expertise and accurate data, which is not always available in construction projects.

Because of this limitation, many managers depend on experience rather than scientific methods. According to Woodruff (2005), risk estimation should include careful evaluation of both probability and impact. However, many organizations fail to apply structured methods in daily practice.

The Analytic Hierarchy Process (AHP), introduced by Saaty (1990), became popular due to its simplicity and logic-based approach. Unlike statistical models, AHP allows managers to convert expert opinions into numerical values. The earliest safety applications of AHP were done by Freivalds (1987) and Henderson and Dutta (1992), who used the method in ergonomic risk analysis. Their studies demonstrated that expert judgment could be quantified effectively. Later, Padma and Balasubramanie (2009) showed that AHP could rank musculoskeletal disorder risks among workers. The authors demonstrated that some work postures were more harmful than others, helping managers focus on controlling high-risk activities. In the construction sector, AHP was applied by Kim, Lee, Park, and Lee (2010) in assessing construction safety influence factors. Their results showed that training, site conditions, and equipment safety play major roles in reducing accident frequency.

Similarly, Badri, Nadeau, and Gbodossou (2012) developed a risk evaluation model using AHP to integrate occupational health and safety into project risk evaluation strategies. They concluded that structured judgment improves decision quality compared to intuitive judgments.

Researchers also studied how effective safety programs are in preventing accidents. Hallowell and Gambatese (2009) used the Delphi technique and AHP to evaluate different safety programs. The study revealed that safety training, safety meetings, and hazard awareness programs significantly reduce accident rates. Hallowell (2008) developed a formal model for construction safety and showed that proactive safety techniques are more effective than reactive approaches. The author argued that most accidents can be prevented through planning rather than punishment.

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The model demonstrated that both over-investment and under-investment in safety lead to financial losses. Everett and Frank (1996) provided real evidence showing that safety failures increase project expenses significantly. According to Manuele and Main (2002), organizations must accept that some risks cannot be eliminated completely, but must be controlled at reasonable cost. The importance of safety investment planning was further discussed by Pinto et al. (2011), who concluded that financial loss from accidents is often much greater than the cost of prevention.

2.1 Limitations of the existing studies

Despite many studies, research linking safety risk analysis with cost planning is limited. Many safety models focus only on hazard identification and fail to address financial planning. According to Aminbakhsh et al. (2013)**,** this gap leads to poorly planned safety budgets. Moreover, existing research often relies on historical accident data, which may not accurately represent future risks.

Studies by Gürcanli and Müngen (2009) used fuzzy logic to handle uncertainty but still lacked cost integration.

To solve these issues, Aminbakhsh, Gunduz, and Sonmez (2013) proposed a combined framework integrating AHP with COS. In their study, hazard types were classified into accident hazards, physical hazards, and chemical hazards. Their case study revealed that trips and falls, machinery hazards, and electricity risks received the highest priority. The COS model was then used to decide how much money should be allocated to reduce these risks.

2.2. Observation from the literature study

It is clearly observed that the construction industry is one of the most hazardous working environments. Almost all researchers agree that construction workers are regularly exposed to dangers such as falls from heights, electrical shocks, moving machinery, and collapsing structures. These hazards make safety management a critical part of construction project success.

The reviewed studies strongly highlight that accidents in construction not only harm workers but also increase project costs and cause delays. Medical costs, compensation payments, equipment repair, and legal issues contribute significantly to financial losses. It is also observed that accidents reduce worker confidence and affect productivity. Many researchers emphasized that the indirect costs of accidents are often greater than direct costs.

Another important observation is that safety is often given less priority than cost and schedule in construction projects. Many companies tend to act only after an accident occurs rather than taking preventive measures. The literature shows that traditional safety practices such as visual inspections and checklist methods are still widely used, but these methods do not provide accurate risk evaluation or clear safety priorities.

The literature also reveals a strong need for structured and scientific safety evaluation methods. Most researchers conclude that relying only on experience and judgment is not sufficient to control risks effectively. Modern safety management requires systematic tools that can identify, measure, and rank safety risks in a logical manner.

One of the major findings is that the Analytic Hierarchy Process (AHP) is an effective tool for ranking safety risks. Researchers agree that AHP helps decision-makers understand which hazards are more dangerous and need immediate attention. The method is also praised for its ability to improve consistency in expert judgments and reduce subjectivity.

It is also observed that cost-related decision-making is often neglected in safety management. Many studies discuss risk evaluation but fail to connect risks with safety budgeting. The Cost of Safety (COS) model addresses this issue by showing how prevention costs and accident costs are related. Literature clearly shows that spending money on safety is an investment, not a loss.

One of the most significant observations is that combining AHP and COS provides better safety planning outcomes. The integration of risk ranking and cost planning allows managers to allocate safety budgets more effectively. This combined approach helps prioritize high-risk hazards and invest appropriately.

Another observation is that studies using real construction projects provide better insights than purely theoretical models. Case studies improve understanding and show how safety frameworks perform in actual conditions. Finally, literature consistently identifies falls, electrical hazards, and machinery accidents as the most dangerous threats in construction.

The literature confirms that effective safety management must include structured methods, financial planning, and expert involvement. The integration of AHP and COS offers a practical solution for improving construction safety and controlling costs.

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CHAPTER 3 - METHODOLOGY

The purpose of this methodology is to explain clearly how safety risks were identified, evaluated, and managed in this study. The approach used in this research is systematic and practical, ensuring that safety decisions are based on reliable analysis rather than assumptions. Since safety problems in construction are complex and involve many factors, a single method is not enough to handle the entire process. Therefore, this study combines two proven methods: the Analytic Hierarchy Process (AHP) and the Cost of Safety (COS) model.

The AHP method is used to identify and rank safety hazards based on expert judgment. It helps convert opinions into numerical values and allows risks to be compared in a structured way. By integrating these two methods, this research ensures that risk prioritization and safety budgeting are handled together. This combined approach helps project managers decide not only which hazards are most dangerous, but also how much money should be spent on each safety measure. The steps followed in this methodology are explained in detail below to ensure that the study can be easily understood and replicated.

The construction safety application follows a structured, scientific approach to ensure that safety decisions are both practical and data-driven. It begins with Hazard Identification, where the project environment is analysed to categorize risks into three primary groups: accident hazards like falls or collapses, physical hazards such as noise and heat, and chemical hazards like dust and toxic fumes. This step ensures that no potential danger is overlooked before the technical analysis begins.

To ensure the system reflects real-world conditions, an Expert Panel Consultation is conducted. Safety engineers and project managers provide their professional insights, ensuring that the data used in the application isn't just theoretical but matches the actual challenges found on a construction site. This human expertise serves as the foundation for the mathematical modelling that follows.

The core of the analysis is the Analytic Hierarchy Process (AHP). This method organizes risks into a hierarchy and uses pairwise comparisons, where experts compare two hazards at a time using a scale of 1 to 9. The application then calculates specific weights for each risk to determine which ones are the most critical. To ensure the results are logical, the system performs a consistency check; if the data is too contradictory, it flags it for review to maintain the integrity of the safety plan.

Parallel to the risk ranking, the Cost of Safety (COS) Model is applied to handle the financial side of the project.

The final stage is the Integration and Allocation of resources. The application takes the total safety budget provided by the user and automatically distributes it based on the AHP risk weights. Hazards with the highest risk scores receive the largest portion of the budget. This automated process transforms complex mathematical data into a clear, actionable financial plan, ensuring that the most dangerous areas of a construction site always have the resources needed to protect the workers.

3.1 Identification of Safety Hazards

The first and most important step in this study is identifying all possible safety hazards present on the construction site. This step helps ensure that no critical risk is ignored during the safety planning process. To prepare a complete list of hazards, previous research papers, safety manuals, and government safety guidelines were reviewed carefully.

The hazards were divided into three main categories to make analysis easier:

- Accident hazards include risks that lead to immediate injuries, such as falls from height, electrocution, crane accidents, tool misuse, and vehicle collisions on site.

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- Physical hazards refer to environmental and working condition problems such as extreme heat or cold, excessive noise, poor lighting, vibration from equipment, and exposure to radiation.
- Chemical hazards include exposure to harmful substances such as cement dust, fumes from welding, chemical solvents, toxic gases, and airborne particles.

Information about hazards was collected directly from the construction site through site visits, visual inspections, and reviewing safety records. Accident history reports, safety audit records, and toolbox talk logs were also studied. This helped ensure the hazards listed were practical and relevant.

3.2 Opinion of Expert Panel

Construction safety depends heavily on experience and professional judgment. Therefore, this study included a group of experts to ensure reliable risk evaluations. The expert panel consisted of safety engineers, construction managers, supervisors, and field experts who had experience working on construction sites. The purpose of conducting expert consultations was to ensure that risk evaluations reflected real-world conditions rather than theoretical assumptions. Each expert provided opinions independently to avoid bias

3.3 Risk Analysis Using AHP

The Analytic Hierarchy Process (AHP) method was used to rank hazards based on how dangerous they are. AHP helps in converting expert opinions into numerical priorities. It also ensures a fair comparison between risks.

- Development of Hierarchy Structure

The risk analysis problem was broken into a simple hierarchical structure:

- The goal was to identify and prioritize safety hazards.
- The criteria were the three hazard categories: accident, physical, and chemical hazards.
- The sub-criteria were individual hazards under each category, such as falling hazards, electrical shocks, machine injuries, heat stress, toxic exposure, etc.

- Pairwise Comparison
  Experts compared hazards two at a time to decide which one was more severe. A standard numerical scale was used (for example, from 1 to 9) to express importance.

VALUE	MEANING
1	Equal importance
3	Slightly more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	In between values

Table 1.saaty's (1-9) scale

- Weight Calculation

The Analytic Hierarchy Process (AHP) normalized pairwise comparison method**,** also known as the row average method, was used to calculate the weights of safety hazards. After experts compared hazards using the pairwise comparison technique, the scores were arranged into a comparison matrix. Each value in the matrix represents the importance of one hazard compared with another. To calculate weights, the matrix was first normalized by dividing each value in a column by the total of that column. This process converts raw comparison scores into proportional values. Then, the average of each row in the normalized matrix was calculated to obtain the final weight of each hazard. These weights indicate the relative importance of the hazards: a higher weight means a higher safety risk and

priority, while a lower weight means a lower level of concern. This method effectively transforms expert judgments into numerical values, allowing hazards to be ranked logically and objectively.

- Consistency Check

In real-life decision-making, people may give inconsistent judgments when comparing risks. For example, an expert may say Hazard A is more dangerous than Hazard B, and Hazard B is more dangerous than Hazard C, but then may incorrectly say Hazard C is more dangerous than Hazard A. To reduce such errors, the AHP method includes a Consistency Check. This check is done by calculating the Consistency Ratio (CR), which shows whether the judgments made by experts are logically acceptable or not.

- Calculate Consistency Ratio (CR)

The Consistency Ratio is calculated using:

$$CR = CI/RI$$

Where:

- CI = Consistency Index
- RI = Random Index value (depends on number of hazards).
  - Calculate Consistency Index (CI)

Consistency Index (CI):

$$CI = (\lambda\, max - n) / (n - 1)$$

Where:

- λ max = Maximum eigenvalue
- n = Number of hazards.

  - Random Index (RI)

Number of Hazards (n)	Random Index (RI)

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2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45

Table 2. Random index

- Acceptable Consistency

$$CR \leq 0.10$$

If:

- CR<0.10 -Accept
- CR>0.10 - Reject

3.4 Cost of Safety (COS)

The Cost of Safety (COS) model was applied to plan how much money should be invested in safety measures. This model helps in understanding how safety spending affects overall project cost. In this study, safety-related expenses were divided into two main groups: prevention costs and accident costs. Prevention costs included expenses such as safety training for workers, providing protective equipment, implementing safety programs, maintaining safety systems, and conducting regular inspections. Accident costs included medical treatment, compensation claims, equipment repair, legal penalties, production delays, and damage to company reputation. Data for these costs were collected from project financial records, insurance documents, and past accident reports. The main goal was to find a balanced level of safety spending where the total cost (prevention plus accidents) is minimized. This approach helps decision-makers understand that spending money on safety is not a waste but an investment that reduces future losses and improves project efficiency.

3.5 Safety Application

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We grouped hazards into categories we talked to safety engineers to understand which risks happen most often in the real world. Basically, the experts compared hazards against each other to see which ones were more important. The app then calculates a "weight" or score for each risk. If the experts gave inconsistent answers, the app catches it and asks for a correction. Finally, the app takes the total safety budget and automatically divides it up. The biggest risks get the most money, ensuring that resources go where they are needed most to keep workers safe.

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CHAPTER 4 - RESULT AND DISCUSSION

The comparison between the assumed hazard calculations and the calculations based on the actual safety equipment used at Chicago Constructions International Pvt Ltd shows a clear difference in analytical focus. The assumed calculation approach evaluates general construction hazards at a broader level, identifying and ranking various types of risks to understand their relative severity in theory. This method provides a conceptual risk hierarchy and helps in understanding which hazards are inherently more critical in construction environments. In contrast, the calculation based on the safety equipment used in Chicago Constructions focuses on practical implementation and resource allocation within the company's actual working conditions. Instead of only identifying hazard severity, it evaluates how safety measures and protective systems are prioritized and managed on site. Therefore, while the assumed calculations offer a theoretical risk assessment framework, the Chicago Constructions analysis reflects real-world application and operational safety planning. Together, both approaches complement each other by linking hazard identification with practical safety management strategies in construction works.

4.1 Identification of Common Construction Hazard (Assumed calculations)

- Physical hazards (A)
- Electrical hazards (B)
- Machinery hazards(C)
- Chemical hazards(D)
- Environmental hazards(E)
- Fire and explosion hazards(F)
- Ergonomic hazards(G)
- Biological hazards(H)
- Organizational hazards(I)

4.2 Pairwise Comparison Using AHP

Compare these hazards with each other to understand their relative severity. Since all hazards do not pose the same level of risk, a systematic comparison was required. For this purpose, the Analytic Hierarchy Process (AHP) was used.

In this method, experienced professionals such as safety engineers, site supervisors, and project managers compared hazards two at a time. This process is called pairwise comparison. The comparison helps determine which hazard is more dangerous and how much more dangerous it is when compared to another. To ensure consistency and clarity in expert judgments, Saaty's 1–9 scale was used. This scale allows experts to express the importance of one hazard over another using numbers.

Application of the Pairwise Comparison Process

- If Hazard A was considered more dangerous than Hazard B, a value from the Saaty scale was assigned. If Hazard B was less dangerous, the reciprocal value (1/value) was used.
- Risks compare itself value is 1.

A VS A	1
B VS B	1
C VS C	1
D VS D	1

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E VS E	1
F VS F	1
G VS G	1
H VS H	1
I VS I	1

Table 3. Risk comparing itself

- Physical hazard compare to other hazards

A VS B	3 - physical accident is more danger than electrical
AVS C	2 - both dangerous , physical is slightly higher
A VS D	5 - physical is strongly more important
A VS E	4 - physical is between strongly and very strongly
A VS F	3 - physical is strongly more significant
A VS G	6 - physical is between very strongly and strongly
A VS H	7 - physical is very strongly more important
A VS I	4 - physical is strongly more important

Table 4.Physical hazard compare to other hazards

B VS A	1/3-Reciprocal of A VS B
C VS A	1/2-Reciprocal of A VS C
D VS A	1/5-Reciprocal of A VS D
E VS A	1/4-Reciprocal of A VS E
F VS A	1/3-Reciprocal of A VS F
G VS A	1/6-Reciprocal of A VS G
H VS A	1/7-Reciprocal of A VS H
I VS A	1/4-Reciprocal of A VS I

Table 5. Reciprocal value of physical compare to other hazards

- Electrical hazard compare to other hazards

B VS C	1/2 - machinery is slightly more important
B VS D	4 - electrical is strongly more important

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B VS E	3 - electrical is strongly more important
B VS F	2- fire is more serious
B VS G	5 - electrical is very strongly important
BVS H	6 - electrical is very strongly more important
B VS I	3 - electrical is strongly more important

Table 6. Electrical hazard compare to other hazards

C VS B	2-Reciprocal of B VS C
D VS B	1/4-Reciprocal of BVS D
E VS B	1/3-Reciprocal of B VS E
F VS B	1/2-Reciprocal of B VS F
G VS B	1/5-Reciprocal of B VS G
H VS B	1/6-Reciprocal of B VS H
I VS B	1/3-Reciprocal of B VS I

Table 7. Reciprocal value of electrical compare to other hazards

- Machinery hazard compare to other hazards

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C VS D	4 – machinery strongly more important
C VS E	3 – machinery slightly more important
C VS F	3 – machinery slightly more important
CVS G	5 – machinery strongly more important
CVS H	6- machinery very strongly more important
CVS I	4 – machinery strongly more important

Table 8. Machinery hazard compare to other hazards

DVS C	1/4-Reciprocal of C VS D
E VS C	1/3-Reciprocal of C VS E
F VS C	1/3-Reciprocal of C VS F
G VS C	1/5-Reciprocal of C VS G
H VS C	1/6-Reciprocal of C VS H
I VS C	1/4-Reciprocal of C VS I

Table 9. Reciprocal value of machinery compare to other hazards

- Chemical hazard compare to other hazards

D VS E	2 – chemical is more harmful
D VS F	1/2 - fire can cause immediate harm than chemical
D VS G	4 – chemical is more serious
D VS H	4 – chemical is more danger
D VS I	3- chemical is more important

Table 10. Chemical hazard compare to other hazards

E VS D	1/2-Reciprocal of D VS E
F VS D	2-Reciprocal of D VS F
G VS D	1/4-Reciprocal of D VS G
H VS D	1/4-Reciprocal of DVS H
I VS D	1/3-Reciprocal of D VS I

Table 11. Reciprocal value of chemical compare to other hazards

- Environmental hazard compare to other hazards

E VS F	1/2 - fire is more danger

E VS G	3 – environmental issues is more danger
E VS H	4 – environmental is danger
E VS I	2 – environmental is more danger

Table 12. Environmental hazard compare to other hazards

F VS E	2-Reciprocal of F VS E
G VS F	1/3-Reciprocal of F VSG
H VS F	1/4-Reciprocal of F VS H
I VS F	1/2-Reciprocal of F VS I

Table 13. Reciprocal value of environmental compare to other hazards

- Fire hazard compare to other hazards

F VS G	4 – fire is more danger
F VS H	5 – fire is more strongly danger
F VS I	3 – fire rated higher

Table 14. Fire hazard compare to other hazards

G VS F	1/4-Reciprocal of F VS G
H VS F	1/5-Reciprocal of F VS H
I VS F	1/3-Reciprocal of F VS I

Table 15. Reciprocal value of fire compare to other hazards

- Ergonomic hazard compare to other hazards

G VS H	2 – ergonomic is danger
G VS I	1/2 - organizational is danger

Table 16. Ergonomic hazard compare to other hazards

H VS G	1/21/3-Reciprocal of G VS H
I VS G	21/3-Reciprocal of G VS I

Table 17. Reciprocal value of ergonomic compare to other hazards

- Biological hazard & Organizational hazard compare

H VS I	1/2- organizational is danger

Table 18. Biological & Organizational hazard compare

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I VS H	2-Reciprocal of H VS I

Table 19. Reciprocal value of biological & organizational compare

- Hazard comparison value matrix form like diagonal matrix

Hazard	A	B	C	D	E	F	G	H	I
Physical (A)	1	3	2	5	4	3	6	7	4
Electrical (B)	1/3	1	1/2	4	3	2	5	6	3
Machinery (C)	1/2	2	1	4	3	3	5	6	4
Chemical (D)	1/5	1/4	1/4	1	2	1/2	4	5	3
Environmental (E)	1/4	1/3	1/3	1/2	1	1/2	3	4	2
Fire& Explosion(F)	1/3	1/2	1/3	2	2	1	4	5	3
Ergonomic (G)	1/6	1/5	1/5	1/4	1/3	1/4	1	2	1/2
Biological (H)	1/7	1/6	1/6	1/5	1/4	1/5	1/2	1	1/2
Organizational (I)	1/4	1/3	1/4	1/3	1/2	1/3	2	2	1
Sum of each column	3.176	7.78	5.026	17.28	16.083	10.78	30.5	38	21

Table 20. Hazard comparison value matrix form like diagonal matrix

4.3 Weight calculation of each hazard

Weight = cell value / column sum

a) Physical hazard (A)

Comparison	Calculation	Result
A/A	1/3.176	0.314
A/B	3/7.78	0.385
A/C	2/5.026	0.397
A/D	5/17.28	0.289

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A/E	4/16.083	0.248
A/F	3/10.783	0.278
A/G	6/30.5	0.196
A/H	7/38	0.184
A/I	4/21	0.1904

Table 21. Weight calculation value of physical hazard

Therefore, weight of physical (A) =0.314+0.385+0.397+0.289+0.248+0.278+0.196+0.184+0.1904 / 9

= 2.4814 / 9 = 0.276 = **27 %**

b) Electrical hazard (B)

Comparison	Calculation	Result
B/A	0.33/3.176	0.1039
B/B	1/7.78	0.1285
B/C	0.5/5.026	0.0994
B/D	4/17.28	0.2314
B/E	3/16.083	0.1865
B/F	2/10.783	0.1854
B/G	5/30.5	0.1639
B/H	6/38	0.1578
B/I	3/21	0.1428

Table 22. Weight calculation value of electrical hazard

Therefore, weight of electrical (B)

=0.1039+0.1285+0.0994+0.2314+0.1865+0.1854+0.1639+0.1578+0.1428 / 9

= 1.3996 / 9 = 0.1555 = **15.55 %**

c) Machinery hazard (C)

Comparison	Calculation	Result
C/A	0.5/3.176	0.157
C/B	2/7.78	0.257
C/C	1/5.026	0.1989
C/D	4/17.28	0.2314
C/E	3/16.083	0.1865
C/F	3/10.783	0.278
C/G	5/30.5	0.1639
C/H	6/38	0.157
C/I	4/21	0.1904

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Table 23. Weight calculation value of machinery hazard

Therefore, weight of machinery (C)

= 1.8201 / 9 = 0.2022 = **20.22 %**

d) Chemical hazard (D)

Comparison	Calculation	Result
D/A	0.2/3.176	0.0629
D/B	0.25/7.78	0.0321
D/C	0.25/5.026	0.04974
D/D	1/17.28	0.05787
D/E	2/16.083	0.1243
D/F	05/10.783	0.0463
D/G	4/30.5	0.13114
D/H	5/38	0.1315
D/I	3/21	0.1428

Table 24. Weight calculation value of chemical hazard

Therefore, weight of chemical (D)

= 0.77865 / 9 = 0.08651 = **8.65 %**

e) Environmental hazard (E)

Comparison	Calculation	Result
E/A	0.25/3.176	0.07871
E/B	0.33/7.78	0.04241
E/C	0.33/5.026	0.06565
E/D	0.5/17.28	0.02893
E/E	1/16.083	0.06217
E/F	0.5/10.783	0.0463
E/G	3/30.5	0.09836
E/H	4/38	0.1052
E/I	2/21	0.0952

Table 25. Weight calculation value of environmental hazard

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Therefore, weight of environmental (E)

= 0.62293 / 9 = 0.069214 = **6.921 %**

f) Fire hazard (F)

Comparison	Calculation	Result
F/A	0.33/3.176	0.103904
F/B	0.5/7.78	0.06426
F/C	0.33/5.026	0.06565
F/D	2/17.28	0.11574
F/E	2/16.083	0.12435
F/F	1/10.783	0.09273
F/G	4/30.5	0.1311
F/H	5/38	0.1315
F/I	3/21	0.1428

Table 26. Weight calculation value of fire hazard

Therefore, weight of fire (F)

= 0.9720 / 9 = 0.108003= **10 %**

g) Ergonomic hazard (G)

Comparison	Calculation	Result
G/A	0.166/3.176	0.05226
G/B	0.2/7.78	0.02570
G/C	0.2/5.026	0.03979
G/D	0.25/17.28	0.01446
G/E	0.33/16.083	0.02051
G/F	0.25/10.783	0.02318
G/G	1/30.5	0.0327
G/H	2/38	0.05263
G/I	0.5/21	0.0238

Table 27. Weight calculation value of ergonomic hazard

Therefore, weight of ergonomic (G)

= 0.28503 / 9 = 0.03167= **3 %**

h) Biological hazard (H)

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Comparison	Calculation	Result
H/A	0.1428/3.176	0.04496
H/B	0.166/7.78	0.02133
H/C	0.166/5.026	0.03302
H/D	0.2/17.28	0.01157
H/E	0.25/16.083	0.01554
H/F	0.2/10.783	0.01854
H/G	0.5/30.5	0.01639
H/H	1/38	0.02631
H/I	0.5/21	0.02380

Table 28. Weight calculation value of biological hazard

Therefore, weight of biological (H)

= 0.211465 / 9 = 0.02349 = **2 %**

i) Organizational hazard (I)

Comparison	Calculation	Result
I/A	0.25/3.176	0.07871
I/B	0.33/7.78	0.04241
I/C	0.25/5.026	0.04974
I/D	0.33/17.28	0.01909
I/E	0.5/16.083	0.03108
I/F	0.33/10.783	0.03060
I/G	2/30.5	0.06557
I/H	2/38	0.05263
I/I	1/21	0.04761

Table 29. Weight calculation value of organizational hazard

Therefore, weight of organizational (I)

= 0.41744 /9 = 0.04638 = **4 %**

Code	Hazard	Weight (Wi)
A	Physical	0.27
B	Electrical	0.15
C	Machinery	0.20
D	Chemical	0.08

E	Environmental	0.06
F	Fire	0.10
G	Ergonomic	0.03
H	Biological	0.02
I	Organizational	0.04

Table 30. Weight table of hazards

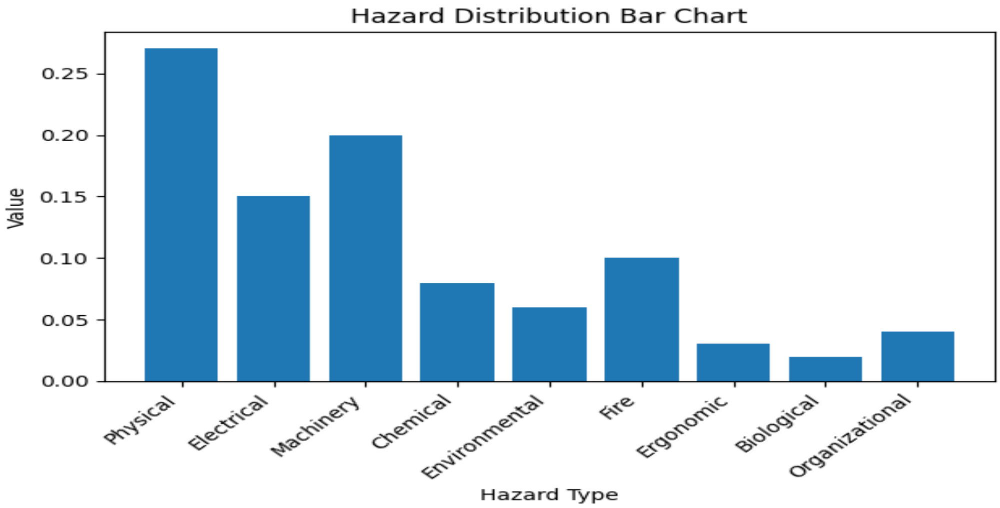

Figure1. Hazard weight distribution bar chart

- Hazards are ranked according to their assigned weights

Rank	Hazard
1	Physical
2	Machinery
3	Electrical
4	Fire
5	Chemical
6	Environmental
7	Organizational
8	Ergonomic
9	Biological

Table 31. Hazard ranked according to weights

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4.4 Consistency check OR Consistency Ratio

CR = Consistency index / random index

- **Consistency Index (CI)**

$$WSVi = \Sigma\ (aij * wi)$$

Where,

WSV_i = ***Weighted sum vector of hazards***

a_{ij} = ***Matrix value***

w_i = ***weight of hazards***

i. Physical hazard

WSV_A = (1×0.27)+(3×0.15)+(2×0.20)+(5×0.08)+(4×0.06)+(3×0.10)+(6×0.03)+(7×0.02)+(4×0.04) = **2.54**

ii. Electrical hazard

WSV_B = (0.33×0.27)+(1×0.15)+(0.5×0.20)+(4×0.08)+(3×0.06)+(2×0.10)+(5×0.03)+(6×0.02)+(3×0.04) = **1.429**

iii. Machinery hazard

WSV_C = (0.5×0.27)+(2×0.15)+(1×0.20)+(4×0.08)+(3×0.06)+(3×0.10)+(5×0.03)+(6×0.02)+(4×0.04) = **1.865**

iv. Chemical hazard

WSV_D = (0.2×0.27)+(0.25×0.15)+(0.25×0.20)+(1×0.08)+(2×0.06)+(0.5×0.10)+(4×0.03)+(5×0.02)+(3×0.04) = **0.7315**

v. Environmental hazard

WSV_E = (0.25×0.27)+(0.33×0.15)+(0.33×0.20)+(0.5×0.08)+(1×0.06)+(0.5×0.10)+(3×0.03)+(4×0.02)+(2×0.04) = **0.583**

vi. Fire hazard

WSV_F = (0.33×0.27)+(0.5×0.15)+(0.33×0.20)+(2×0.08)+(2×0.06)+(1×0.10)+(4×0.03)+(5×0.02)+(3×0.04) = **0.9501**

vii. Ergonomic hazard

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WSV_G =
(0.166×0.27)+(0.2×0.15)+(0.2×0.20)+(0.25×0.08)+(0.33×0.06)+(0.25×0.10)+(1×0.03)+(2×0.02)+(0.5×0.04) = **0.2696**

viii. Biological hazard

WSV_H =
(0.142×0.27)+(0.166×0.15)+(0.166×0.20)+(0.2×0.08)+(0.25×0.06)+(0.2×0.10)+(0.5×0.03)+(1×0.02)+(0.5×0.04) = **0.2024**

ix. Organizational hazard

WSV_I = (0.25×0.27)+(0.33×0.15)+(0.25×0.20)+(0.33×0.08)+(0.5×0.06)+(0.33×0.10)+(2×0.03)+(2×0.02)+(1×0.04) = **0.396**

Hazard	WSV_i
Physical (A)	2.54
Electrical (B)	1.429
Machinery (C)	1.865
Chemical (D)	0.7315
Environmental (E)	0.583
Fire (F)	0.9501
Ergonomic (G)	0.269
Biological (H)	0.2024
Organizational (I)	0.396

Table 32. Weighted sum vector of hazards

$$\tau i = \frac{WSVi}{Wi}$$

Where,

λ_i = ***Eigen value (consistency value for hazard i)***

Hazard	WSV_i	W_i	τi
Physical	2.54	0.27	9.407
Electrical	1.429	0.15	9.526
Machinery	1.865	0.20	9.325
Chemical	0.7315	0.08	9.143
Environmental	0.585	0.06	9.75
Fire	0.9501	0.10	9.501
Ergonomic	0.269	0.03	8.96

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Biological	0.2024	0.02	10.12
Organizational	0.396	0.04	9.9

Table 33. Eigen value of hazards

$$\tau\, max = \Sigma\, \tau i/n$$

Where,

$\lambda\, max = Max\, Eigen\ value$

$n = Matrix\ size$

λ_{max} = 9.407+9.526+9.325+9.143+9.75+9.501+8.96+10.12+9.9 / 9 = **9.514**

∴ Consistency Index = $\lambda_{max} - n\ /n\text{-}1$

= 9.514 – 9 / 8 = **0.064**

- **Random Index Table (RI)**

Number of Hazards (n)	Random Index Value (RI)
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45

Table 34. Random index table

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∴ Consistency Ratio = 0.064 / 1.45 = **0.0441(Acceptable)**

4.5 Safety resource allocation

Priority level	Resource allocation
High	Maximum resource
Medium	Moderate resource
Low	Basic resource

Table 35. Safety resource allocation

4.6 Budget calculation

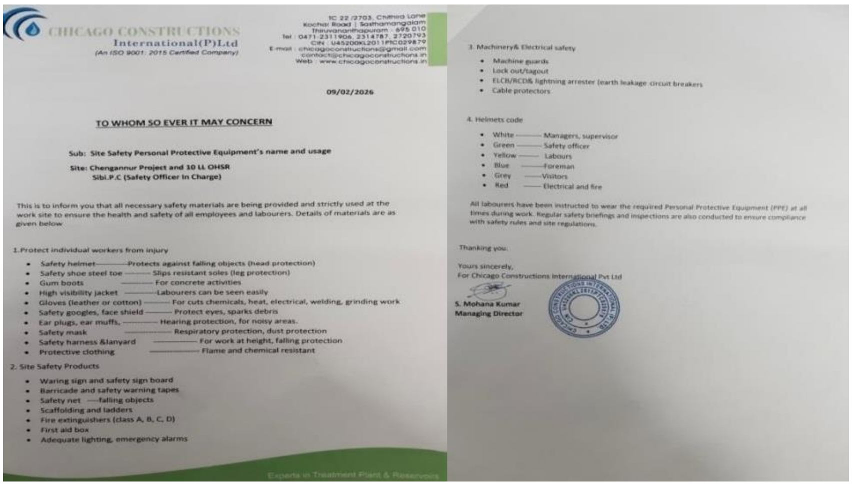
Total safety budget = 10, 00,000 ₹

Budget for each hazard = Weight of each hazard× Total budget

Hazard	Budget %	Budget ₹
Physical	27 %	270000 ₹
Machinery	20 %	200000 ₹
Electrical	15 %	150000 ₹
Fire and explosion	10 %	100000 ₹
Chemical	8 %	80000 ₹
Environmental	6 %	60000 ₹
Organizational	4 %	40000 ₹
Ergonomic	3 %	30000 ₹
Biological	2 %	20000 ₹
Total sum		950000 ₹

Table 36. Budget calculation

Safety Budget calculation for the work of Chicago Constructions International Pvt Ltd



CHICAGO CONSTRUCTIONS
International(P)Ltd
(An ISO 9001: 2015 Certified Company)

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09/02/2026

TO WHOM SO EVER IT MAY CONCERN

Sub: Site Safety Personal Protective Equipment's name and usage

Site: Chengannur Project and 10 LL OHSR
Sibi.P.C (Safety Officer In Charge)

This is to inform you that all necessary safety materials are being provided and strictly used at the work site to ensure the health and safety of all employees and labourers. Details of materials are as given below

1.Protect individual workers from injury

- Safety helmet———Protects against falling objects (head protection)
- Safety shoe steel toe ——— Slips resistant soles (leg protection)
- Gum boots ——— For concrete activities
- High visibility jacket ———Labourers can be seen easily
- Gloves (leather or cotton) ——— For cuts chemicals, heat, electrical, welding, grinding work
- Safety googles, face shield ——— Protect eyes, sparks debris
- Ear plugs, ear muffs, ——— Hearing protection, for noisy areas.
- Safety mask ——— Respiratory protection, dust protection
- Safety harness &lanyard ——— For work at height, falling protection
- Protective clothing ——— Flame and chemical resistant

2. Site Safety Products

- Waring sign and safety sign board
- Barricade and safety warning tapes
- Safety net —falling objects
- Scaffolding and ladders
- Fire extinguishers (class A, B, C, D)
- First aid box
- Adequate lighting, emergency alarms

3. Machinery& Electrical safety

- Machine guards
- Lock out/tagout
- ELCB/RCD& lightning arrester (earth leakage circuit breakers
- Cable protectors

4. Helmets code

- White ——— Managers, supervisor
- Green ——— Safety officer
- Yellow ——— Labours
- Blue ———Foreman
- Grey ———Visitors
- Red ——— Electrical and fire

All labourers have been instructed to wear the required Personal Protective Equipment (PPE) at all times during work. Regular safety briefings and inspections are also conducted to ensure compliance with safety rules and site regulations.

Thanking you.

Yours sincerely,
For Chicago Constructions International Pvt Ltd

S. Mohana Kumar
Managing Director

Figure2. Details of site safety's used in chicago constructions

Payment Breakup

Name of work :- Design, construction, commissioning and maintenance of 5MLD WTP , 6m dia Intake well cum pump house,10LL OHSR ,5LL OHSR ,supplying, laying, testing, commissioning and maintenance of Raw Water Pumping Main,Clear water pumping mains to OHSRs and distribution systems with providing FHTCs ,Supply and erection of Raw water and Clear water motor pump sets

	Accepted PAC	Rs 357152750					
Sl No	Description of Item	Qty	Percentage	Amount	Full	80%	Actual Balance
I	**SUPPLYING AMND LAYING RAW WATER PUMPINHG MAIN - COST OF MATERIALS - (80% OF ESTIMATE RATE)**						
	Supply of DI K9 Pipe Conforming to IS 8329/2000, 300mm Dia.	2805 m	2.2227%	7938486.60	9923108.25	7938486.60	1984621.65
	Supply of CI Air Valve with Flanges, Conforming to IS 14845 - 2000, Kinetic Air Valve Type DS2, Size 80mm.	5 Nos	0.0049%	17471.60	21839.5	17471.6	4367.90
	Providing and fixing gun metal gate valve with C.I. wheel of approved quality (screwed end) :80 mm nominal bore	5 Nos	0.0029%	10377.91	12972.39	10377.912	2594.48
	Supply of CI Non Return Valve, Conforming to IS 5312 Part I - 1984, PN 1.0, Size 300mm.	1 Nos	0.0075%	26645.92	33307.4	26645.92	6661.48
	Supply of CI Double Flanged Sluice Valve Conforming to IS 14846 - 2000, Sluice Valve with Hand Wheel PN 1.6, Size 200mm.	1 Nos	0.0027%	9550.88	11938.6	9550.88	2387.72
	Supply of CI Double Flanged Sluice Valve Conforming to IS 14846 - 2000, Sluice Valve with Cap PN 1.6, Size 300mm.	1 Nos	0.00485%	17323.16	21653.95	17323.16	4330.79
	RAW WATER PUMPING MAIN - WORKING CHARGES						
	Conveying and laying of 300mm DI K9 Pipes including earth work excavation in all classes of soil ,hard soil, medium rock and hard rock etc ,conveying,cutting,jointing,testing with required test pressure ,fencing,demolishing CC and RCC ,dismantling bituminious road ,refilling the trenches ,supplying and fixing necessary DI specials, providing Anchor blocks in bends, etc complete, including balance amount of materials as per scope of work in NIT	2750 m	1.6313%	5826323.36			
	Conveying and fixing 300mm Non Return valve - 3Nos,fixing 200mm Sluice valve 1No and fixing 80mm Air valve 5Nos with 80mm GM valve including balance amount of materials and all works as per scope of work in NIT		0.0076%	27212.55			
	Construction of Valve chamber for NRV and Scour valve including necessary earythwork excavation,PCC,RCC,Centering and provinding Protection tube for Air valves all work specified in the NIT	3 Nos	0.0231%	82533.82			
	Casting and fixing of Identification blocks along the alignment of pipe line as specified in the NIT	5 Nos	0.0012%	4165.47			
	CLEAR WATER PUMPING MAIN 5 LL OHSR - COST OF MATERIALS - 80%OF ESTIMATE RATE						
	Supply of DI K9 Pipe Conforming to IS 8329/2000, 200mm Dia.	3213 m	1.5117%	5399253.72	6749067.15	5399253.72	1349813.43
	Supply of CI Air Valve with Flanges, Conforming to IS 14845 - 2000, Kinetic Air Valve Type DS2, Size 80mm.	5 Nos	0.0049%	17471.60	21839.5	17471.6	4367.90

Figure3. Budget allocation

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4.7 Site safety equipment's used for the work

- Personal individual workers from injury (PPE) – A
- Site Safety & Protection Systems – B
- Machinery & Electrical Safety – C
- Helmets - D

4.8 Pair wise comparison using AHP & saaty's scale (1 -9)

- A compare to other safety equipment's

A VS A	1 – Risk compare itself value is 1
A VS B	1/2 - Site safety products slightly more important than PPE
A VS C	1/3 – Machinery and electrical is more danger
A VS D	4 – PPE is slightly more important than helmets

Table 37.A compare to other safety equipment's

- B compare to other safety equipment's

B VS A	2 – Reciprocal of A VS B
B VS B	1 - Risk compare itself value is 1
B VS C	1/2 - Machinery and electrical is slightly more important than B
B VS D	5 – B is strongly more important than D

Table 38.B compare to other safety equipment's

- C compare to other safety equipment's

C VS A	3 - Reciprocal of A VS C
C VS B	2
C VS C	1 - Risk compare itself value is 1
C VS D	6 – Machinery and electrical is very strongly and strongly more important than D (in between)

Table 39.C compare to other safety equipment's

- D compare to other safety equipment's

D VS A	1/4 - Reciprocal of A VS D

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D VS B	1/5 - - Reciprocal of BVS D
D VS C	1/6 - Reciprocal of C VS D
D VS D	1 - Risk compare itself value is 1

Table 40.D compare to other safety equipment's

4.9 Pairwise comparison matrix

Hazard	A	B	C	D
A – PPE	1	1/2	1/3	4
B – Site safety products	2	1	1/2	5
C – Machinery & electrical	3	2	1	6
D – Helmets	1/4	1/5	1/6	1
Sum of each column	6.25	3.7	2	16

Table 41. Pairwise comparison matrix of safety equipment's

4.10 Weight calculation of each safety equipment's

a) Weight Calculation Of A

A/A	1/6.25	0.16
A/B	0.5/3.7	0.135
A/C	0.33/2	0.165
A/D	4/16	0.25

Table 42. Weight calculation of A

Weight of A = 0.71/4 = 0.1775 = **17.7%**

b) Weight Calculation of B

B/A	2/6.25	0.32
B/B	1/3.7	0.2702
B/C	0.5/2	0.25
B/D	5/16	0.312

Table 43. Weight calculation of B

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Weight of B = 1.152/4 = 0.288 = **28.8%**

c) Weight Calculation Of C

C/A	3/6.25	0.48
C/B	2/3.7	0.5405
C/C	1/2	0.5
C/D	6/16	0.375

Table 44. Weight calculation of C

Weight of C = 1.895/4 = 0.473 = **47.3%**

d) Weight Calculation Of D

D/A	0.25/6.25	0.04
D/B	0.2/3.7	0.054
D/C	0.166/2	0.083
D/D	1/16	0.062

Table 45. Weight calculation of D

Weight of D = 0.239/4 = 0.06 = **6 %**

Hazard	Weight (w_i)
A	0.177
B	0.288
C	0.473
D	0.06

Table 46. Weight table of safety equipment's

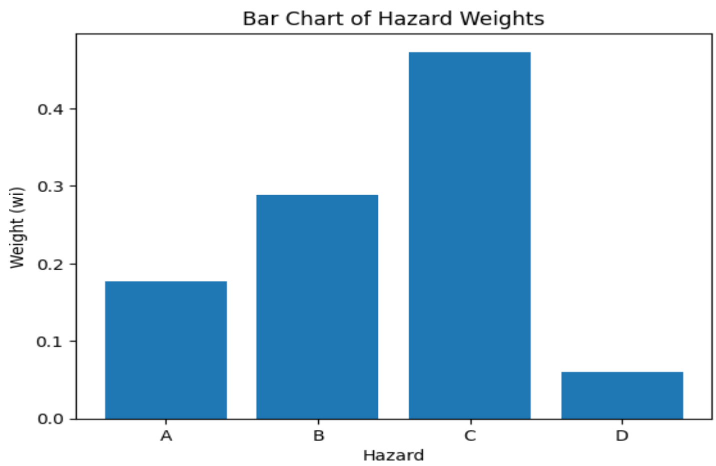

Figure 4. Hard - weight distribution bar chart

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Safety equipment's are ranked according to their assigned weights

Hazard	Rank
A	3
B	2
C	1
D	4

Table 47. Safety equipment's ranked according to their weights

4.11 Consistency check / Consistency ratio

CR = Consistency index / random index

- **Consistency Index (CI)**

$$WSVi = \Sigma\,(aij * wi)$$

Where,

WSV_i = ***Weighted sum vector of hazards***

a_{ij} = ***Matrix value***

w_i = ***weight of hazards***

i. WSV_A = (1×0.177) + (0.5×0.288) + ((0.33×0.473) + (4×0.06) +) = **0.717**

ii. WSV_B = (2×0.177) + (1×0.288) + (0.5×0.473) + (5×0.06) +) = **1.17**

iii. WSV_C = (3×0.177) + (2×0.288) + (1×0.473) + (6×0.06) +) = **1.94**

iv. WSV_D = (0.25×0.177) + (0.2×0.288) + (0.166×0.473) + (1×0.06) +) = **0.240**

$$\tau i = \frac{WSVi}{Wi}$$

Where,

λ_i = ***Eigen value (consistency value for hazard i)***

Hazard	λi

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A	0.717 / 0.177 =4.05
B	1.178 / 0.288 = 4.09
C	1.94 / 0.473 = 4.101
D	0.24 / 0.06 = 4

Table 48. Eigen value of safety equipment's

$$\tau\, max = \Sigma\, \tau i/n$$

Where,

$\lambda\, max$ = *Max Eigen value*

n = Matrix size

λ_{max} = 4.05+4.09+4.101+4 / 4 = **4.0602**

∴ Consistency Index = $\lambda_{max} - n\ /n\text{-}1$

= 4.0602 - 4 / 3 = **0.020**

∴ Consistency Ratio = 0.020 / 0.90 = **0.02 (Acceptable)**

4.12 Budget calculation

Total safety budget = 359851.04 ₹

Tank 1 total amount = 0.0181+0.1410+0.7390+0.6343+0.8423+0.6922+0.2361+0.3276 = 3.6306 %

= 357152750 × 3.6306 / 100

= 12966787.74 ₹

Tank (2) total = 0.0333 +0.2611+1.3622+1.1691+1.3729+1.3814+0.4351+0.6039 = 6.6190 %

= 357152750 × 6.6190 /100

= 23639940.52 ₹

Water tank Plant total =

0.0990+0.0022+0.0244+0.0907+0.0156+0.0022+0.0873+0.0171+0.0122+0.1182+0.6985+0.1856+0.1856+0.3459+0.0974+0.0992+0.1583+0.0629+0.0197+0.1583+0.4981+0.1993+0.1714+0.1714+0.4186+0.2849+0.2682+0.0648+0.1949+0.0998+0.3063+0.0984+0.28+0.2182+0.5472+0.3082+0.134+0.1

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206+0.1154+0.2525+0.1462+0.2424+0.1669+0.0825+0.0548+0.0903+0.7065+0.4625+0.4385+0.278

4 = 9.9015 %

= 357152750 × 9.9015 / 100

= 35363479.54 ₹

Total % = 3.6306 + 6.6190 + 9.9015 = 20.1511 %

Total amount of construction work = 35363479.54+2.3639940.52+12966787.74 = 71970208.00 ₹

Total amount of safety = 71970207.81 × 0.50 = 359851.04 ₹ (0.5 % of total amount)

Budget for each hazard = Weight of each hazard× Total budget

Hazard	Budget %	Budget ₹
A	17 %	61174.68 ₹
B	28 %	100758.29 ₹
C	47 %	169130.99 ₹
D	6 %	21591.06 ₹
Total amount		352655.02 ₹

Table 49. Budget calculation

4.13 Construction safety application

Construction safety app is a Python-based web application developed to support decision-making in construction safety. The main purpose of this application is to provide interactive tools that help users evaluate construction equipment and safety options using structured analytical methods. The system mainly uses decision-making techniques such as the Analytic Hierarchy Process (AHP) and additional safety or cost-related computations (COS). Through a user-friendly web interface, users can enter their data, perform evaluations, and clearly view the results. This makes the application useful for improving safety planning and selecting the most suitable equipment or safety measures in construction projects.

The main file, app.py, acts as the entry point of the application and handles web requests using the Flask framework. The logic and calculations are separated into different Python files such as ahp.py, ahp_equipment.py, and cos.py, which contain the core decision-making algorithms. This separation ensures that the application logic remains independent from the user interface. The project also includes HTML template files such as *cos.html* and *ahp_main.html*, which are responsible for displaying forms and results to users. Styling is managed through a CSS file named *style.css*, ensuring

the application has a clean and readable interface. In addition, the project contains a *requirements.txt*

file to manage dependencies and test files (test_*.py) to validate the correctness of the system.

The application is built using several important technologies. Python is used as the main programming language because it is easy to read, flexible, and has a strong ecosystem for scientific and mathematical applications. Flask is used as the web framework because it is lightweight and simple, allowing developers to quickly connect web pages to backend logic without unnecessary complexity. Jinja2 templates are used to connect Python code with HTML pages, enabling dynamic content to be displayed based on user input and calculated results. HTML and CSS are used to design the user interface, ensuring the system can be accessed easily through any web browser. Together, these technologies create a smooth and interactive web application.

These modules calculate weights, compare alternatives, and check consistency in decisions. This method is especially useful in construction safety, where multiple factors such as cost, risk, and performance must be considered at the same time. By keeping these calculations separate from the user interface, the system remains modular, easier to maintain, and easier to test.

Testing is another important part of this project. The test files (test_*.py) are used to automatically verify that the calculations and application routes are working correctly. Automated testing increases confidence in the system and makes future improvements safer, as errors can be detected early. The presence of a *requirements.txt* file ensures that all necessary libraries can be installed easily, allowing other developers to reproduce the same working environment. The project also includes a *Procfile.txt*, which provides instructions for deploying the application on cloud platforms. This makes it easier to host the application online and access it from different locations.

The design of the project offers several advantages. The modular structure improves maintainability because each component has a specific role. The separation between computation logic, web routing, and presentation makes the system cleaner and more organized. The AHP logic can also be reused in other projects that require multi-criteria decision-making. Furthermore, the web-based interface makes the tool accessible to users who may not have programming knowledge. Instead of writing code, users can simply fill out forms and receive clear results.

In conclusion, the Construction safety app project is a well-structured and practical decision-support system designed for construction safety evaluation. It combines analytical algorithms with a simple web interface to help users make informed decisions. The use of Python, Flask, structured modules, and automated testing ensures that the system is reliable, maintainable, and easy to extend in the future. With further improvements such as enhanced documentation, additional example data, and improved user interface design, the application can become an even more powerful tool for safety management in construction projects.

- Hazard Risk Analysis Using AHP

One of the core features of the system is evaluating nine construction hazard categories using the Analytic Hierarchy Process (AHP). As described in the construction notes, AHP is used to structure multi-criteria decision-making and provide explainable ranking of alternatives based on weighted criteria.

The nine hazard categories included in the system are:

- Physical Hazards
- Electrical Hazards
- Machinery Hazards
- Chemical Hazards
- Environmental Hazards
- Fire & Explosion Hazards
- Ergonomic Hazards
- Biological Hazards
- Organizational Hazards

The system allows users to compare hazards pairwise using a scale from 1 to 9 (Saaty scale). These comparisons are then used to build a pairwise comparison matrix. The matrix is constructed so that the diagonal elements are 1 (because each hazard is equally important to itself), and the lower triangular values are the reciprocals of the upper triangular values.

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```
# Random Index values
RI_DICT = {
    1: 0.00,
    2: 0.00,
    3: 0.58,
    4: 0.90,
    5: 1.12,
    6: 1.24,
    7: 1.32,
    8: 1.41,
    9: 1.45,
    10: 1.49
}
```

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```
# 9 Construction Hazard Categories
HAZARD_NAMES = [
    'Physical Hazards',
    'Electrical Hazards',
    'Machinery Hazards',
    'Chemical Hazards',
    'Environmental Hazards',
    'Fire & Explosion Hazards',
    'Ergonomic Hazards',
    'Biological Hazards',
    'Organizational Hazards'
]

SHORT_NAMES = ['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I']


def build_matrix_from_comparisons(comparisons_dict, n=9):
    """Build pairwise comparison matrix from user inputs.

    Args:
        comparisons_dict: Dictionary with keys like 'h0_h1', 'h0_h2', etc.
                         Values are floats (1-9 scale)
        n: Matrix dimension (default 9 for 9 hazards)

    Returns:
        numpy array: n x n pairwise comparison matrix
    """
    # Initialize matrix with 1s on diagonal
    matrix = np.ones((n, n), dtype=float)

    # Fill upper triangle from user inputs
    for i in range(n):
        for j in range(i + 1, n):
            key = f'h{i}_h{j}'
            if key in comparisons_dict:
                try:
                    value = float(comparisons_dict[key])
                    # Validate value is between 1 and 9
                    if 1 <= value <= 9:
                        matrix[i][j] = value
                        matrix[j][i] = 1 / value  # Reciprocal rule
                except (ValueError, TypeError):
                    # Skip invalid values
                    pass

    return matrix


def calculate_ahp(matrix):
    """Calculate AHP weights from pairwise comparison matrix.

    Args:
```

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```
        matrix: n x n pairwise comparison matrix (numpy array or list)

    Returns:
        tuple: (hazard_names, weights, lambda_max, CI, CR, consistency_status)
            - hazard_names: List of hazard category names
            - weights: Normalized priority weights (sum = 1)
            - lambda_max: Maximum eigenvalue
            - CI: Consistency Index
            - CR: Consistency Ratio
            - consistency_status: 'Consistent' if CR < 0.1, else 'Review Needed'
    """
    matrix = np.array(matrix, dtype=float)
    n = matrix.shape[0]

    # Eigenvalue decomposition
    eigenvalues, eigenvectors = np.linalg.eig(matrix)

    # Find maximum eigenvalue and corresponding eigenvector
    lambda_max = np.max(eigenvalues.real)
    max_index = np.argmax(eigenvalues.real)
    weights = eigenvectors[:, max_index].real

    # Normalize weights so sum = 1
    weights = weights / np.sum(weights)

    # Consistency Index
    CI = (lambda_max - n) / (n - 1)

    # Consistency Ratio
    RI = RI_DICT[n]
    CR = CI / RI if RI != 0 else 0

    # Consistency Status
    consistency_status = 'Consistent' if CR < 0.1 else 'Review Needed'

    return HAZARD_NAMES, weights, lambda_max, CI, CR, consistency_statuso world!')
```

After building the matrix, the system performs eigenvalue decomposition using NumPy to calculate the priority weights and consistency measures:

```
def calculate_ahp(matrix):
    matrix = np.array(matrix, dtype=float)
    n = matrix.shape[0]

    eigenvalues, eigenvectors = np.linalg.eig(matrix)

    lambda_max = np.max(eigenvalues.real)
    max_index = np.argmax(eigenvalues.real)
    weights = eigenvectors[:, max_index].real
    weights = weights / np.sum(weights)
```

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```
    CI = (lambda_max - n) / (n - 1)
    RI = RI_DICT[n]
    CR = CI / RI if RI != 0 else 0

    consistency_status = 'Consistent' if CR < 0.1 else 'Review Needed'

    return HAZARD_NAMES, weights, lambda_max, CI, CR, consistency_status
```

This implementation ensures that hazard ranking is not based on guesswork but on structured mathematical computation. The Consistency Ratio (CR) verifies whether the decision-maker's comparisons are logically consistent.

- Equipment Safety Evaluation Using AHP

In addition to hazard evaluation, the system also evaluates construction safety equipment using AHP. As mentioned in the construction notes, separating algorithm logic from UI ensures modularity and easier testing.

The four equipment categories evaluated are:

- Personal Protective Equipment (PPE)
- Site Safety & Protection Systems
- Machinery & Electrical Safety
- Helmets

```
import numpy as np

EQUIPMENT_NAMES = [
    'Personal Protective Equipment (PPE)',
    'Site Safety & Protection Systems',
    'Machinery & Electrical Safety',
    'Helmets'
]

def build_equipment_matrix(comparisons):
    n = 4
    mat = np.ones((n, n), dtype=float)

    idx = {
        ('A', 'B'): (0, 1),
        ('A', 'C'): (0, 2),
        ('A', 'D'): (0, 3),
        ('B', 'C'): (1, 2),
        ('B', 'D'): (1, 3),
        ('C', 'D'): (2, 3),
    }
```

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```
    for key, (i, j) in idx.items():
        k = f"{key[0]}_{key[1]}"
        if k in comparisons:
            try:
                val = float(comparisons[k])
                if val <= 0:
                    val = 1.0
            except Exception:
                val = 1.0
        else:
            val = 1.0

        mat[i, j] = val
        mat[j, i] = 1.0 / val

    return mat
```

The AHP calculation for equipment is performed as follows

```
def calculate_equipment_ahp(matrix):
    n = matrix.shape[0]
    eigenvalues, eigenvectors = np.linalg.eig(matrix)

    eigvals_real = eigenvalues.real
    max_idx = int(np.argmax(eigvals_real))
    lambda_max = eigvals_real[max_idx]

    principal_eigvec = eigenvectors[:, max_idx].real
    principal_eigvec = np.abs(principal_eigvec)

    weights = principal_eigvec / np.sum(principal_eigvec)

    CI = (lambda_max - n) / (n - 1)
    RI = 0.90
    CR = CI / RI if RI != 0 else float('inf')
    consistency_status = CR < 0.1

    return EQUIPMENT_NAMES, weights, float(lambda_max), float(CI), float(CR), consistency_status
```

- Budget Allocation Based on Risk Weights

According to the project design, the modular logic allows reuse of AHP results for financial decision-making. After computing hazard weights, the system allocates the total safety budget proportionally.

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```
def calculate_budget_allocation(total_budget, risk_weights):
    """Allocate budget based on hazard risk weights.

    Args:
        total_budget: Total safety budget to allocate
        risk_weights: List of weights for each hazard category (should sum to 1)

    Returns:
        List of allocated amounts for each hazard category
    """
    allocation = []
    for weight in risk_weights:
        allocated = weight * total_budget
        allocation.append(allocated)
    return allocation


def calculate_total_cost(prevention_cost, accident_cost):
    """Calculate total safety cost (prevention + accident costs).

    Args:
        prevention_cost: Cost of prevention measures
        accident_cost: Cost of handling accidents

    Returns:
        Sum of prevention and accident costs
    """
    return prevention_cost + accident_cost
```

- Total Safety Cost Calculation

The system calculates total safety cost by combining prevention and accident costs

```
def calculate_total_cost(prevention_cost, accident_cost):
    return prevention_cost + accident_cost
```

This calculation helps organizations understand whether increasing prevention investment can reduce overall long-term accident costs.

4.14 Construction safety application screens

This page provides users with a clear overview of the system’s two primary functional modules: AHP Risk Assessment and COS Budget Allocation. The layout is designed to be simple and user-friendly

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so that safety managers or project engineers can easily navigate through different analytical functions. On the left side of the interface, a navigation panel titled "Safety System" is displayed. This panel includes several navigation options such as Home, AHP Analysis, COS Budgeting, Equipment AHP, and Equipment Budgeting. These menu items allow users to move between different modules of the system without difficulty. The blue sidebar improves accessibility and ensures that users can quickly access the specific analytical component they need. In the centre of the screen, two major functional cards are displayed. The first card represents the AHP Risk Assessment module. This module helps determine the relative importance or priority of various hazards and also provides a consistency check to validate the reliability of the judgments entered by the user. Buttons such as "Risk Analysis," "Consistency Check," and "Start AHP Analysis" enable users to begin the evaluation process. The second card displayed on the home page represents the COS Budget Allocation module, which focuses on allocating safety budgets across different hazard categories based on their calculated priorities. This module assists decision-makers in distributing financial resources efficiently to achieve maximum safety improvement. Options like "Budget Planning," "Optimization," and "Allocate Budget" guide the user to the budgeting process. Overall, this interface acts as the central control panel of the application, linking risk evaluation and budget allocation in a structured decision-support workflow.

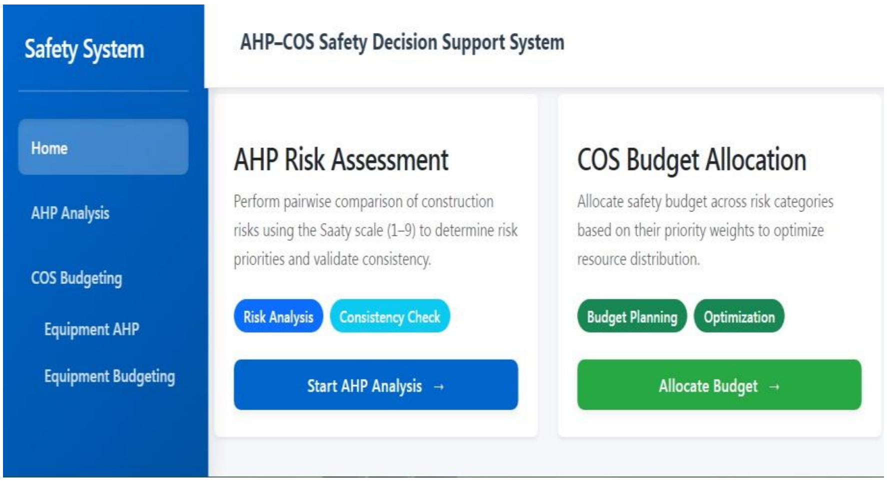

Figure 5. Home page of safety app

This page enables users to perform pairwise comparisons between hazard categories, which is a key step in the AHP methodology. The comparisons allow decision makers to express how much more important one hazard is relative to another using the Saaty scale values ranging from 1 to 9. In this interface, the system lists different hazard categories represented by alphabetical labels such as A, B, C, and D, corresponding to hazards like Physical Hazards, Electrical Hazards, Machinery Hazards, and Chemical Hazards. Each row represents a comparison between two hazard categories. For example, the interface shows comparisons such as Physical Hazards vs. Electrical Hazards, Physical

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Hazards vs Machinery Hazards, and Physical Hazards vs. Chemical Hazards. Users can input numerical values in the comparison fields to indicate the relative importance between the two hazards. A value of 1 indicates equal importance, while larger values indicate stronger importance of one hazard over another. This page plays a crucial role in the system because the pairwise comparison data collected here is used to calculate priority weights for each hazard category. The system later uses these weights to determine which hazards require more attention and resources. The values entered in the comparison fields represent the user's judgment regarding the importance of one equipment type over another..

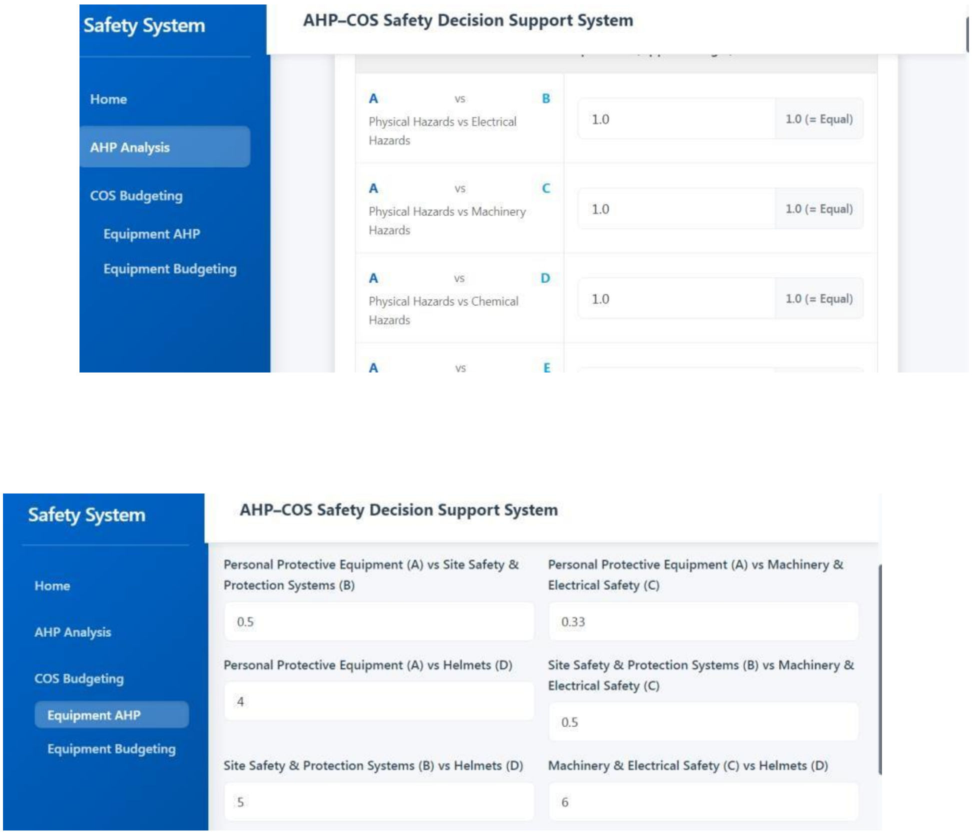

Figure 6. Weight input page

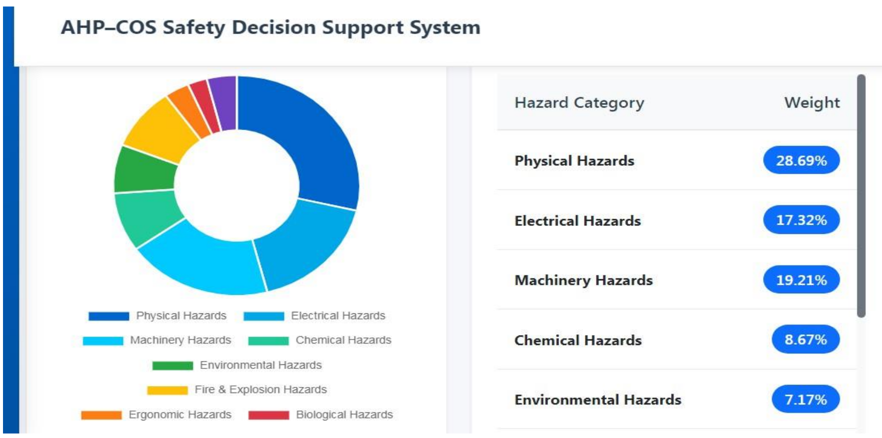

Figure7. Pages showing the total weight and a bar chart of the weights

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Personal Protective Equipment (PPE)	0.1754	18%	-
Site Safety & Protection Systems	0.2885	29%	-
Machinery & Electrical Safety	0.4771	48%	-
Helmets	0.0590	6%	-

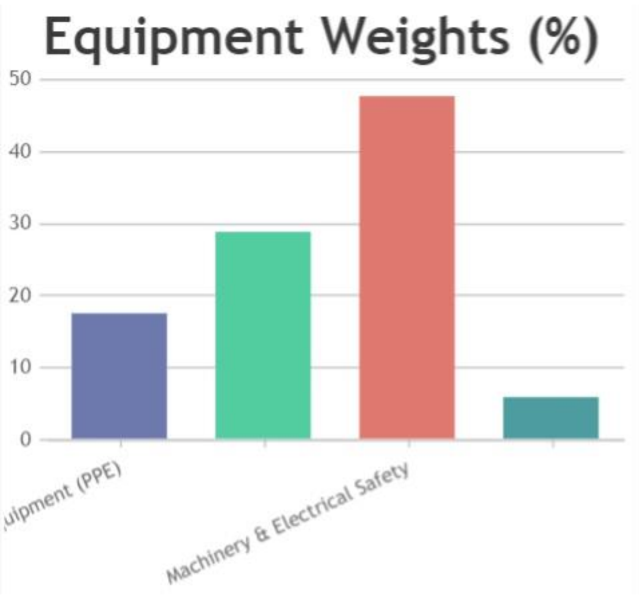


Figure 8. Pages that shows the total weight in % and a bar chart of the weight %

The COS Budget Allocation interface, which is responsible for distributing safety budgets across hazard categories based on the priorities, calculated using the AHP method. The purpose of this page is to ensure that financial resources are allocated in a way that maximizes safety performance and reduces the most critical risks first. At the top of the interface, a purpose description box explains the objective of the module. It states that the system allocates safety budgets across nine hazard categories based on AHP risk assessment results, helping optimize the distribution of safety resources. This description ensures that users clearly understand how the budgeting process is linked with the earlier risk evaluation stage. Below the description, the interface contains a budget input section labelled Total Safety Budget. In this field, users can enter the total amount of money available for safety improvements. An example value is also provided to guide users on how to input the budget correctly. This helps ensure that the system receives valid financial data for performing the allocation. Once the budget amount is entered, users can click the “Calculate Allocations” button. The system then calculates how much budget should be allocated to each hazard category based on its AHP priority weight. This automated calculation ensures that higher-risk hazards receive a larger portion of the safety budget, enabling more effective risk mitigation. This page demonstrates how analytical results can be converted into practical financial decision-making for safety management.

The budget allocation process ensures that financial resources are distributed efficiently according to risk priorities, thereby improving overall safety management and reducing the likelihood of accidents.

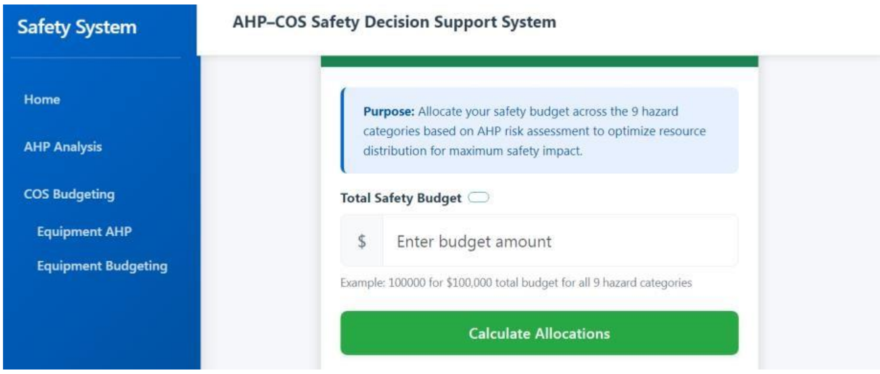
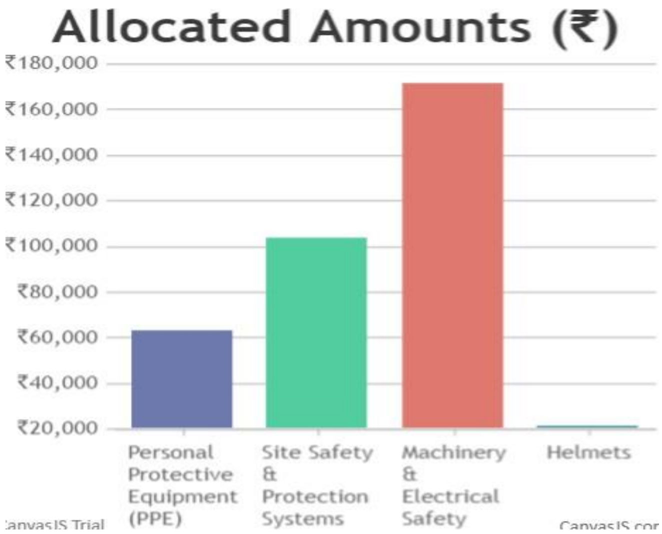
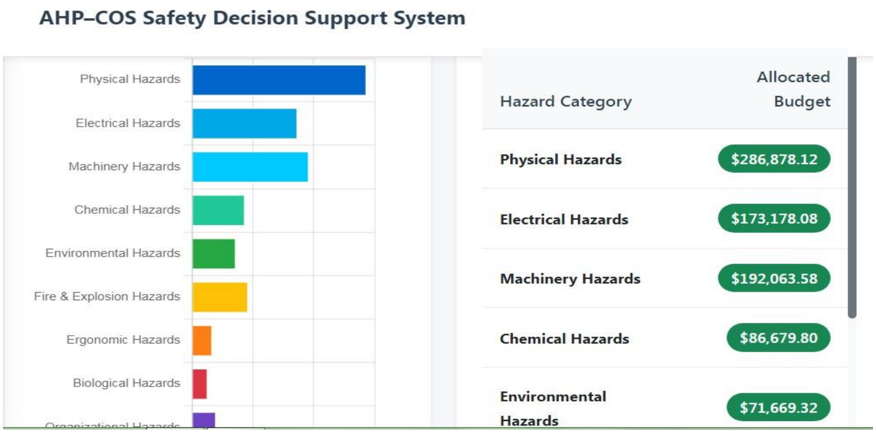


Figure 9.A page that enter budget





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Personal Protective Equipment (PPE)	0.1754	18%	₹ 63,121.54
Site Safety & Protection Systems	0.2885	29%	₹ 103,811.87
Machinery & Electrical Safety	0.4771	48%	₹ 171,669.21

Figure 1. Pages showing a bar chart of the safety budget allocated for each safety equipment's

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CHAPTER 5 - CONCLUSION

The construction industry plays an important role in national development, but it is also one of the most dangerous industries because of its complex and changing work environment. This project focused on improving construction safety by using a more structured and scientific approach instead of relying only on experience or occasional safety inspections.

In this study, nine major types of construction hazards were identified, including physical, electrical, machinery, chemical, environmental, fire, ergonomic, biological, and organizational hazards. Identifying these hazards helped create a better understanding of the different risks present on construction sites.

The Analytic Hierarchy Process (AHP) was used as an effective decision-making method to evaluate and prioritize these hazards. By using pairwise comparisons based on Saaty's 1–9 scale, expert opinions were converted into numerical values, which helped determine which risks were more critical.

The Cost of Safety (COS) concept was also applied in this study to show that safety spending should be considered an investment rather than an expense. Investing in safety measures early can reduce future losses caused by accidents, such as medical costs, delays, and legal issues. This approach helps allocate safety resources more effectively.

Another important outcome of this project was the development of a Construction Safety Application using Python. This application helps automate complex calculations and makes the safety evaluation process easier for engineers and project managers. It allows users to analyse risks, prioritize hazards, and plan safety budgets more efficiently.

The system was also applied in a case study of Chicago Constructions International Pvt Ltd, showing how the tool can support practical safety planning. By using data-based analysis instead of guesswork, project managers can ensure that the most dangerous areas receive proper safety attention.

Overall, this research shows that combining AHP analysis with Cost of Safety principles can significantly improve construction safety management. The developed Python-based system helps in better decision-making, reduces risks, and supports safer construction environments.

In the future, the system can be further improved by adding features such as real-time monitoring, AI-based risk prediction, and advanced data visualization, which will help move closer to the goal of achieving a zero-accident construction environment.

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.

ANNEXURE

i. Site safety used in Chicago constructions

CHICAGO CONSTRUCTIONS
International(P)Ltd
(An ISO 9001: 2015 Certified Company)

TC 22 /2703, Chithira Lane
Kochar Road : Sasthamangalam
Thiruvananthapuram - 695 010
Tel : 0471 2311906, 2314787 2720793
CIN : U45200KL2011PTC029879
E-mail : chicagoconstructions@gmail.com
contact@chicagoconstructions.in
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09/02/2026

TO WHOM SO EVER IT MAY CONCERN

Sub: Site Safety Personal Protective Equipment's name and usage

Site: Chengannur Project and 10 LL OHSR
Sibi.P.C (Safety Officer In Charge)

This is to inform you that all necessary safety materials are being provided and strictly used at the work site to ensure the health and safety of all employees and labourers. Details of materials are as given below

1.Protect individual workers from injury

- Safety helmet-----------Protects against falling objects (head protection)
- Safety shoe steel toe --------- Slips resistant soles (leg protection)
- Gum boots ---------- For concrete activities
- High visibility jacket -----------Labourers can be seen easily
- Gloves (leather or cotton) -------- For cuts chemicals, heat, electrical, welding, grinding work
- Safety googles, face shield --------- Protect eyes, sparks debris
- Ear plugs, ear muffs, ----------- Hearing protection, for noisy areas.
- Safety mask --------------- Respiratory protection, dust protection
- Safety harness &lanyard -------------- For work at height, falling protection
- Protective clothing ---------------- Flame and chemical resistant

2. Site Safety Products

- Waring sign and safety sign board
- Barricade and safety warning tapes
- Safety net ---falling objects
- Scaffolding and ladders
- Fire extinguishers (class A, B, C, D)
- First aid box
- Adequate lighting, emergency alarms

Experts in Treatment Plant & Reservoirs

3. Machinery& Electrical safety

- Machine guards
- Lock out/tagout
- ELCB/RCD& lightning arrester (earth leakage circuit breakers
- Cable protectors

4. Helmets code

- White --------- Managers, supervisor
- Green --------- Safety officer
- Yellow ------- Labours
- Blue --------Foreman
- Grey -------Visitors
- Red ------- Electrical and fire

All labourers have been instructed to wear the required Personal Protective Equipment (PPE) at all times during work. Regular safety briefings and inspections are also conducted to ensure compliance with safety rules and site regulations.

Thanking you.

Yours sincerely,
For Chicago Constructions International Pvt Ltd

S. Mohana Kumar
Managing Director

ii. Budget calculation

Payment Breakup				
Name of work :- Design, construction, commissioning and maintenance of 5MLD WTP , 6m dia Intake well cum pump house,10LL OHSR ,5LL OHSR ,supplying, laying, testing, commissioning and maintenance of Raw Water Pumping Main,Clear water pumping mains to OHSRs and distribution systems with providing FHTCs ,Supply and erection of Raw water and Clear water motor pump sets				
	Accepted PAC Rs 357152750			
Sl No	Description of Item	Qty	Percentage	Amount
I	SUPPLYING AMND LAYING RAW WATER PUMPINHG MAIN - COST OF MATERIALS - (80% OF ESTIMATE RATE)			
	Supply of DI K9 Pipe Conforming to IS 8329/2000, 300mm Dia.	2805 m	2.2227%	7938486.60
	Supply of CI Air Valve with Flanges, Conforming to IS 14845 - 2000, Kinetic Air Valve Type DS2, Size 80mm.	5 Nos	0.0049%	17471.60
	Providing and fixing gun metal gate valve with C.I. wheel of approved quality (screwed end) :80 mm nominal bore	5 Nos	0.0029%	10377.91
	Supply of CI Non Return Valve, Conforming to IS 5312 Part I - 1984, PN 1.0, Size 300mm.	1 Nos	0.0075%	26645.92
	Supply of CI Double Flanged Sluice Valve Conforming to IS 14846 - 2000, Sluice Valve with Hand Wheel PN 1.6, Size 200mm.	1 Nos	0.0027%	9550.88
	Supply of CI Double Flanged Sluice Valve Conforming to IS 14846 - 2000, Sluice Valve with Cap PN 1.6, Size 300mm.	1 Nos	0.00485%	17323.16
	RAW WATER PUMPING MAIN - WORKING CHARGES			
	Conveying and laying of 300mm DI K9 Pipes including earth work excavation in all classes of soil ,hard soil, medium rock and hard rock etc ,conveying,cutting,jointing,testing with required test pressure ,fencing,demolishing CC and RCC ,dismantling bituminious road ,refilling the trenches ,supplying and fixing necessary DI specials, providing Anchor blocks in bends, etc complete, including balance amount of materials as per scope of work in NIT	2750 m	1.6313%	5826323.36
	Conveying and fixing 300mm Non Return valve - 3Nos,fixing 200mm Sluice valve 1No and fixing 80mm Air valve 5Nos with 80mm GM valve including balance amount of materials and all works as per scope of work in NIT		0.0076%	27212.55

CONSTRUCTION OF 6M DIA INTAKE WELL						
On submission of approved design of Intake well		0.0228%	83884.17			
Earth work excavation for Intake well in all classes of soil, ordinary rock including providing necessary ring bund, bailing out water during the course of work as specified in the NIT		0.7964%	2844364.50			
Earth work excavation for Intake leading pipe in all classes of soil, ordinary rock including providing necessary ring bund, bailing out water during the course of work as specified in the NIT		0.9374%	3347949.88	1.3752%		0.4378%
Rock blasting for Intake well up to the depth of well as specified in the NIT including bailing out water during the course of work		0.9358%	3342235.43	0.4981%		0.9359%
RCC for Intake well at bottom surface, beds, steining up to top, floor slab including driving and fixing down bars, centering, plastering inside of well, coming and all works as specified in the NIT		0.7580%	2707056.32			
Construction of Pump house superstructure, roofing of lintel and sunshade etc		0.3108%	1110051.21			
Providing Rolling shutter, windows, hand rails, plastering, painting, flooring and providing hoisting equipments of 1Tonne capacity all finishing works of Pump House as specified in the NIT		0.3398%	1213741.61			
Providing RCC Ramp with column support including necessary earthwork excavation PCC etc complete		0.0484%	172729.98			
Conveying and laying of 600mm DI leading pipe including fixing 600mm Sluice Valve and Valve chamber and providing SS fabricated meshes as specified in the NIT		0.4314%	1540708.42			
SUPPLY AND ERECTION OF RAW WATER AND CLEAR WATER PUMPSETS AND FLOW METERS						
Supply and erection of Vertical Turbine Pump sets of 54m head, 47 lps discharge as specified in the NIT	2 Nos	0.3617%	1291957.15			
Supplying and fixing of 250mm dia an electro-magnetic flow meter as specified in the NIT	1 Nos	0.0396%	141520.73			
Supply and erection of Centrifugal Pump sets Discharge-15 lps, Total head-56 m for Odanur zone as specified in the NIT	2 Nos	0.1298%	463486.20			
Supplying and fixing of 200mm dia an electro-magnetic flow meter as specified in the NIT	1 Nos	0.0267%	95243.00			
Supply and erection of Centrifugal Pump sets Discharge-30 lps, Total head-38 m for Kottavi zone as specified in the NIT	2 Nos	0.2052%	732896.32			
Supplying and fixing of 200mm dia an electro-magnetic flow meter as specified in the NIT	1 Nos	0.0267%	95243.00			
MS STRUCTURES FOR CROSSING CANALS						
Structural steel work for crossing water course		0.3929%	1403301.88			
PWD ROAD CROSSING BY HDD						
HDD for PWD road crossing 500mm MS, 10mm thick pipe as casing including all charges as specified in the NIT	60 m	0.3105%	1108887.09			
HDD for PWD road crossing 600mm MS, 10mm thick pipe as casing including all charges as specified in the NIT	60 m	0.4347%	1552642.86			
ROAD RESTORATION						
Refilling the trenches with a wet mix of close graded granular materials (Stone aggregate - 25mm nominal size - 17.5%, Stone aggregate - 10mm nominal size - 17.5%, Crushed Stone - 2.36mm to 11.5mm - 25%, Stone chippings / screenings - 4.75mm nominal size - 20%, Stone chippings / screenings - 150 micron nominal size - 20%), mixing properly after adding sufficient quantity of water, refilling in layers not exceeding 150mm, compacting properly at Optimum Moisture Content with Surface Plate Vibrator and disposing the excavated material etc. complete, including traffic control, providing caution boards and as per direction of Engineer-in charge for road restoration works in pipeline laying sites.	4008.06 m3	7.8279%	27963450.48			
Providing and laying in position cement concrete of specified grade excluding the cost of centering and shuttering - All work up to plinth level(1:3:6 (1 cement : 3 coarse sand : 6 graded stone aggregate 20 mm nominal size)	5004.03 m3	3.0742%	10980947.64			
Preparation and consolidation of sub grade with power road roller of 8 to 12 tonne capacity after excavating earth to an average of 22.5 cm depth, dressing to camber and consolidating with road roller including making good the undulations etc. and re-rolling the sub grade and disposal of surplus earth with lead upto 50 metres.	13368.20m2	0.6468%	2310469.84			
Taking out existing CC interlocking paver blocks from footpath/ central verge, including removal of rubbish etc., disposal of unserviceable material to the dumping ground, for which payment shall be made separately and stacking of serviceable material within 50 metre lead as per direction of Engineer-in-Charge	1600.00 m2	0.0465%	165998.18			
Laying old cement conc. interlocking paver blocks of any design/ shape laid in required line, level, curvature, colour and pattern over and including 50 mm thick compacted bed of coarse sand, filling the joints with fine sand etc. all complete as per the direction of Engineer-in-charge. (Old CC paver blocks shall be supplied by the department free of cost.)	1600.00 m2	0.1602%	572212.40			
Total		100.0000%	357152750.00			72201995
					3.00	

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ANU B KRISHNAN