Assessment of Lifting & Rigging Operations for Unloading Heavy Consignments

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Abstract – *As one of the most noticeable objects on construction sites and a symbol of modern construction operations, cranes possess the capacity of lifting heavy loads and maneuvering the loads over long spans. When properly located on a site, cranes can strategically lift and lower loads to virtually any desired location on a construction site. Unfortunately, when large numbers of cranes have been dispatched to a construction site, the hazard exposure also increases for construction workers who work with, around or under these cranes. The more important aspect of these crane-related fatalities is that they were totally preventable if proper safety precautions had been taken and workers are properly equipped with knowledge of hazard self-perception.*

The objective of this study is to evaluate the effectiveness of the fuzzy TOPSIS method for the evaluation of hazards using expert's views aiming to minimize the hazard exposure of construction workers during lifting of heavy consignments.

Key Words: Lifting Operation, Lift Plan, Crane, TOPSIS, Fuzzy Logic

1.INTRODUCTION

Rigging and lifting are the key process of handling heavy materials which comes under the comprehensive subject of "Material Handling" in which load is initially secured and then arrangements are made for its pre-determined movement like pushing, pulling, lifting, carrying and shifting from one destination to other. Rigging generally involves binding, securing and preparing the load to be relocated whereas the movement of load opposing gravitational pull is lifting.

Applications of rigging and lifting process by means of cranes can be seen everywhere around the world. Cranes have major applications in transport industry for loading and unloading cargo, in manufacturing industry to transfer and lump together heavy loads, in construction industry to transfer material from ground level to an elevated level. Other applications of crane can be seen in Glazing Works, Skyscrapers, Rooftop Work, Civil Engineering and Major Erection Projects, Residential Construction, Industrial Maintenance (Plant, Factory & Automotive), Electric & Nuclear Power Plants, Confined Areas, Railways, Marine, Ports & Harbours, Aviation Industry & Airports, Oil & Gas industries.

In all the metro cities in India and around the world, cranes can be seen working away at a construction site of high rise building or skyscrapers. Lifting equipment plays a vital role in reaching new heights in construction industry with latest and technically advance cranes which can comfortably secure tonnes of load and move it around. Overall it can be said the lifting crane has made the work easier for the worker and accelerated the efficiency of work.

1.2 Historical Background

The concept of lifting heavy objects is not something new to humans, there has been some arrangement and practice of lifting dating back for as long as humans required to lift and move objects which were too heavy for their bare hands to lift and move. The foremost identified crane-like-tool was a water-lifting device with a lever mechanism named "shadoof" which was invented in ancient Mesopotamia around 3000 BC and then later seen in ancient Egyptian technology (circa 2000 BC).

The first documented construction cranes were developed by the Ancient Greeks and were driven by men, horses and donkeys. During the Renaissance age, architect Domenico Fontana in 1586 erected Vatican Obelisk having a height of 83.6 feet weighs around 331 tons on Peter's Square in Rome with the help of a lifting tower which took a concerted effort of around 900 men and 75 horses and countless pulleys to erect this monument which stand still today.

Figure 1 Construction site of the Vatican obelisk (1586) (Carlo Fontana, 1694) [1]

Another historical engineering marvel which involved securing and moving heavy object was displayed by Marinos Charvouris in 1769/1770 for the transportation of the Thunder Stone of Saint Petersburg. The Thunder Stone is a massive granite boulder meant to form the base of the bronze horse-riding statue of Peter the Great. It was claimed to be the largest stone ever moved by man weighing 1250 tons. It was brought to Saint Petersburg partly overland and partly through sea from Finland. Marinos Charvouris developed a system of ball bearings above which the rock was moved horizontally. In the meanwhile, stonecutters continued to silhouette the enormous granite in a sweat to shed weight so that its transportation was easier. When it was extracted from the ground, the boulder weighed more than 1,500 tons. By the time it arrived at Saint Petersburg it weighed 1,250 tons. The work of transporting the stone was done entirely by men; no animals or machines were used in the process. [2]

Figure 2 The transportation of the thunder-stone. (Y.M.Felten, 1770)

The earliest cranes were built from wood, but cast iron and steel replaced them with the imminent of the Industrial Revolution. With the commencement of the Industrial Revolution the foremost modern cranes were mounted at harbours for loading cargo. In the year 1834, first cast iron crane was constructed.

Till the early nineteenth century, the Vatican obelisk remained the point of reference for all the engineers that had to transport heavy loads and above all large monoliths. Later, LeBas' lifting device can be considered a turning point mostly for its substantial difference from Fontana's model. Finally, in 1851, the path breaking innovation of the steam powered crane was made which was the foremost step toward a truly hydraulic crane. With the arrival of steam power in crane, any load could be lifted at desired speed, as long as the engine was powerful enough.

In 1878, the obelisk of London (Cleopatra's Needle) weighing 187 tons was re-erected in London lifted by means of hydraulic jacks instead of the tackles and capstans previously used. Similarly, in the year 1881, the second Cleopatra's Needle (Obelisk of New York) was lifted by means of hydraulic jacks.

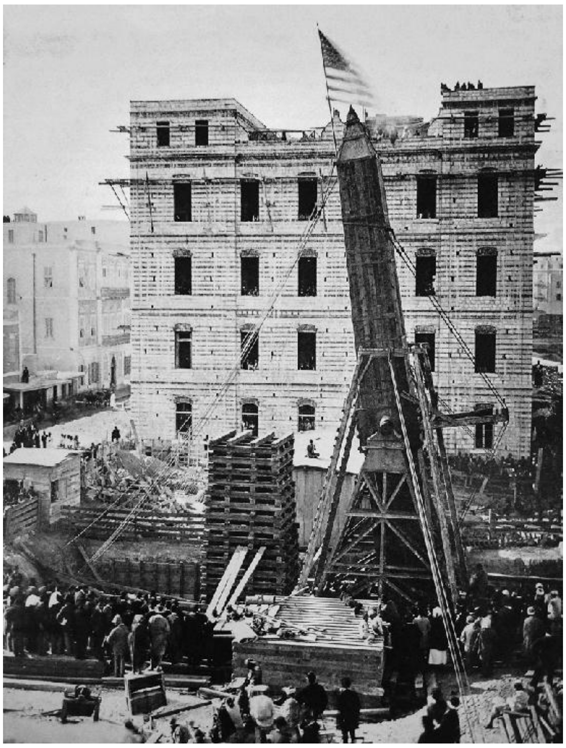

Figure 3 Erection of Obelisk in Alexandria in 1879. [3]

Earlier to 1870 cranes had fixed position having restricted movement. Later, crane which operated with steam power were manufactured by Appleby Brothers at Paris in 1867 and Vienna in 1873. Appleby Crop. started to manufacture truck-mounted cranes in 1922. In 1992, the adoption of the internal combustion engine and the development of telescopic jibs took place which were some key steps in developing crane. In 1960, cranes were made to increase their height which amplified operation costs. Later, different crane manufacturing companies developed advanced telescopic hydraulic boom techniques and drive mechanism which brought together several state of the art development.

1.2 Types of Crane

On the basis of present crane study and development cranes can be categorized in two general types:

1. Fixed crane
2. Mobile or movable crane
3.

A fixed crane or stationary crane is the type of crane which lift the loads without any appreciable movement. Fixed cranes are broadly used on building construction work sites as well as on other construction projects which requires enormous vertical clearances and have restricted space in the work zone. These type of cranes are able to move loads over a wide area in and around work zone and have an almost unlimited vertical range.

A mobile crane is the type of crane which moves from one place to another as well as movement of the crane basic tools. Mobile cranes are broadly used in construction as they are made to move freely around a construction site. Rubber tired cranes are also capable of moving rapidly between construction projects. Crawler cranes also have tremendous mobility however it must be transported on equipment trailers between construction projects. In this research work, the main work is carried out for mobile crane, hence only mobile cranes will be focused here

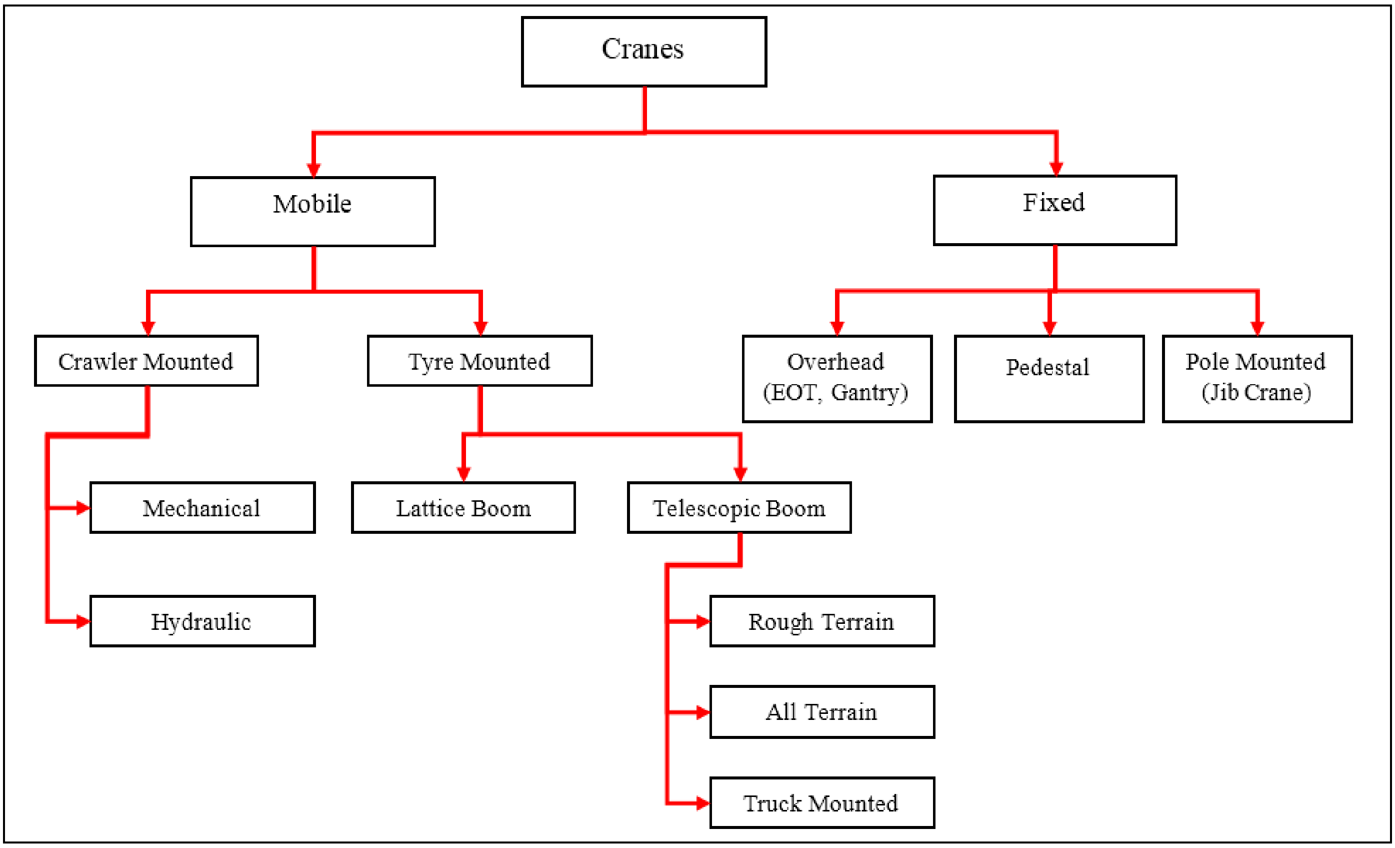

Figure 4 Types of cranes

1.2.1 Rough terrain crane

Rough terrain crane is a crane mounted on an undercarriage with four rubber tires that is designed for pick-and-carry operations and for off-road and "rough terrain" applications.

- Lifting capacity:200 tons at 3m working radius
- The rough terrain crane is used for building bridges, operations in power and chemical plants and refineries and for large- scale projects.
- These cranes are mounted on two-axle carriers.
- These units have a lower cost.

- These units are equipped with unusually large wheels and closely spaced axles to Improve maneuverability at the job site.
- They further earn the right to their name by their high ground c1earence allowance, as well as the ability of some models to move on slopes of up to 70%.
- Most units can travel on the highway but have maximum speeds of only about 30 mph.
- In the case of long moves between projects, they should be transported on low-bed trailers.

1.2.2 All-Terrain Crane

A mobile crane with the necessary equipment to travel at speed on public roads, and on rough terrain at the job site using all-wheel and crab steering. AT's combine the road ability of Truck-mounted Cranes and the maneuverability of Rough Terrain Cranes.

- Lifting capacity: up to 300 tons
- Working radius: 34m
- All-terrain mobile cranes are excellent for use in places where ground is uneven or not very accessible like a beach or a rocky expanse.
- Designed for long-distance highway travel.
- The carrier has all-axle drive and all-wheel steering, crab steering, large tires, and high ground clearance.
- All-terrain cranes have dual cabs, a lower cab for fast highway travel, and a superstructure cab that has both drive and crane controls.
- Most appropriate machine when multiple lifts are required at scattered project sites or at multiple work locations on a single project.
- It has a higher cost than an equivalent capacity telescoping truck crane or rough-terrain crane.
- All-terrain machine can be positioned on the project without the necessity of having other construction equipment prepare a smooth travel way as truck cranes would require.

1.2.3 Crawler Crane

A crawler crane is a crane mounted on an undercarriage with a set of tracks (also called crawlers) that provide stability and mobility.

- Lifting capacity from about 35 to 40 tones
- This particular asset class is ideal for working in confined or small area where a big crane cannot reach.
- Crawler crane command their position at many of power plants, thermal plants and at big infra projects.
- These crane are well suited for piling, drilling and pipe laying operation by just adding suitable attachment.
- The full revolving superstructure of this type of unit is mounted on a pair of continuous, parallel crawler tracks.
- The crawlers provide the crane with good travel capability around the job site.
- Inclined lattice mast, which helps decrease compressive forces in the boom.
- Relocating a crawler crane between projects requires that it be transported by truck, rail, or barge.
- These machines usually have lower initial cost per rated lift capability, compared with other mobile crane types, but movement between jobs is more expensive.
- Therefore, crawler-type machines should be considered for projects requiring long duration usage at a single site.

1.2.4 Telescoping-Boom Truck-Mounted Cranes

Telescopic boom cranes are typically called hydraulic crane.

- These truck-mounted cranes have a self-contained telescoping boom.
- Most of these units can travel on public highways between projects under their own power with a minimum of dismantling.
- These machines, however, have higher initial cost per rated lift capability.
- For small jobs requiring crane utilization for a few hours to a couple of days, a telescoping truck crane should be preferred.
- Telescoping-boom truck cranes have extendable outriggers for stability.
- The booms are composed of a series of rectangular, trapezoidal, or other shape of symmetrically cross-sectional segments, fitting into each other.
- The largest segment, at the bottom of the boom, is called the base section or boom butt.
- The smallest section, at the top of the boom, is called the tip section or boom tip.
- In between there can be one or more sections called the first, second, and so forth, sections.
- With the boom fully retracted, the telescopic boom crane is highly manoeuvrable and easy to transport to jobsites.

1.1.5 Latticed-Boom Truck-Mounted Cranes

- The lattice-boom truck crane has a fully revolving superstructure mounted on a multi axle truck/carrier.
- The advantage of this machine is the lattice boom. The lattice-boom structure is lightweight.
- This reduction in boom weight means additional lift capacity, as the machine predominately handles hoist load and less weight of boom.
- The lattice boom does take longer to assemble. The lightweight boom will give a less expensive lattice-boom machine the same hoisting capacity as a larger telescoping-boom unit.

- The disadvantage of these units is the time and effort required to disassemble them for transport. In the case of the larger units, it may be necessary to remove the entire Superstructure.

1.3 Booms Types

1.3.1 Lattice Boom

A lattice boom resembles pipe pieces connected together. It is cable suspended and acts as a compression member. The structure is lightweight, which means extra lifting capacity. This boom is usually transported in sections that are assembled at the site. Crawler and tower cranes typically have lattice booms. Most heavy lifting is done with lattice booms.

1.3.2 Telescoping Boom

A telescoping boom works in the same manner as a retractable telescope. As lift height is needed, the boom is telescoped or extended. This boom acts a bending member when lifting. Typically, the boom comes ready for lifting when it arrives at the site. Mobile hydraulic cranes, sky track type lifters use telescoping booms. Moderate to medium lifting can be done with telescoping booms.

2. PROBLEM IDENTIFICATION

In order to lay the foundation for the research with a problem statement, a visit to JM Warehouse, Fatehpur, Harayana was made by the author. The visit provided exposure to real working environments along with a practical perspective of a theoretical concept relevant to material handling domain. Few significant benefits of the conducting a visit are given below:

- A chance to meet industry leaders, professionals, entrepreneurs, policymakers, and corporates who share their wisdom, learning, and experiences.
- To see and experience real unloading stations, machines, systems and interact with highly trained and experienced personnel.
- To learn about company policies in terms of production, quality, and service management.
- To open many doors for corporate training and internships, which in turn increase the employability.
- To understand how managers, engineers, employees work in tandem to achieve a common target, which is a management lesson in itself.
- To identify the learning towards safety and to decide future work areas like lifting, rigging, signalling, safety etc.

In this research work, only unloading of heavy consignments from Truck Trailers are covered using cranes. Table 3.2 shows the details of different consignments along with their Net weight, Gross Weight, Length, Width, Height and Vehicle number and unloading day.

Table -1.1: Summary of unloading

Unloading Date	Vehicle Count	No. of Packages
Day 1	7	23
Day 2	8	25
Day 3	3	10
Day 4	6	27
Day 5	5	19
Day 6	2	7
Grand Total	**31**	**111**

Figure 5 Trailer loaded with the consignment to be unloaded

3. METHODOLOGY

3.1 TOPSIS

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method (MCDA) which was developed by two researchers Hwang & Yoon, (1981). TOPSIS was further modified and improved by Yoon, (1987) and Hwang et al., (1993). This MCDA works on the primary concept of collection of alternative next to the ideal and extreme away from the negative.

Here, the Ideal substitute is the best suitable feature which may be maximum or minimum depending on the type of criteria Although, Negative ideal alternative is the foulest attribute value which can also be maximum or minimum depending on the type of conditions.

The conventional technique of Technique for Order of Preference by Similarity to Ideal Solution is to pick out distinct positive ideal solution (PIS) and distinct negative ideal solution (NIS) of the problem, calculate the distance from respectively substitute to PIS and NIS, then compare the ratio standards of the second distance to the sum of the two remoteness and advances the final ranking of the options.

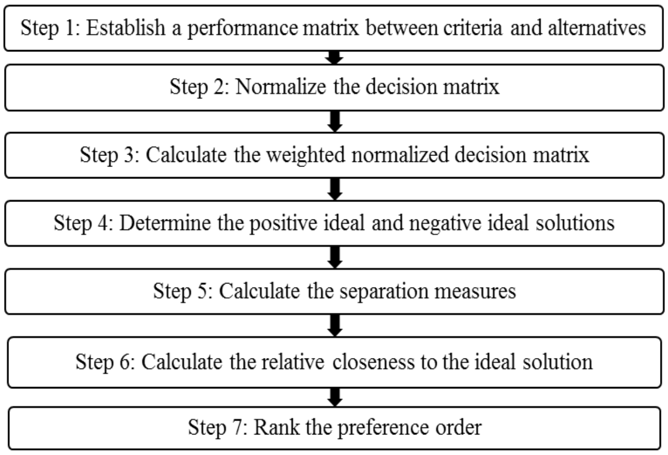

Figure 6 TOPSIS process flow chart

Step 1: Establish a performance matrix

The performance value of the alternatives is denoted by zij with respect to some attribute(A) / criterion (C);

$$M = \begin{matrix} & \begin{matrix} w_1 & w_2 & \cdots & w_n \\ C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{pmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{pmatrix} & \begin{pmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ z_{m1} & z_{m2} & \cdots & z_{mn} \end{pmatrix} \end{matrix} \quad \text{Eq.(1)}$$

Step 2: Normalize the decision matrix

The following transformation equation can be used to obtain the normalized performance matrix.

$$n_{ij} = \frac{z_{ij}}{\sqrt{\sum_{j=1}^{m} (z_{ij})^2}} \quad \text{Eq.(2)}$$

j= 1,.........,n, i=1,...........,m.

Step 3: Calculate the weighted normalized decision matrix

Since the weights of criteria in problem have different mean and importance. Therefore, the normalized value is computed as:

$$v_{ij} = w_j \times n_{ij} \quad \text{Eq.(3)}$$

The weight is computed by direct assignation by the author on the basis of the field experience.

Step 4: Determine the positive ideal and negative ideal solutions

The positive ideal and the negative ideal value set ‘A’ are computed as follows:

$$A^+ = \{v_1^+, \ldots, v_n^+\} = \left\{ \left(\max_i v_{ij},\ j \in J \right) \left(\min_i v_{ij},\ j \in J' \right) \right\} \quad \text{Eq.(4)}$$

$$A^- = \{v_1^-, \ldots, v_n^-\} = \left\{ \left(\min_i v_{ij},\ j \in J \right) \left(\max_i v_{ij},\ j \in J' \right) \right\} \quad \text{Eq.(5)}$$

In the above equation, J is linked with benefit criteria, and J' is linked with Non-benefit criteria.

Step 5: Calculate the separation measures

The distance of each alternative from the positive ideal solution (PIS) A+ is:

$$d_i^+ = \left\{ \sum_{j=1}^{n} (v_{ij} - v_j^+)^2 \right\}^{\frac{1}{2}} \quad \text{Eq.(6)}$$

The distance of each alternative from the negative ideal solution (NIS) A- is:

$$d_i^- = \left\{ \sum_{j=1}^{n} (v_{ij} - v_j^-)^2 \right\}^{\frac{1}{2}} \quad \text{Eq.(7)}$$

Step 6: Calculate the relative closeness to the ideal solution

The relative closeness “R”, to the ideal solution can be expressed as:

$$R_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, \ldots, m \quad \text{Eq.(8)}$$

$$\text{If } \bar{R}_i = 1 \rightarrow A_i = \bar{A}^+$$
$$\text{If } \bar{R}_i = 0 \rightarrow A_i = \bar{A}^-$$

The closer the R_i is to 1, the higher the will be the priority.

Step 7: Rank the preference order

Rank the suitable alternative in decreasing order on the basis of R_i

4. RESULTS

Based on the available data of crane accidents and previous studies discussed in Section 1, the most common hazards associated with crane accidents responsible for failure are: : Struck by Load

- Electrocution
- Crushed During Assembly/Disassembly
- Failure of Boom/Cable
- Crane Tip Over
- Struck by Cab/Counterweight
- Falls

In order to assess these hazards in terms of the risk they have to human life Fuzzy TOPSIS methodology is used. The step-by-step process of implementing Fuzzy TOPSIS is discussed in Section 3. The assessment of risk is carried out by rigorous one-on-one interview with the operators, supervisor, signaler, rigger and safety officer.

4.1 Details of experts

It is essential to take into consideration the views, comments and suggestions of the field experts in order to understand the major issues during any operation. Therefore, unbiased views of experts were taken by one-on-one interview during the visit as soon as the unloading operation ended. In order to keep the identity of the interviewee hidden, the names of experts have been numbered in the table below:

Table 4.1 Details of inputs from experts on likelihood, severity and detectability of different hazards

S No.	Hazard	Expert	Likelihood		Severity		Detectability		Total
			Out of 5	Avg.	Out of 5	Avg.	Out of 5	Avg.	
		Expert 1	4		4		5		
		Expert 2	4		4		5		
		Expert 3	4		3		5		
		Expert 4	4		4		5		
		Expert 5	3		3		4		
Alt -01	Struck by Load	Expert 6	4		3		5		11.92
		Expert 7	3	3.58	4	3.58	4	4.75	
		Expert 8	3		3		5		
		Expert 9	3		4		5		
		Expert 10	3		3		4		
		Expert 11	4		4		5		
		Expert 12	4		4		5		
		Expert 1	3		5		2		
		Expert 2	3		5		3		
		Expert 3	3		4		3		
		Expert 4	3		5		3		
Alt -02	Electrocution	Expert 5	2	2.83	4	4.42	2	2.42	9.67
		Expert 6	2		4		2		
		Expert 7	3		4		3		
		Expert 8	4		5		2		
		Expert 9	3		4		2		
		Expert 10	2		5		3		
		Expert 11	4		4		2		
		Expert 12	2		4		2		
		Expert 1	2		3		3		
		Expert 2	2		3		4		
		Expert 3	2		4		3		
		Expert 4	3		3		3		
		Expert 5	3		4		4		
		Expert 6	4		3		4		
Alt -03	Crushed During Assembly/Disassembly	Expert 7	3	2.50	3	3.42	4	3.50	9.42
		Expert 8	2		3		3		
		Expert 9	3		4		3		
		Expert 10	2		3		3		
		Expert 11	2		4		4		
		Expert 12	2		4		4		
		Expert 1	1		5		2		
		Expert 2	1		5		2		
		Expert 3	2		5		3		
		Expert 4	2		4		2		
		Expert 5	2		5		2		
		Expert 6	2		4		3		
Alt -04	Failure of Boom/Cable	Expert 7	1	1.58	4	4.50	2	2.33	8.42
		Expert 8	2		5		2		
		Expert 9	2		4		2		
		Expert 10	2		4		3		
		Expert 11	1		5		2		
		Expert 12	1		4		3		
		Expert 1	4		5		4		
		Expert 2	3		5		3		
		Expert 3	4		5		4		
		Expert 4	3		4		3		
		Expert 5	3		5		4		
		Expert 6	4		5		4		
Alt -05	Crane Tip Over	Expert 7	3	3.42	4	4.67	4	3.83	11.92
		Expert 8	2		5		4		
		Expert 9	3		4		5		
		Expert 10	4		5		3		
		Expert 11	4		4		4		
		Expert 12	4		5		4		
		Expert 1	3		3		4		
		Expert 2	2		2		4		
		Expert 3	3		3		4		
		Expert 4	3		3		5		
		Expert 5	3		2		5		
		Expert 6	2		2		4		
Alt -06	Struck by Cab/Counter weight	Expert 7	2	2.67	3	2.67	4	4.50	9.83
		Expert 8	3		3		5		
		Expert 9	3		2		5		
		Expert 10	3		3		5		
		Expert 11	2		3		4		
		Expert 12	3		3		5		
		Expert 1	4		3		5		
		Expert 2	3		2		4		
		Expert 3	4		3		5		
		Expert 4	4		2		5		
		Expert 5	4		2		5		
		Expert 6	2		3		5		
Alt -07	Falls	Expert 7	3	3.50	2	2.50	5	4.75	10.75
		Expert 8	4		3		5		
		Expert 9	3		3		4		
		Expert 10	4		2		5		
		Expert 11	4		3		4		
		Expert 12	3		2		5		
Weight			-	0.3	-	0.4	-	0.3	1

The next task is to categorized the criteria between beneficiary and non-beneficiary criteria. As lower count of likelihood and severity is desirable, hence they come under Non-beneficiary criteria

Furthermore, the next step involves the assignment of proper weightage is assigned to likelihood, severity and detectability.

Table 4.2 Allocated value of weightage to the criteria

Criteria	Likelihood	Severity	Detectability	SUM
	Cr-01	Cr-02	Cr-03	
Weight in decimal	0.3	0.4	0.3	1
Weight in percentage	30%	40%	30%	100%

The next step involves computation of Normalize the decision matrix using Eq.(2). Table 4.3 below shows the Normalize the decision matrix computed using the values obtained in Table 4.1

Table 4.3 Normalized decision matrix

S No.	Likelihood	Severity	Detectability
Alternative -01	1.6486338	1.2878343	2.2166576
Alternative -02	1.0307305	1.9564773	0.5737793
Alternative -03	0.8024719	1.1708218	1.2035038
Alternative -04	0.3218804	2.0310032	0.5348906
Alternative -05	1.4988391	2.1842338	1.4436588
Alternative -06	0.9130346	0.7132192	1.9894655
Alternative -07	1.5728448	0.6268528	2.2166576

Now, using Eq. (3) the weighted normalized decision matrix is made from the values of Table 4.3 .Table 4.4 also shows the determined the positive ideal (A+) and negative ideal solutions (A-) using Eq. (4) and Eq. (5).

Table 4.4 Weighted normalized matrix

S No.	Likelihood	Severity	Detectability
Alternative -01	0.4945902	0.5151337	0.6649973
Alternative -02	0.3092192	0.7825909	0.1721338
Alternative -03	0.2407416	0.4683287	0.3610511
Alternative -04	0.0965641	0.8124013	0.1604672
Alternative -05	0.4496517	0.8736935	0.4330976
Alternative -06	0.2739104	0.2852877	0.5968397
Alternative -07	0.4718535	0.2507411	0.6649973
A+	0.0965641	0.2507411	0.1604672
A-	0.4945902	0.8736935	0.6649973

The next step involved the determination of distance of each alternative from the positive ideal solution (PIS) A+ , d_i^+ and Negative ideal solution (NIS) A-, d_i^- using Eq (6) and Eq.(7) as shown in Table 4.5. Table 4.5 also shows the relative closeness (R_i)from the ideal solution for each alternative using Eq.(8). Then on the basis of R_i values, the alternatives are ranked.

Table 4.5 Ranking of alternatives

S No.	d_i^+	d_i^-	R_i	Rank
Alternative -01	0.6949	0.3586	0.3404	2
Alternative -02	0.5729	0.5344	0.4826	3
Alternative -03	0.3292	0.5667	0.6326	7
Alternative -04	0.5617	0.6455	0.5347	5
Alternative -05	0.7662	0.2362	0.2356	1
Alternative -06	0.4723	0.6321	0.5724	6
Alternative -07	0.6288	0.6234	0.4978	4

Table 4.6 Ranking of hazards using TOPSIS

Alternative No.	Hazard	Rank
Alternative -05	Crane Tip Over	1
Alternative -01	Struck by Load	2
Alternative -02	Electrocution	3
Alternative -07	Falls	4
Alternative -04	Failure of Boom/Cable	5
Alternative -06	Struck by Cab/Counterweight	6
Alternative -03	Crushed During Assembly/Disassembly	7

Table 4.6 shows the ranking of hazards based on their likelihood, severity and detectability record in descending order. The significance of the ranking obtained in the above table is to determine the hazards with past accident record requiring immediate intervention through proper training of the workers. This prioritization of hazards for work specific training will help to identify the domain of work which needs more training in order to prevent any accident, incident and near miss in the near future.

It can be clearly observed from Table 4.6 that hazards like Crane tip over and being stuck by load have significantly contributed in the ranking index. Therefore, more emphasis should be given to the training provided to the workers on these hot topics. Whereas, the contribution of other hazards listed in Table 4.6 is very less, therefore there is no need to give more emphasis on specific training to the workers of these companies. Periodic general safety training along with induction training should suffice the task.

5. CONCLUSIONS

The research sets out the result of investigation performed by authors to identify the safest approaches for carrying out heavy lifting operations using cranes safely following all the norms and regulations. The methodology adopted by the research to assess different aspects of safety were successful in providing the desired outcome. The Fuzzy TOPSIS approach is used to rank the relevant hazards during lifting operation on the basis of likelihood, severity and detectability of the hazards as recorded by interviewing the lifting experts. The ranking approach used in the research for identification of hazards that need immediate work specific training can also be used in different application to set the priority of work. Few major conclusions drawn from the research also shows that the training program delivered to the especially to the operators and riggers were not meeting several aspects faced in the heavy lifting construction industry. Work specific training and task oriented training is required for the workers working in the lifting job. Also, Safety training contents should cover all the hazardous aspects to which the workers are exposed during lifting work. But, it was observed that while designing the safety training programmes, no adequate care is taken in scheming the contents of the programmes.

As the lifting operation comes under unorganised sector, the parent company should give proper care while designing and conceiving the safety training programmes. Administrators who are accountable for providing training for the workforces should analyse the usefulness of such training programmes. It is established that satisfactory steps are not available to take care of the effectiveness of such training programmes.

The future work in the research may involve the development of a system in place wherein the feedback is acquired periodically from the trainees which may be assessed to determine the effectiveness of the work specific and hazard oriented safety training programs and adjust the design of the training programs wherever necessary.

REFERENCES

[1] C. Fontana, *Templum Vaticanum et ipsius origo, Rome*. 1694.

[2] M. Charvouris, "Monument élevé a la gloire de Pierre-le-Grand, Paris," 1777. [Online]. Available: http://cnum.cnam.fr/redir?FOLRESK8.1.

[3] C. Voigts, "Constructing a discourse on the art of engineering: Domenico Fontana and the Vatican obelisk," *Heine, Eike-Christian Under Constr. Build. Mater. imagined world (= Kult. und Tech. 30). Berlin LIT*, pp. 141–161, 2015.

[4] P. Naveen, "Madhya Pradesh: 3 dead, 1 critical after crane crashes down in Gwalior," *The Times of India*.

[5] S. Sonawane, "Nashik: 40-year-old man crushed under crane at Sinnar Phata," *The Times of India*.

[6] G. S. Rao, "At least 11 dead as crane collapses at Hindustan Shipyard Limited in Vizag," *The Times of India*.

[7] W. C. Hornaday, C. T. Haas, J. T. O'Connor, and J. Wen, "Computer-aided planning for heavy lifts," *J. Constr. Eng. Manag.*, vol. 119, no. 3, pp. 498–515, 1993.

[8] P. Zhang, F. C. Harris, P. O. Olomolaiye, and G. D. Holt, "Location optimization for a group of tower cranes," *J. Constr. Eng. Manag.*, vol. 125, no. 2, pp. 115–122, 1999.