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Risk Management for Earthworks Equipment

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Abstract: ***The development in construction industry in past two decade was accompanied by the occurrence of many accidents as a result of use high-tech construction equipment during the execution of works which led to loss in cost, time and quality of projects. This study aims to survey the reality of the construction equipment used in earthworks and identify the construction equipment that most used in earthworks, in addition to identify the risks associated with earthworks equipment by work a questionnaire survey of a sample of engineers. The results of questionnaire survey was there is no system for managing earthworks equipment in the construction projects of Iraq, and was identified ten risks that possible occur. The risks associated with failures and maintenance are the most occurrence, while the risks that lead to the fall of equipment and exposure to crush the least occurrence, then reached to many of conclusions and recommendations.***

Keywords: Management Earthworks Risk Equipment

1. Introduction

Utilization of heavy equipment on construction sites is on the rise for the last three decades in the world due to unique and complex construction projects that feature creative, ergonomic and effective design, and the ever increasing demand for residential projects. Heavy equipment unquestionably provides efficiency and speed in construction projects, but at the same time it creates a hazardous work environment for all workers who are directly or indirectly involved in heavy equipment operation. Workers that are directly involved mainly consists of: operators who are specially trained to drive and operate the vehicle, and cooperators (flaggers, signal persons and spotters) who direct traffic through a construction site and help to backup vehicles using gestures, signs or flags. Workers that are indirectly involved are usually on-foot construction workers who are engaged in other construction activities in the same construction site. Variety of fatal hazards exist on heavy construction sites that harbor such workers, mainly physical hazards such as struck by vehicle, struck by objects, rollovers and others. Table (1-1) illustrating number of accidents in the different countries construction sites during the period from 2000 to 2010 [9].

[1] highlighted some of the examples of meaningful employee participation as participating in the development of safety programs and in workplace inspections, having a membership on joint labor/ management committees, and actively getting involved in accident and "near-miss" investigations. [4] states that risk perceptions must be carefully solicited in a standardized fashion to quantify and compare among risk tolerances (i.e. an individual's subjective assessment of acceptable risk).

2. Research Hypothesis

The research adopted on the main hypothesis is lack of a real system for managing risks of construction equipment in projects of Iraq, in addition to the lack of a clear vision in the project managers about the causes of accidents as a result of the use of construction equipment.

3. Research Objectives

The objectives can be summarized as the following:

1) Gathering information about construction equipment that used in earthworks such as types of equipment and advantages and disadvantages of each type ...etc.
2) Identify the main possible risks that occur as a result of using construction equipment in the earthworks.

4. Importance of Use Construction Equipment

There are several benefits for using construction equipment, as follow [2, 13]:

1) To reduce the duration of the process.
2) To reduce costs (where labour is expensive)
3) The energy sources of machines is cheaper than the energy sources of muscles
4) To reduce (heavy) manual work
5) A machine makes the work of many workers: excavator (0,5 m3) = 75 persons, tower crane (5 t, 50 m) = 140 persons. Construction equipment makes possible / easier / faster the processes.

5. Factors Affecting on Choosing Construction Equipment

To choose any construction equipment there many affecting factors on it, as follow [11]:

1) The aim of the machine – the work to carry out – the planned technologies.
2) The material / elements to work with.
3) The quality to achieve.
4) The capacity needed.
5) The conditions at the site.
6) The schedule.
7) The budget.

6. Types of Earthwork Equipment

Following typical types of heavy equipment that commonly used on construction sites [9]:

6.1 Excavators

To excavate earth and load it into trucks or deposit it. Variations:
1) Crawler-mounted: slow, but can operate on soft soil.
2) Wheel-mounted (rubber tyres): moves faster and can travel on public roads.
3) Operated by hydraulics.
4) Operated by ropes.
5) Several types :

6.2 Excavators: Power shovel / face shovel

1) The excavator operates from a flat , prepared surface;
2) Works usually above the tracks, against a face or a bank;
3) It digs by pushing the soil away from the power unit.

6.3 Excavators: Pull shovel / backactor / backhoe (hoe)

The main difference is that the position of the bucket is the reverse to that of the power shovel.
1) It is designed to dig below the level of the machine.
2) It digs by pulling the load toward the power unit.

6.4 Excavators: Dragline – an attachment used on a crane boom

1) It consists of a dragline bucket and some cables.
2) The machine is operated by pulling the bucket toward the power unit.
3) It does not dig to as accurate grade as a pull / power shovel, but it has larger working range.
4) It is suited to digging in excavations below water level and in mud / quicksand.

6.5 Excavators: Clamshell – a hinged bucket used on a crane boom

1) Used for vertical excavating at, above and below ground level.
2) The clamshell bucket consists of two scoops hinged together to work like the shell of a clam.
3) Hung from a lattice-boom crawler crane or hydraulic clamshell buckets on hydraulic hoes.
4) Special clamshell buckets for slurry walls.

6.6 Dozers, bulldozers

A dozer is a tractor unit that has a blade attached to the machine's front.
1) Wheel dozer.
2) Crawler dozer.

Used for:
1) Stripping top soil.
2) Clearing vegetation.
3) Shallow excavation;
4) Spreading and grading soil.
5) Ripping of rock.

6.7 Loaders

A loader is one machine in common use to pick up excavated material.

It consists of a crawler or wheeled tractor with a shovel or a bucket mounted in front.

Are self-loading, transporting machines used for general leveling of plane surfaces
1) To excavate and haul away large volumes;
2) Can cut the soil layers from 15-30 cm.
3) A scraper is a combination machine, in that it loads, hauls and discharges material.
4) Graders are multipurpose machines used for finishing, bank sloping ,ditching, spreading, leveling and light stripping operation

7. Risk of Using Earthwork Equipment

From the previous studies , The ways of occurrence of fatal traffic and equipment accidents on construction sites, identified many hazards of occurrence the accidents, as follows: [2, 10, 12, 5, 3].
1) Traffic accident (Collision with trees, vehicles, structures and persons).
2) Overloading (causing overturning or failure of lifting mechanism).
3) Overturning (because of work on the edge or due to overloading or poor ground conditions (Machine falling into excavation i.e slips falls when getting in or out of excavator or causing collapse of side of excavation)).
4) Risks associated with the repair and maintenance of excavators (Stop operation of the mechanism as a result of mechanical or hydraulic failure.
5) Electrocution (i.e contact with high voltage electric lines).
6) Contact with overhead or underground services.
7) Being crushed as a result of falling from the equipment.
8) Risks associated with the bucket and other attachments (Failure of Quick bucket).
9) Exposure to high levels of noise.
10) Material falls (rocks etc.) on the equipment.

8. The Causes of Occurrence The Construction Equipment Accidents

The construction industry is one of the major high risk industries worldwide. The accidents that occur include falling from height and collisions are the most prevalent. Many accidents are caused by the large and heavy plant that commonly used on construction sites.

Generally, there are many causes of occurrence accidents as a result of uses the construction equipment in the sites, as follow [6, 8, 7]:
1) Machine attachments such as breakers and large excavator buckets are very heavy and can therefore cause significant personal injury, or in the extreme death, if they become detached and fall upon anyone such as a ground worker. It has previously been reported that out of 16 incidents of workers being struck by a bucket in this way, in nine incidents, the resulting injuries were fatal.
2) Inadequate, or lack of, safety training has been identified as an important contributing factor to high accident rates in the construction industry. An efficient safety training programme, therefore, can improve safety performance

through preventing accident occurrence and is regarded as an important and effective method for enhanced occupational safety and health.

3) Safety climate and the psychological stress of employees. Safety climate involves safety attitudes and communication. Safety attitudes refer to employees' attitudes to safety and they reflect the employees' cognition of safety knowledge. High psychological stress can lead to high accident rates The psychological stress of employees can be reduced through training.

9. Field Survey

9.1 Interviews

The researcher conducted field visits to a number of construction projects in Baghdad which included interviews with the managers and engineers of those projects and also with the drivers of construction equipment. As a result information was collected on use of equipment and discuss the causes of accidents. All this has helped in the preparation of questions of the questionnaire form.

9.2 Build A Questionnaire Form

The researcher prepared twelve questions in the questionnaire form. These questions focused on how use the equipment in projects, in addition to identify the main risks that possible occurrence when use the construction equipment. The researcher distributed the questionnaire form to a sample of engineers working in the field of construction industry in Iraq, where has been distributed thirty-five questionnaire form in Arabic language.

9.3 Statistical Analysis

After distribution the questionnaire form, has been received 32 form and after excluding the forms that contains the mistakes that number was two. The number of the sample Become (30) engineer. The researcher used (spss) program to calculate the arithmetic mean and standard deviation of the questions that have the five Likers scale were relying on the weight value that shown in the table (1) in the statistical analysis process.

Table 1: Weight value of Descriptive Frequencies

Descriptive Frequency	*Class Interval*	*Weight Value (WV)*
Very high	8 – 10	9
High	6 – 8	7
Medium	4 – 6	5
Low	2 – 4	3
Very low	0 – 2	1

9.3.1 Statistical Analysis of the personal information

The following is an explanation of the personal information to the sample study:

Figure (1) shows the percentage of public sector have a highest percentage (53 %) from the private sector (47 %), which means engineers are working in the public sector more than the private sector in Iraq.

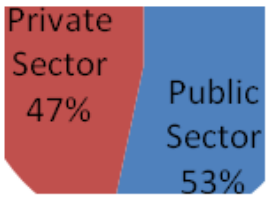

Figure 1: The work Sectors of the study sample

Figure (2): shows the percentage of males and females of the study sample, that most of the research sample of male and were by (80 %) while the percentage of females (20 %).

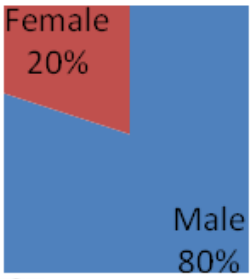

Figure 2: The Gender of the study sample

That most of the research sample were from the specialization of the Civil Engineering by (86.67 %), followed by the specialization of the mechanics by (6.67 %), and (3.33%) to the specialization of architecture and (3.33%) of electrical engineering, Figure (3) illustrates the specialization of sample individuals.

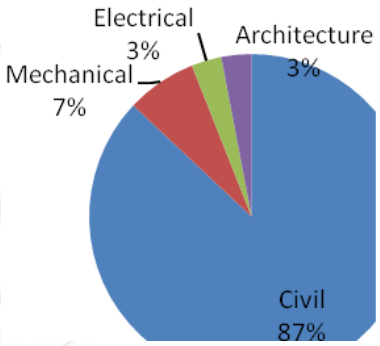

Figure 3: The specialization of sample individuals

Figure (4) shows the academic grade for engineers who filled the questionnaire form, where the B.Sc degree have the highest percentage of the sample size (80 %) and engineers with M.Sc degree have a percentage (17%) and engineers with Ph.D. degree have a percentage (3 %).

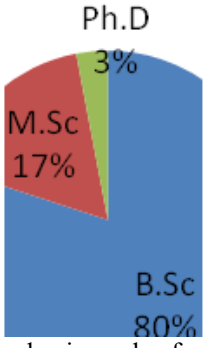

Figure 4: The academic grade of sample individuals

9.3.2 Statistical Analysis of the Questionnaire Questions
The researcher analyzed the sample answers according to the questionnaire form, as follow:

Q.1: 93.33 % of the sample answered not found any system for managing risks of construction equipment in projects of Iraq, while 6.67 % of the sample size showed there is a system for managing risks of construction equipment. Figure (5) illustrate that.

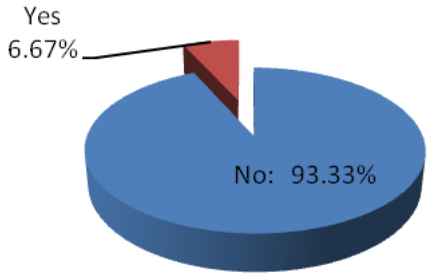

Figure 5: The answers of sample size about apply or non apply system for managing risks of construction equipment

Q.2: 43.33% of sample size answered that the main contractor is charge of about risks management for construction equipment, and also 43.33% of sample size answered that the project manager is charge of, while 30% of sample size answered that the execution engineer is charge of, and 20% answered that the operator is charge of . figure (6) illustrate that.

Figure 6: The answers of sample size about the charge of on risks management for construction equipment.

Q.3: The answers of sample size showed that the probability of occurrence fatal accident in construction projects as a result of use equipment is low, and the probability of occurrence sever accident is medium, and the probability of occurrence light accident is high, while the probability of non occurrence any accident is low. The table (2) shows the mean and standard deviation and the probability degree, and figure (7) shows the probability of occurrence for each accidents type.

Table 2: The mean and standard deviation for the probability of occurrence for each accidents type

Types Of Accidents	Answers of sample size					Mean	Std. Deviation	Probability Degree
	Very low (1)	Low (3)	Medium (5)	High (7)	Very high (9)			
Fatal	6	13	9	2	0	3.47	1.717	Low
Serve	1	11	10	8	0	4.57	1.749	Medium
Light	0	2	7	15	6	6.67	1.668	High
No accident	12	6	8	2	2	3.4	2.486	Low

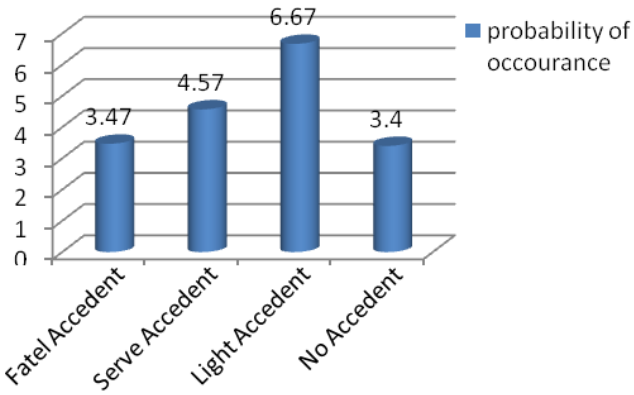

Figure 7: The mean for each type of accidents.

Q.4: The answers of sample size showed the highest probability of occurrence the accidents in excavation works, and followed by in structure works, mobilization works, and finishing works, respectively. the figure (8) shown these answers.

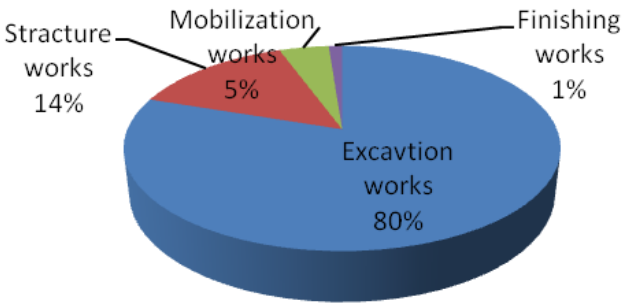

Figure 8: The mean for works nature

Q.5: The table (3) showed that the probability of use the earthwork equipment types in projects of Iraq according to the answers of sample size, and the figure (9) shows the probability degree.

Table 3: The mean and standard deviation of use the construction equipment types in projects of Iraq.

Types of Equipment						Mean	Std. Deviation	Probability Degree
	Very low (1)	Low (3)	Medium (5)	High (7)	Very high (9)			
Shovel	0	0	1	4	25	8.6	0.9684	Very High
Dragline	1	3	9	10	7	6.2	2.1324	High
Clamshell	5	9	7	6	3	4.533	2.5014	Medium
Bulldozers	0	4	13	8	5	5.933	1.8742	Medium
Loaders	1	3	5	10	11	6.800	2.2499	High
Graders	1	1	8	14	6	6.533	1.8705	High

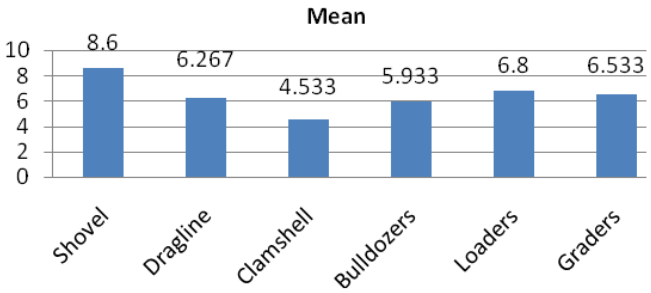

Figure 9: The mean for each type of earthwork equipment.

Q.6: The table (4) showed that the effect of use the earthwork equipment types in projects of Iraq on the cost, time, and quality, according to the answers of sample size, and the figure (10) shown the probability degree.

Table 4: The mean and standard deviation of the effect of use the earthwork equipment types in projects of Iraq

Types of Accidents	Answers of sample size					Mean	Std. Deviation	Probability Degree
	Very low (1)	Low (3)	Medium (5)	High (7)	Very high (9)			
Cost	0	0	8	14	8	7	1.4855	High
Time	0	0	9	13	8	6.933	1.5297	High
Quality	3	7	8	9	3	5.133	2.3449	Medium

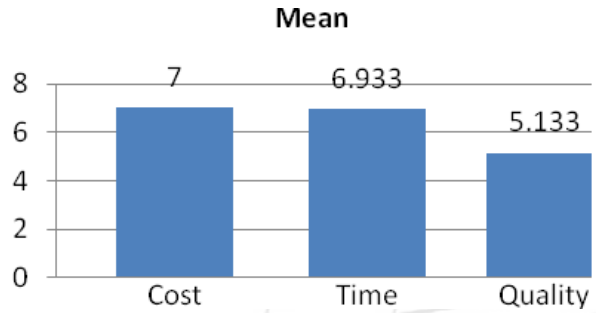

Figure 10: The mean for each type of use the earthwork equipment

Q.7: The table (5) showed that the probability of occurrence the following risks during use the earthwork equipment types in projects of Iraq according to the answers of sample size, and the figure (11) shows the probability degree.

Table 5: The mean and standard deviation of the probability of occurrence the following risks during use the earthwork equipment (sorted from high to low)

Risks	Answers of sample size					Mean	Std. Deviation	Probability Degree
	Very low (1)	Low (3)	Medium (5)	High (7)	Very high (9)			
1. Risks associated with the repair and maintenance of excavators (Stop operation of the mechanism as a result of mechanical or hydraulic failure).	0	2	11	9	8	6.53	1.87	High
2. Exposure to high levels of noise.	1	1	9	12	7	6.53	1.94	High
3. Contact with overhead or underground services.	1	5	5	12	7	6.26	2.25	High
4. Overturning because of work on the edge or due to overloading or poor ground conditions.	1	5	9	11	4	5.8	2.07	Medium
5. Overloading (causing overturning or failure of lifting mechanism).	2	2	13	9	4	5.73	2.06	Medium
6. Traffic accident (Collision with trees, vehicles, structures and persons).	5	6	8	10	1	5	1.61	Medium
7. Material falls (rocks etc.) on the equipment.	2	7	13	7	1	4.86	1.88	Medium
8. Electrocution (i.e contact with high voltage electric lines).	6	8	4	6	6	4.86	2.92	Medium
9. Risks associated with the bucket and other attachments (Failure of Quick bucket).	0	13	10	5	2	4.73	1.87	Medium
10. Being crushed as a result of falling from the equipment.	6	8	13	2	1	3.93	2.01	Low

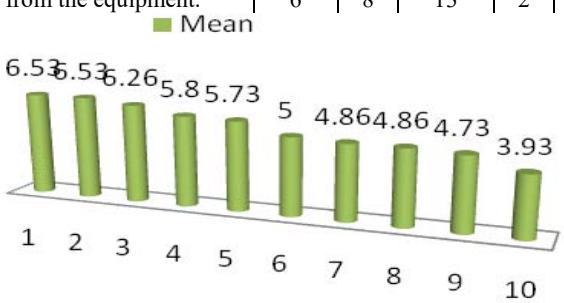

Figure 11: The mean for each risk (sorted according the table (3-5).

Q.8: The table (6) showed that the probability of occurrence the following risks with each the earthwork equipment types in projects of Iraq according to the answers of sample size.

Table 6: The probability of occurrence the following risks with each the earthwork equipment types

Risks	Shovel (%)	Dragline (%)	Clamshell (%)	Dozer (%)	Loader (%)	Grader (%)
1. Traffic accident (Collision with trees, vehicles, structures and persons).	83.3	16.67	3.33	30	60	26.67
2. Overloading (causing overturning or failure of lifting mechanism).	46.6	43.33	30	-	60	3.33
3. Overturning (because of work on the edge or due to overloading or poor ground conditions.	56.6	15	43.33	20	46.67	33.33
4. Risks associated with the repair and maintenance of excavators (Stop operation of the mechanism as a result of mechanical or hydraulic failure.	76.6	76.67	63.33	63.33	60	60
5. Electrocution (i.e contact with high voltage electric lines).	53.3	53.33	56.67	16.67	30	10
6. Contact with overhead or underground services.	83.3	46.67	40	40	26.67	30
7. Being crushed as a result of falling from the equipment.	66.6	30	26.67	60	53.33	43.33
8. Risks associated with the bucket and other attachments (Failure of Quick bucket).	60	70	66.67	26.67	43.33	13.33
9. Exposure to high levels of noise.	60	60	50	56.67	46.64	60
10. Material falls (rocks etc.) on the equipment.	60	56.67	40	6.67	63.33	13.33

Q.9: The table (7) showed that the probability of occurrence the following risks with the persons case in projects site of Iraq according to the answers of sample size.

Table 7: The probability of occurrence the following risks on the persons in projects site.

Risks	(%)			
	Involved In Activity	Close To Activity	Every One On Site	Members Of Public
1. Traffic accident (Collision with trees, vehicles, structures and persons).	73.33	46.67	30	40
2. Overloading (causing overturning or failure of lifting mechanism).	66.67	66.67	10	10
3. Overturning (because of work on the edge or due to overloading or poor ground conditions.	70	60	23.33	10
4. Risks associated with the repair and maintenance of excavators (Stop operation of the mechanism as a result of mechanical or hydraulic failure.	63.33	30	20	6.67
5. Electrocution (i.e contact with high voltage electric lines).	73.33	43.33	10	6.67
6. Contact with overhead or underground services.	56.67	36.67	20	50
7. Being crushed as a result of falling from the equipment.	80	16.67	-	6.67
8. Risks associated with the bucket and other attachments (Failure of Quick bucket).	56.67	36.67	10	6.67
9. Exposure to high levels of noise.	73.33	66.67	66.67	56.67
10. Material falls (rocks etc.) on the equipment.	80	40	6.67	6.67

Q.10: The figure (12) showed the experience years of construction equipment operators, according to the answers of sample size.

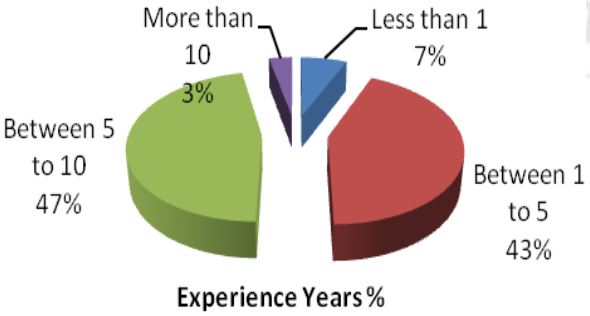

Figure 12: The experience years of construction equipment operators

Q.11: 87% of the sample size indicated that the operators of earthwork equipment not have any license from the training office, while 13 % of the sample size indicated indicated the operators have license. figure (13) illustrate that.

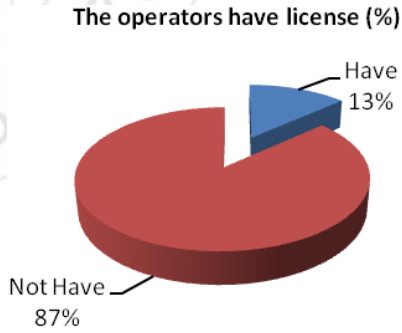

Figure 13: The operators license.

Q.12: 90% of the sample size indicated that the advance technology helping in training operators of earthwork equipment, while 10 % of the sample size indicated that the advance technology not help in training operators of earthwork equipment. figure (14) illustrate that.

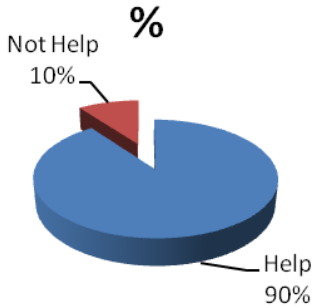

Figure 14: Show if the advance technology helping in training operators of earthwork equipment or not

10. Conclusions

After completed the statistical analysis of the questionnaire form, the researcher concluded the following issues:

1) There is no any system for managing risks of construction equipment in projects of Iraq.
2) The contractor is charge of risks management for construction equipment in projects of Iraq, and followed by the project manager, the execution engineer, the operator, respectively.
3) The probability of light accidents in construction projects as a result of use equipment is high, while probability of the severe accidents is medium, and probability of fatal accidents is low.
4) The highest probability of occurrence the accidents in excavation works, and followed by in structure works, mobilization works, and finishing works, respectively.
5) The probability of use the shovel in earthwork in projects of Iraq is very high, while use the dragline, loader, and grader is high, but use the clamshell and bulldozers is medium.
6) The effect of use the earthwork equipment types on the cost and time of project is high, while on the quality is medium.
7) The probability of occurrence most risks during use the earthwork equipment types in projects of Iraq is high.
8) About 50 % of the operators of earthwork equipment have experience years more than 5 years in projects of Iraq.
9) About 87 % of the operators of earthwork equipment in projects of Iraq not have any license from the training office.
10) The advanced technology helping greatly in training operators of earthwork equipment.

11. Recommendations

1) Build a system for managing risks that associated with earthwork equipment.
2) Reducing the risks of earthworks equipment by apply the standard control measures
3) Use the advanced technology in training the operators, such as game technology-based safety training platform.

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