Global Journal of Scientific Researches
Available online at gjsr.blue-ap.org
©2017 GJSR Journal. Vol. 5(1), pp. 5-8, 28 February, 2017
E-ISSN: 2311-732X

Study of the relationship between type of crane and type of accidents happened to them during project phase 14 of South Pars from excavation to 60% progress in project, according to linear programming (LP)

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Received: 01 February, 2017 *Accepted: 14 February, 2017* *Published: 28 February, 2017*

ABSTRACT

One of the activities involved in the construction of all refineries and most industries is movement, lifting and installation of light and heavy equipment by means of various cranes. In the event of an accident as a result of these activities, such consequences as damage to equipment, manpower injury or death seem probable. The basis of the research is to categorize various types of cranes and type of accident happened to them since the beginning of 1389 (2010) until the end of 1393 (2014) in the refinery project phase 14 of South Pars in Iran, and explore the link between type of accident and type of crane by using a linear programming modeling. Sampling from the population with N cranes was performed, which was chosen using n Morgan table. Causes of accidents were investigated in three classes; machine causes, human factor, and environmental conditions for cranes. The cranes under study are in four main types namely overhead, hydraulic, tower, and crawler. Drawing on causes of accidents and types of crane, a model of linear programming is developed, for which the first constraint of each model was reported for guidelines of risk evaluation of phase 14 refinery and the second constraint for pairwise investigation of accident factors in an attempt to take account of accident factors mentioned in accident reports. LP models were predicted in three modes namely causal, machine-human, machine-environmental, and environmental-human factors, and for each problem an optimal level is determined for objective function and the corresponding optimal solution. Given the final table of each LP models, some results were obtained that can serve as an instrument for making proper decision by crane supervisors and operators of heavy lifting in an effort to increase safety and secure better control of accident factors in each of crane types.

Keywords: *Crane accident, Crane type, Heavy lifting, Linear programming, Crane safety.*

INTRODUCTION

Movement, lifting and installation of light and heavy equipment are considered activities performed by various types of cranes in industries and refineries. In the event of an accident as a result of these activities, such consequences as damage to equipment, manpower injury or death seem probable. According to the Occupational Safety and Health Administration (OSHA), about 137 deaths associated with cranes were reported in the US from 1992 to 2001 (Juang et al, 2013, 506). Likewise, Japan has reported an annual death toll of 41 individuals in this regard (Tam et al., 2010; 208). To improve safety situation of construction projects, it is advisable to opt for methods by which the best choice of suitable crane with type of operation and environmental conditions is made (Zhang & Hammad, 2012; 397). In a case study conducted in Hong Kong into the level of drivers' training, human factors and safety features playing a part in crane accidents were studied (Tam et al., 2010; 208). However, this study just dealt with a certain kind of tower cranes, which does not include various types of cranes in general.

Typically, the root causes of crane structural failures were elaborated and can be identified (Marquez et al., 2014; 63), but it is not easy to identify which kind of crane experiences structural failure mostly, and human factors and environmental conditions contribute accidents; generally speaking, experience of an accident for cars is dependent on three factors; machine, human characteristics, and environmental conditions (Schoor okaret van, 2001; 713). This research explored the link between type of cranes and type of accident happened to them as a result of human, environmental or machine factors.

2. Method of application

2.1. Linear Programming model

According to the definition of the Scientific Research Society of America, operation research deals with scientific decision-making in order to design and aid machine-human systems to operate under special circumstances and limited resources. In 1947, Simplex method was developed by Georg Danzig in order to solve linear programming problems posed by modeling. The first successful attempt to solve linear programming models in UK National Standards Institute was made for the first series of computers (Research in operation 1, Jahanshahlou; 4). As for applications of programming modeling in solving transportation problems is problem assignment, etc. (Jahanshahlou, 158). One of the most important benefits of using this method is its power of solving real world problems by a theory. The overall form of an LP model is as follows;

Maximize or minimize Z = f (x)

$g(x) \leq b_i \quad i=1,2,3,\ldots,m$

$X_i \geq 0,\ b_i \in R,\ X \in R^n \qquad (1)$

Where f objective function and the unequal $g(x) \leq b_i$ are called constraint. The standard form of (1) has an important role in solving it, which is as follows:

Maximize $Z=\sum_{j=1}^{n} C_j X_j$

s.t

$\sum_{j=1}^{n} a_{ij} x_j + S_i = b_i$

$i=1,2,3,\ldots,m$

$x_j \geq 0,\ j=1,2,\ldots,n$

$S_i \geq 0,\ i=1,2,3,\ldots,m \qquad (2)$

Solution steps of LP model are as follows;

A) standardize the problem. B) start with a basic feasible solution to the problem and put data in the original simplex table. C) calculate all variables by using relative benefit internal multiplication rule. D) if all obtained relative benefits were non-positive, the solution which is a basic feasible solution is the optimal solution, if not, choose the variable x_k which becomes the basis, so choose x_k from the relative benefits which have non-positive values. E) find the variable attempting to be non-basic by means of minimum rule. F) find basic feasible solution by applying axial operation of new table. G) calculate relative benefits and return to step (C).

3. Problem modeling

X_1, X_2, X_3, X_4 are overhead, hydraulic, tower and crawler cranes, respectively. According to the following model, accident factors of cranes suffered accident and chosen by Morgan table (n=221) were studied in three categories namely machine factors, human factors and environmental conditions by using a questionnaire whose validity was ensured by Cronbach's alpha. The research questionnaire contains 13 items including human factors namely operator's age, level of training, education, level of experience, machine factors namely machine tonnage, safe working load (SWL) of crane, correct function of computers, crane levels, and records of crane check, and environmental factors namely quality assurance, soil compaction of accident site, weather conditions, compliance with permitted distance from accident factors such as power current-carrying lines, and drilling sites. The answer to the questions were obtained from accident reports and supervision records as well as checklists provided by safety unit, and then the data were changed from quantitative to qualitative state.

Table 1. Results obtained from the sample and separation of accident factors for each kind of crane by using questionnaire

The number of accidents caused by machine factor	The number of accidents caused by environmental factor	The number of accidents caused by human factor	The number of accident happened	Number	Type of crane
3	2	3	4	18	X_1
13	8	10	14	154	X_2
6	4	4	7	31	X_3
4	2	3	4	18	X_4

3.1. Method of application

The goal is to find the link between type of cranes and type of accidents by means of linear programming. Accident factors or the experience of an accident happen to cars are as follows (Okaret Van Schoor, 2001; 714).

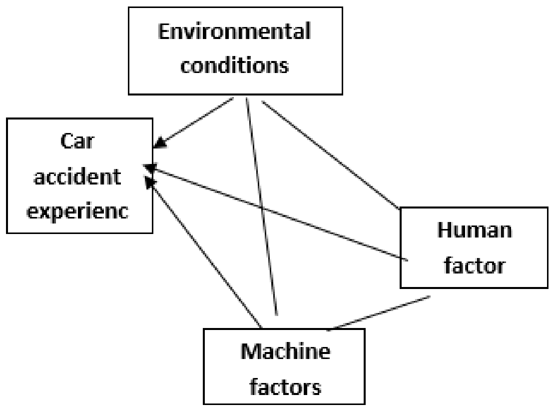

Figure 1. exploring the relation of various factors in an accident experience

In each type of crane, the goal is to find the relationship of them to the type of accident happened to them, as well as considering problem limitations.

$\text{Max}(Z) = {}_1X_1+C_2X_2+.......+C_n X_n$ (3)

Where X_i stands for types of cranes and C_i variable coefficient.

The first limitation of the model: the guideline for risk evaluation of phase 14 refinery holds that the number of iteration of one kind of accident as a result of an accident factor should not exceed 50 percent of total accidents happened as a result of the same factor, because conversely the accident has an obvious risk for which revising and controlling actions including the cessation or immediate revision of the activity are urgent.

$a_{11}X_1+a_{12}X_2+a_{12}X_3+...+a_{1n}X_n \leq a_{11}+a_{12}+\cdots+a_{1n}$ (4)

Where X_i s are types of crane and a_{ij} the number of accidents happened as a result of each factor.

The second limitation of the model: the pairwise study of the accident factors was used for linear programming problems in an attempt to consider the similarity of accident factors, which were mentioned in accident reports. By considering the circumstances of the project, each four X_i are always greater than or equal to zero, because the number of cranes is usually positive and in the case of project cessation it becomes zero; no number becomes negative. Thus, given TABLE (1), (1) and (2), and the type of problem along with its limitations, the following linear programming models exist;

$\text{Max}(Z_1) = 4X_1+ 14X_2+ 7X_3+ 4X_4$

S.t

$3X_1+ 10X_2+ 4X_3+ 3X_4 \leq 10$

$2X_1+ 8X_2+ 4X_3+ 2X_4 \leq 8$

$X_1 \geq 0, X_2 \geq 0, X_3 \geq 0, X_4 \geq 0$ (5)

$\text{Max}(Z_2) = 4X_1+ 14X_2+ 7X_3+ 4X_4$

S.t

$3X_1+ 10X_2+ 4X_3+ 3X_4 \leq 10$

$3X_1+ 13X_2+ 6X_3+ 4X_4 \leq 13$

$X_1 \geq 0, X_2 \geq 0, X_3 \geq 0, X_4 \geq 0$ (6)

$\text{Max}(Z_3) = 4X_1+ 14X_2+ 7X_3+ 4X_4$

S.t

$2X_1+ 8X_2+ 4X_3+ 2X_4\leq 8$
$3X_1+ 13X_2+ 6X_3+ 4X_4\leq 13$
$X_1\geq0, X_2\geq0, X_3\geq0, X_4\geq0$ (7)

4. Results of the proposed models

In linear programming, each Z_i stands for an optimal solution. By finding final optimal solutions for each model and comparing them in an ascending or descending fashion, the concept to which model the greatest cause of accident is related, solutions to the proposed linear programming models are obtained as follows;

$Z_1=15$
$X_1=X_2=X_5=X_6=0$
$X_3=1$
$X_4=2$ (8)

$Z_2=16.1$
$X_4=X_2=X_5=X_6=0$
$X_1=1.4$
$X_3=1.5$ (9)

$Z_3=14$
$X_6=X_5=X_3=X_4=X_1=0$
$X_2=1$ (10)

(8) practical application of the solutions following selection of each model is that X_i s included in the base are the greatest causes of them in the same model, and then after selection of the crane in question by this instrument, we know what factors can be the greatest accident factors in that type of crane.

5. Conclusion

Following each model of linear programming, each obtained an optimal value Z, where there are X_i that are solutions. Given that the objective function is a maximum type and the goal is the least occurrence of accident, in each model some factors $X_i\neq0$ are discussed. Given Z_3 and X_2, the greatest causes of accident in hydraulic cranes are environmental and machine factors. Given Z_1 and X_3 and X_4, the greatest causes of accident in tower cranes and crawler cranes are human factor and environmental conditions. Given Z_2, X_1 and X_3, the greatest cause of accident in overhead and tower cranes are human factors and machine factors. The results can serve as good instruments for choosing cranes and identifying weaknesses of each crane and causes of accident in them for accident experts and clients.

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