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Optimization of Safety Audit Planning: A Case Study of Process Plant in India

S.V.S Raja Prasad *

National Institute of Construction Management and Research, Shamirpet, Hyderabad, Telangana, India; rajaprasad@nicmar.ac.in.

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Abstract

Safety audit is a system for evaluating the adherence of an occupational safety and health plan to fulfill statutory requirements with prior planning. Safety audit planning is the predetermining activity of what, how, where, when and by whom the audit will be carried out to achieve its objective. Safety audit planning is a complex process and an anticipatory function which will provide audit activity on time with the least audit risk and cost by assigning the auditors with the required ability and skill level to the activities to be audited. In general, the safety audit planning is based on the professional judgment of a lead auditor by considering the qualitative characteristics of the auditors. However, the audit planning is possible by framing a mathematical model with an assumption that the auditors possess similar characteristics. The objective of the study is to optimize the safety audit planning by allocating auditors to activities using a linear programming model so as to minimize the audit cost; which is not possible with statistical tools. The study was conducted in an integrated cement plant located in India and the results of the study show that the number of hours and the activity of the auditors was specified with a minimum cost. Similar studies can be conducted to optimize time and cost of safety audit for industrial units involving more number of activities with large batch size of auditors by planning the audit process in advance.

Keywords: Occupational safety and health (OSH), Safety audit, Auditors, Linear programming.

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1 | Introduction

Safety audit is a comprehensive assessment and appraisal of all components of safety management system to establish compliance with guidelines and standards [1]. The purpose safety audit is to detect nonconformities, renew certifications, and fulfill goals and objectives [2] Annual Occupational Safety and Health (OSH) audits are instrumental to ensure best safety practices in construction sites, which includes safety management system, employee protection and safety

Corresponding Author: rajaprasad@nicmar.ac.in

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practices [3]. OSH audit is carried out by safety auditors or professionals in the domain of safety management system and the report prepared by the audit team is useful to initiate preventive/ corrective measures [4]. Safety audits assist in identifying failures within a system, process and the information gathered helps to determine the best course of corrective action [5]. Safety audits are basically of two types; structural and operational audits. Structural audits are based on available documentation and a consideration whether these documented activities meet the established criteria whereas operational audits also include interviews and observations to verify whether safety rules and routines are implemented in practice [6] and [7].Typically, the process of OSH audit includes; gathering evidence through systematic data collection, usually by reviewing documentation, conducting interviews and observing worksites; evaluating the evidence against audit criteria; and summarizing and reporting the results [8]. OSH management audits are used to evaluate workplaces' OSH management structures and processes. The audits typically determine whether the organization is compliant with one or more standards; such as its organizations own policies and procedures, applicable legislation and regulations.

Safety audit is a tool to measure the level of safety performance in any organization. The findings of safety audit are useful to conduct root cause analysis and preventive/corrective actions. Safety auditing was an awareness tool; for hazard identification and risk assessment, and behavior modification of employees. The OSH audit needs to focus not only on the physical hazards in the workplace but also on the safety culture at organization level which has an impact on overall safety performance. Organizations should ensure that all levels of management take notice on the use of audit as an important appraisal method in OSH management. The criteria for conducting OSH audits are revealing the findings of audits to employees, time frame/deadline for conducting audits and continuous review of OSH audits; the number of audits performed and reviewed in a given period [9]. The strength and weakness of safety management system can be noticed by continuously auditing and reviewing the management systems and operational procedures in order to achieve safety performance [10]. The quantitative results of audits are often used by organizations as performance measures [11]. Safety audit is the leading indicator while measuring the safety performance. Indeed, the safety audit may apply similar methodologies used in financial audits to mitigate safety risks within an organization.

The characteristics of safety auditors have an impact audit quality. The main attributes of safety auditors are independence, unbiased approach and competency. Lack of independence in conducting safety audit may lead to less likely to report irregularities, thereby impairing audit quality [12] and [13] Identifying independent and qualified safety auditors is of paramount importance in audit planning. The report of the safety auditors is considered a positive feedback loop and assists to reinforce the safety management system implementation. The debits of possible loss or injury situations should balance against the credits of adequate safeguards [14]. Auditing provides a means of exposing the organizations frequent and deliberate efforts to raise safety awareness and compliance.

In India, due to the growing awareness of safety in the industrial sector and introduction of various legislations for implementing directives of the statutory bodies, the need has been felt to formulate the Indian Standard 14489: Code of practice on OSH audit, which will give a guideline to audit safety aspects in the industrial and other units of concern [15]. While formulating the standard, utmost care has been taken to cover all the possible elements relating to safety. This standard doesn't include rating system but it gives qualitative analysis of safety elements. From the available literature and discussions with the safety professionals, it is noticed that the importance of OSH audit, attributes and selection of safety auditors were highlighted in the past; and the task of audit planning was not discussed. The gap in the literature motivated to conduct the present study with an objective to optimize safety audit planning by allocating auditors to OSH activities by developing a linear programming model so as to minimize the audit cost and time.

As the industries are framing their own safety policies and procedures in addition to complying the statutory requirements, the safety auditing has become vital to establish that the existing procedures are consistent with procedures/requirements. The industrial units are mainly accomplish safety through

operational-level experience and with a low level of formalisation, the audits have a primary focus on formal documentation and gathering audit evidence at the strategic and tactical levels in the units [16]. In general, the audit organization allocate shorter timeframes for the conduct of an audit than are necessary in practice irrespective of type of safety audit. Allocating insufficient audit time may lead to rushing and consciously cutting sampling of activities or records which can dilute the accuracy of the audit. Safety audit planning is the process of balancing the time and cost with prior assessment and planning for determining the OSH practices are functional and effective.

2 | Methodology

In India, the need of safety audit is mainly to fulfill safety and statutory requirements. Indian Standard 14489 establishes audit objectives, criteria and practices, and provides guidelines for establishing, planning, conducting and documenting of audits on OSH systems at workplace. It provides guidelines for verifying the existence and implementation of elements of OSH system and for verifying the system's ability to achieve defined safety objectives. It is sufficiently general in nature to permit it to be applicable or adaptable to different kinds of organizations [15]. The need to perform an audit is determined by the client, taking into account of specified or regulatory requirements and any other pertinent factors. Significant changes in management, organization, policy, techniques or technologies that could affect the OSH system, or changes to the system itself and the results of recent previous audits, are typical of the circumstances to be considered when deciding audit frequency. Normally an external or third-party safety audit should be conducted once in two years and an internal audit may be organized once in every year.

2.1 | Safety Audit Procedure (IS 14489)

The safety audit procedure as per the Indian standard is detailed below.

The lead auditor and the team of auditors have to adopt the procedure while conducting safety audit.

- *Constitution of Audit team (at least two members).*
- *Constitution of auditee representatives.*
- *Recording identification and brief history of the auditee industry.*
- *Deciding audit goals, objectives and scope.*
- *Drawing audit plan with time schedule.*
- *Holding opening meeting with the auditee.*
- *Study of process and applicability of safely laws and standards.*
- *Plant visit and noting observations.*
- *Examining records and documents.*
- *Filling checklists of audit points.*
- *Holding of closing meeting and discussing findings.*
- *Preparation and submission of audit report*
- *Report distribution for compliance.*
- *Compliance audit if required by the audittee or client.*
- *Visit for compliance audit and its report.*

The standard also specified the details of safety audit goals, objectives, scope, plan, and verification of records, checking applicability of safety legislations, plant visits, consolidation of observations and report preparation and submission.

2.2 | Study Area

The study was conducted in an integrated cement plant located in north east of India with a capacity of one million tons per annum. The present strength of employees of the plant is more than 2000 and the management is committed towards OSH and welfare of the employees. The plant is certified with ISO 9001, ISO 14001 and OHSAS 18001certifications. Safety department of the plant is actively involved in organizing the safety training programmes, conducting the mock drills and implementing the motivational schemes to create awareness towards OSH systems. The management of the plant strictly follow to conduct the safety audits to comply with legislations and to provide safe workplace for employees. The management of the plant organizes to conduct an external safety audit by engaging safety auditors to fulfill the statutory requirements. The scope of the audit involves auditing the various departments of the plant, preparation and submission of the report to the management for further action.

The management of the plant was decided to utilize the services of three safety auditors including a lead auditor to complete the audit. The auditors vary in their experience and qualifications but capable of conducting audit all the departments. The auditors are designated as Lead Auditor (LA), auditor 1 (*A1*) and auditor 2 (*A2*) respectively. The lead auditor in consultation with management has finalized the number of hours required to complete the audit, time required for auditing each department and the number of hours auditors are supposed to work in each department. The audit fee for LA, *A1* and *A2* are fixed as *Rs*.2500, *Rs*.2100 and *Rs*.1800 per hour respectively. The total audit time required for completion is 80 hours. Based on audit fee, number of audit departments and number of hours required for each department, a linear programming problem was formulated. The details of the departments and number of hours required to conduct as per estimate is presented in *Table 1*.

Table 1. Departments, activities and hours required for audit.

S/N	Department	Activity No	No of hours for audit
1	Process plant.	Activity 1	10
2	Mechanical equipment.	Activity 2	13
3	Electrical & Instrumentation Department.	Activity 3	11
4	Civil Engineering Department.	Activity 4	9
5	Safety, Health &Environment, Occupational Health Centre.	Activity 5	16
6	Human resources and Stores Department.	Activity 6	7
7	Supply and dispatch.	Activity 7	8
8	Audit report preparation/submission.	Activity 8	6

2.3 | Linear Programming Problem Formulation

Optimization techniques enable to achieve certain goals (cost or time minimization) by efficient use of resources and it is widely applied in the decision-making process. Linear programming is a method used in optimization techniques to obtain the optimal utilization of resources so as to minimize cost/time or maximize profit [17]. Linear Programming (LP) is a group of mathematical techniques that can obtain the very best solution to problems which have many possible solutions. In most of the situations, resources available to the decision maker are limited. With the help of linear programming those scarce resources are allocated in an optimal manner on the basis of a given criterion of optimality [18]. The structure of all LP Problem has three important components; decision variable (activities), objective function (goal) and constraints.

Linear programming technique is based on the following assumptions [19]:

- *The objective function must be defined accurately (maximization or minimization).*
- *Variables should be quantitative. Linear programming is not used for qualitative.*
- *Variables should be correlated with one another.*
- *Resources to be used should be limited.*

- *Established relations among variables should be linear.*
- *Dependent variables should be positive or zero.*

LP is one of the most popular technique to find best solution in variety of situations such as man power planning, production management, marketing, financial management, etc. [18]. The objective function and the constraints are shown in *Eq. (1)* and *Eq. (2)*, respectively. The LP problem can be expressed in compact form as follows:

Optimize (Maximize or Minimize)

$$Z=\sum_{j=1} c_j x_j . \quad (1)$$

Subject to constraints,

$$\sum_{j=1}^{n} a_{ij}\ x_j\ (\leq or = or \geq) b_{i;}\ i=1,2,3\ldots m \quad (2)$$

and $x_i \geq 0$; j=1,2,…n (Non negative Constraints).

$x_1, x_2, x_3 \ldots\ldots x_n$ are decision variables and contribution of each decision variable are $c_1, c_2, c_3 \ldots . c_n$ respectively. Technical coefficient and resource capacity is represented by a_{ij} and b_i respectively. The objective function is represented by *Z*.

In all LP problems, left hand side of constraints is either less than, or equal to or greater than right hand side [18].

2.3.1 | Application of LP problem formulation of study area

The objective of the present study is to allocate the auditors to audit activities so as to minimize the cost. In this context, the objective function is formulated and shown as *Eq. (3)*.

$$\text{Minimize}\quad Z=2500x_{11}+2500x_{12}+2500x_{13}+2500x_{14}+2500x_{15}+2500x_{16}+2500x_{17}+2500x_{18}+ 2100x_{21}+2100x_{22}+2100x_{23}+2100x_{24}+2100x_{25}+2100x_{26}+2100x_{27}+2100x_{28}+ 1800x_{31}+1800x_{32}+1800x_{33}+1800x_{34}+1800x_{35}+1800x_{36}+1800x_{37}+1800X_{38}. \quad (3)$$

Subjected to constraints,

1) Minimum number of hours for auditors. The minimum number hours of audit of LA, *A1* and *A2* are 15, 35 and 30 hours respectively, and the total audit hours are 80 hours. The *Eq. (4)* to *Eq. (7)* represent the constraints auditor wise.

Lead Auditor; $x_{11}+x_{12}+x_{13}+x_{14}+x_{15}+x_{16}+x_{17}+x_{18}\geq 15$. (4)

Auditor 1; $x_{21}+x_{22}+x_{23}+x_{24}+x_{25}+x_{26}+x_{27}+x_{28}\geq 35$. (5)

Auditor 2; $x_{31}+x_{32}+x_{33}+x_{34}+x_{35}+x_{36}+x_{37}+x_{38}\geq 30$ and (6)

$x_{11}+x_{12}+x_{13}+x_{14}+x_{15}+x_{16}+x_{17}+x_{18}+x_{21}+x_{22}+x_{23}+x_{24}+x_{25}$

$+x_{26}+x_{27}+x_{28}+x_{31}+x_{32}+x_{33}+x_{34}+x_{35+}x_{36+}\mathbf{X}_{37+x38}\geq 80$. (7)

2) Activity wise time constraints (From *Table 1*). The constraints for eight departments are represented by *Eq. (8)* to *Eq. (15)*.

Activity 1: $x_{11}+x_{21}+x_{31}\geq 10$. (8)

Activity 2: $x_{12}+x_{22}+x_{32}\geq 13$. (9)

Activity 3: $x_{13}+x_{23}+x_{33}\geq 11$. (10)

Activity 4: $x_{14}+x_{24}+x_{34}\geq 9$. (11)

Activity 5: $x_{15}+x_{25}+x_{35}\geq 16$. (12)

Activity 6: $x_{16}+x_{26}+x_{36}\geq 7$. (13)

Activity 7: $x_{17}+x_{27}+x_{37}\geq 8$. (14)

Activity 8: $x_{18}+x_{28}+x_{38}\geq 6$. (15)

3) Minimum working hours required to conduct the audit by the LA on the basis of audit scope of the departments are represented by *Eq. (16)* to *Eq. (23*).

LA: $x_{11}\geq 2$. (16)

LA: $x_{12}\geq 1$. (17)

LA: $x_{13}\geq 1$. (18)

LA: $x_{14}\geq 1$. (19)

LA: $x_{15}\geq 1$. (20)

LA: $x_{16}\geq 1$. (21)

LA: $x_{17}\geq 1$. (22)

LA: $x_{18}\geq 2$. (23)

Minimum working hours required to conduct the audit by the *A1* (Auditor 1) on the basis of audit scope of the departments are represented by *Eq. (24)* to *Eq. (31)*.

A1: $x_{21}\geq 3$. (24)

A1: $x_{22}\geq 3$. (25)

A1: $x_{23}\geq 3$. (26)

A1: $x_{24}\geq 3$. (27)

A1: $x_{25}\geq 3$. (28)

A1: $x_{26}\geq 3$. (29)

A1: $x_{27}\geq 3$. (30)

A1: $x_{28}\geq 2$. (31)

Minimum working hours required to conduct the audit by the *A2* (Auditor 2) on the basis of audit scope of the departments are represented by *Eq. (32)* to *Eq. (39)*.

A2: $x_{31} \geq 2$. (32)

A2: $x_{32} \geq 2$. (33)

A2: $x_{33} \geq 2$. (34)

A2: $x_{34} \geq 2$. (35)

A2: $x_{35} \geq 2$. (36)

A2: $x_{36} \geq 2$. (37)

A2: $x_{37} \geq 2$. (38)

A2: $x_{38} \geq 2$. (39)

3 | Results and Discussion

The formulated linear programming model consists of 24 variables and 36 constraints. The objective function and constraints are run in LINDO software to solve the linear programming problem. The output of the formulated model was tabulated and the consolidated results of safety auditor's allocation to auditing departments are shown in *Table 2*.

Table 2. Allocation of safety auditors to departments.

Auditors	Departments								Total
	1	2	3	4	5	6	7	8	
LA	2	1	6	1	1	1	1	2	15
A1	3	3	3	3	12	4	5	2	35
A2	5	9	2	5	3	2	2	2	30
	10	13	11	9	16	7	8	6	80

Output summary is shown in *Fig. 1*, the number of hours allocated to each auditor for a department and audit fee are mentioned in the summary. The minimum total cost is *Rs* 165000 (Rupees one lakh sixty-five thousand) to complete the audit of the plant.

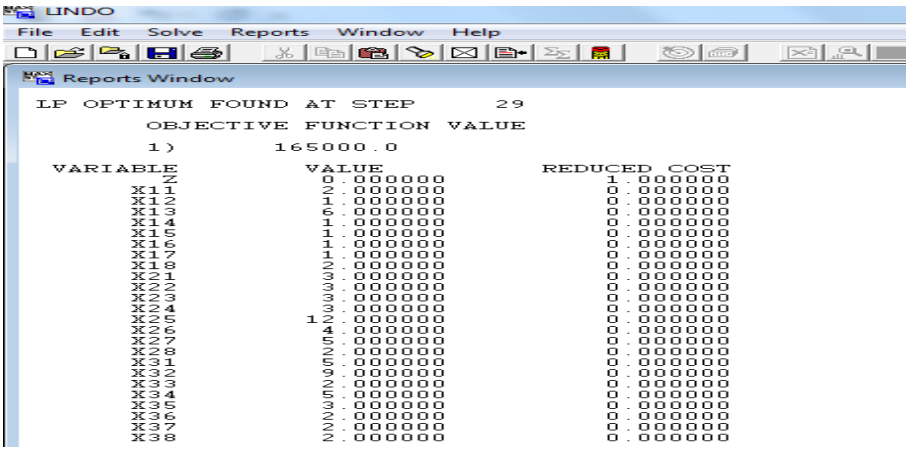

Fig. 1. Output summary of LINDO software.

From the *Table 2*, the lead auditor should work one hour each for auditing mechanical, civil engineering department, safety, health &environment, occupational health center and supply and dispatch and two hours each for process plant and audit report preparation/submission; and six hours for electrical and instrumentation departments. The auditor *A1* should work maximum for twelve hours to audit safety, health and environment, occupational health center; and the auditor *A2* should work for maximum of nine hours to audit mechanical equipment. It is also observed from the results that the safety, health

&environment, occupational health center and mechanical equipment auditing require sixteen and thirteen hours respectively.

The audit fee for LA, *A1* and *A2* are *Rs*.37500, *Rs*.73500 and *Rs*.54000, respectively so that the total cost involved for audit will be minimum. The auditor *A1* fee is high among others due to expertise in conducting safety audit of cement plants. The lead auditor role is mainly to monitor the smooth conduct of audit, guide the audit team, discussions with the management and preparation of report with the assistance of the team members.

4 | Conclusion

A sound safety audit plan has a direct impact on the success of audit activity. Allocating the right auditors to the right department bestow to the accomplishment of safety audit with minimum cost. Conducting safety audit for an integrated cement plant require quality audit and allocation of auditors to different departments is crucial. The application of optimization techniques like linear programming is useful in this context instead of allocating the auditors randomly. The audit planning is a useful tool for the lead auditors to allocate specific audit work in the time frame of a particular department so as to avoid duplication of work. Similar studies are useful particularly for safety audit planning of refineries, fertilizer and pulp and paper industry due to presence of number of departments and also handling of hazardous chemicals.

The limitation of the study is the audit planning was conducted by framing a LP model with an assumption that the auditors possess similar characteristics but in reality, it may not so. The auditor's expertise in the domain of OSH is vital when the company's compliance with the legal requirements is to be evaluated. The results of the audit should be reliable which means that the different auditors should come to same conclusions. The audits conducted by different auditors should reach similar results when the same operation is audited under the same conditions. In this study, the auditors are allotted to conduct audit to different departments based on their experience and qualification which may lead to inaccurate results. In future, while conducting the similar studies the inter observer reliability is to be assessed as it is useful to examine the variation which occurs when one auditor performs multiple judgements at different times.

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