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## Causes of construction accidents in Oman

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**Abstract:** Considering the costs associated with accidents in construction, a model identifying root causes of accidents is proposed for construction organisations in Oman. The model classifies the accidents in construction mainly arising from main four causes: 'equipment/materials', 'workers', 'environment' and 'management'. The model is applied to a road construction project in Oman to trace the root causes of accidents. It can also be applied to construction projects in other sectors such as building or process plant construction. Further research is recommended to extend the study to other projects in the construction sector in order to generalise the findings. Although the frequency distribution of accidents is likely to vary from project to project, understanding the underlying pattern of their causes helps to pinpoint the key areas where resources should be directed in the organisations' efforts to deliver the goal of zero accidents.

**Keywords:** health and safety; management; construction hazards; accidents; workers; materials and equipment; environment; highway project; cost of accidents; types of construction accidents; inspections; project management.

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## **1 Introduction**

Worldwide occupational injury rates in the construction sector are high compared with all other major industries (Lehtola et al., 2008). Unlike other industries such as manufacturing, construction is composed of a transient workforce (Dubois and Gadde, 2002; Kadefors, 1995), where project personnel from different cultures and backgrounds are expected to work together in a constantly changing work organisation and structure. Construction is always risky due to outdoor operations, work at height, complicated on-site plant machinery and equipment operations coupled with the worker's attitudes and behaviours towards safety (Choudhry et al., 2007). Statistics published by the International Labor Organization in 2016 indicate that at least 108,000 workers are killed on construction sites every year, a figure that represents about 30% of all fatal occupational injuries. Data from a number of industrialised countries show that construction workers are three to four times more likely than other workers to die from accidents at work. In the developing world, the risks associated with construction work may be three to six times higher. Accidents include not only direct physical injury to persons or damage to property, but also short and long term effects or incidents due to other exposures on sites that affect the workers' health and physical well-being. The costs of accidents (direct and indirect) can be substantial. The costs of accidents in the USA were determined as 6.5% of the total value of completed work and in the UK it is approximately 8.5% of the tender value (BRT, 1995; Anderson, 1997). Research conducted in the UK on cost and benefit analysis revealed that when total costs of accident prevention were compared to the total benefits of accident prevention, the benefits far outweigh the costs of accident prevention by a ratio of approximately 3 : 1, which means that when contractors, irrespective of their sizes, spend £1.00 on accident prevention, they gain £3.00 (Ikpe et al., 2012). The cost of accidents can be understood by contractors and represents a tangible measure that can be related to project financial accounts and both the income statement and balance sheet of a contractor (Tang et al., 2004; Booth and Panopoulos, 2005). The costs of accident also affect the workers and society, as illustrated in Table 1. Thus, this category of cost is very often at the forefront of considerations of the costs of health and safety.

Construction is a major industry providing jobs to millions of people and contributing to countries and the world economy. Contribution towards the Omani economy is around

10% of the total gross domestic product (GDP) and employs 18% of the total population (NCSI, 2015). Oman labour law empowers the ministry of manpower to ensure the health and safety standards through ministry inspectors and in event of the existence of any danger which threatens the safety and health of the workers, the Ministry can take necessary measures to close down the place of work wholly or partially, or to stop the operation of one or more machinery until the elimination of the causes of such danger. The ministry could improve further the process of inspections and penalties by benchmarking its system with Occupational Safety and Health Administration (OSHA) (USA) and health, safety and environment (HSE) (UK).

**Table 1** Costs of accidents incurred by stakeholders

| <i>Stakeholders</i>                       | <i>Intangible costs</i>  | <i>Tangible costs</i>  |
|---|--|--|
| Worker                                    | Pain and suffering, moral and psychological suffering (especially in the case of death and permanent disability) | Loss of salary, reduction of professional capacity, loss of time (medical treatment), site compliance of health, and safety issues   |
| Family and friends of the affected worker | Moral and psychological suffering, medical and family burden   | Financial loss, extra costs, loss of time to take care of the injured worker   |
| Coworkers                                 | Bad feeling, worry, or panic (in case of serious or frequent accidents)  | Loss of time, increase of workload, and training of temporary staff  |
| Employer                                  | Bad reputation, litigation cost, insurance cost, and compensation cost   | Decrease in production; damages to machinery, equipment, and material; quality losses; recruitment and training of new staff; increase of production costs; increase of insurance premium; administrative costs; litigation costs; and absenteeism |
| Society                                   | Reduction of the human labour potential, and reduction of the quality of life                                    | Loss of production, increase of social costs, medical treatment and rehabilitation costs, and decrease of standard of living   |

*Source:* Ikpe et al. (2012)

Knowing the root causes of accidents can help construction organisations in preventing accidents in future through appropriate risk mitigation measures and by addressing the weak areas associated with accidents. This paper develops a model for identifying the root causes of accidents in construction. The root causes of accidents are broadly divided into four categories: equipment/materials, workers, environment and management. The model described in this paper will help construction organisations in Oman to identify the root causes of accidents which will further help the construction organisations in developing strategies to reduce accidents on construction sites.

## 2 Literature review

Construction researchers have proposed several accident causation models and root causes. McClay's (1989) 'universal framework' identified three key elements of

accidents: hazards, human actions, and functional limitations. Hinze's (1996) distraction theory argued that production pressures can distract workers from the hazards and increase the probability of accidents. Abdelhamid and Everett (2000) identified management deficiencies, training, and workers' attitude as the three general root causes. The 'constraints-response' model by Suraji et al. (2001) argues that project conditions or management decisions can cause responses that create inappropriate conditions or actions that lead to accidents. Gibb et al. (2006) identified worker, workplace, material and equipment as shaping factors of accidents in construction. The accident root causes tracing model (ARCTM) presented by Abdelhamid and Everett (2000) discussed four main causes of accidents that are from:

- management actions/inactions
- unsafe acts of worker or coworker
- non-human related events
- an unsafe condition that is a natural part of initial construction site conditions.

The model proposed by Mitropoulos et al. (2005) identifies the need for two accident prevention strategies

- reliable production planning to reduce task unpredictability
- error management to increase the workers' ability to avoid, trap, and mitigate errors.

A study into the causes of accidents in the construction industry in Uganda linked the major causes of accidents in construction to inadequate supervision, use of incompetent personnel and use of inappropriate construction techniques (Lubega et al., 2000). The research concluded that accidents are caused by a wide range of factors including:

- lack of awareness of safety regulations
- lack of enforcement of safety regulations
- poor regard for safety by people involved in construction projects
- engaging incompetent personnel
- non-vibrant professionalism
- mechanical failure of construction machinery/equipment
- physical and emotional stress
- chemical impairment.

Research conducted by Hamid et al. (2008) in Malaysia on the causes of accidents on construction sites concludes that the main cause of construction accidents are workers' negligence, failure of workers to obey work procedures, work at high elevation, operating equipment without safety devices, poor site management, harsh work conditions, low knowledge and skill level of workers, failure to use personal protective equipment and poor workers attitude about safety.

Haslam et al. (2005) in their studies of 100 individual construction accidents summarised the levels of involvement of key factors in the accidents as: problems arising from workers or the work team (70% of accidents), workplace issues (49%), shortcomings with equipment-including personal protective equipment (PPE) (56%), problems with suitability and condition of materials (27%), and deficiencies with risk management (84%). They further suggest that design and cultural factors shape the circumstances found in the work place, giving rise to the acts and conditions which, in turn, lead to accidents. It is argued that attention to the originating influences will be necessary for sustained improvements in construction safety to be achieved.

Research on the causes and effects of accidents on construction sites conducted in Nigeria found that workers are the major contributors to the causes of accidents on construction sites, which ranges from 53% to 67% of the main causes of accidents in different sizes of construction organisation. Although there are further 25 different factors which contribute to accidents on construction sites, the research also concludes that workers are the most affected people from accidents whatever the cause (Kadiri et al., 2014).

The study by Ali et al. (2010) reveals that accidents are generally caused by unsafe acts and unsafe conditions besides other sub-causes. Accidents can result from a combination of contributory causes. The main causes of construction accidents identified in their study are the human element, poor site management, failure to use personal protective equipment and unsafe equipment used in construction work.

On the basis of the above literature review the proposed model for tracing the root causes of accidents discussed in this paper classifies the accidents arising from four main causes that can be related to:

- equipment/materials
- worker
- environment
- management.

### **3 Research methodology**

The main research question in this research is to identify the main causes of accidents in construction in Oman. The methodology adopted in this research includes the collection of actual accidents data from a construction organisation that just completed a major highway project. Five main construction organisations that were involved in delivering the project were asked for cooperation to investigate the root causes of accident on the project. These organisations were informed about the purpose of the research and the information required for the purpose of the research. Only one construction organisation agreed to cooperate on the condition that the name of the organisation would not be revealed. This construction organisation was carrying out a 75 km road construction project estimated to cost of US\$ 305.90 million. The project was started in September 2011 and 82 % of the work was completed in April 2016. The accidents data was collected directly from the project H&S team and included following information:

- type, nature and location of accident
- statement of workers involved in the incident
- report of the safety or site supervisor
- photos of the accidents
- medical reports in case of medical injury.

A total of 623 accidents data was provided by the H&S team. These accidents were of different types in nature. Based on the accident data, the different types of accidents were initially classified based on their nature under.

### *3.1 Alternate work injury (AWI)*

A work injury that results in the injured person being able to perform only restricted (light) duties in the original workplace on the first scheduled work day or shift (or any subsequent work day or shift) on the day after the incident.

### *3.2 First aid injury (FAI)*

A work injury that requires first aid treatment, including observations, tetanus toxoid (TT) injections, non-prescription drugs, pain killers, examination, X-rays, oral rehydration, minor dressings even if carried out in the hospital.

### *3.3 Loss time injury (LTI)*

A work injury or disease resulting in a fatality, permanent disability or time lost from work of one or more complete work days or shifts, following the fourth day or shift of the incident. Fatalities causes from suicide or natural causes are excluded.

### *3.4 Medical treatment injury (MTI)*

A work injury that requires treatment other than first aid at a hospital or other medical facility.

### *3.5 Property/equipment damage*

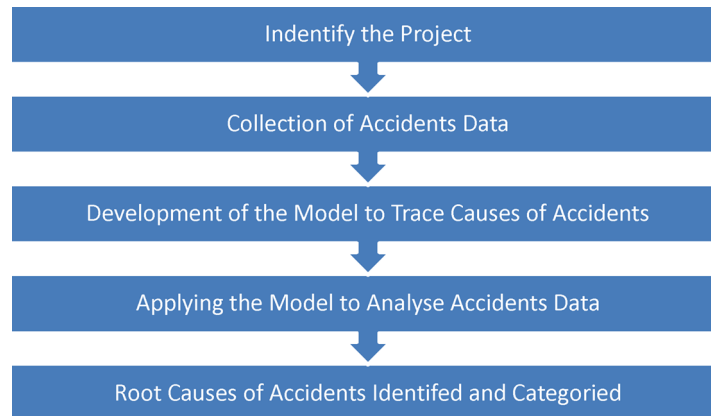
These are incidents resulting from workplace activities that caused damage to property or equipment only.

To find the root causes of these incidents a model was developed to identify the causes of accidents and to relate them to the main causes from material/equipment, workers, environment and management as shown in Table 2. These main causes of accidents were identified from a literature review on different models of the root causes of accidents in construction.

The process used in this research to identifying the root causes of accidents in construction is explained in Figure 1.

**Table 2** Model for tracing roots causes of accidents

| Equipment/Materials   | Worker  | Environment   | Management  |
|---|---|---|---|
| There was excessive noise from equipment or machines involved in the incident.                              | The worker involved in the incident was under fatigue/stress.                                       | There was an ambient condition (wind, dust, rain, etc.) at the place of incident.   | The incident was caused by hazardous method specified.                                  |
| The machines, equipment or tools which were involved in the incident were difficult to operate.             | The worker involved in the incident was having physical disability which was affecting performance. | There was excessive noise at the place of incident.                                 | The incident was caused by lack of supervision/supervisor competence.                   |
| The machines, tools or equipment involved in the incident were malfunctioning or defective.                 | The incident was caused by the worker culpable act.   | The incident was caused by poor lighting.   | The incident was caused by the non - provision of correct safety equipment or clothing. |
| The materials/equipment involved in the incident was difficult to handle and maintain.                      | The incident was caused by worker skylarking or misconduct.   | The incident was caused by terrain condition.                                       | The incident was caused by inadequate training provided.                                |
| There was inadequate guarding or protection with the machines, tools or equipment involved in the incident. | The worker involved in the incident was having personal problems.                                   | The incident was caused by temperatures.  | The incident was caused by poor housekeeping standard.                                  |
| The machine tools, or equipment involved in the incident is manual handling.                                | The worker involved in the incident was inexperienced in the task being performed.                  | The incident was caused by poor housekeeping.                                       | The incident was caused by poorly maintained equipment.                                 |
|   | The incident caused by failure of worker to use safety clothing.                                    | The incident was caused by building surface conditions (stairs, floors etc.)        | The incident was caused by non-availability of suitable plant/equipment.                |
|   | The worker involved in the incident used a hazardous work method.                                   | The incident was caused by storage/staking of material.                             | The incident was caused by inadequate or non-documented procedures.                     |
|   | The worker involved in the incident was under the influence of alcohol or drugs.                    | The incident was caused by exposure or contact chemicals or other harmful material. | The incident was caused by insufficient/inadequate instruction or information.          |
|   | The incident caused by act or omission of another person or worker.                                 | The incident was caused by exposure to infectious sickness/disease.                 | The incident was caused by production pressure from a supervisor or manager.            |
|   |   | The incident was caused by poor visibility.   |   |
|   |   | The incident was caused by congested work-area.                                     |   |

**Figure 1** Process to identify root causes of accidents (see online version for colours)

#### 4 Number of accidents in selected project

The record maintained by the project HSE team shows that there were a total of 623 accidents from September 2011 to April 2016 as shown in Table 3. Property/equipment damage accidents were at the top with a total number of 580 accidents, followed by MTI (15), FAI (14), LTI (9) and AWI (5). The average numbers of workers on the project during this period (September 2011–April 2016) were 2000.

**Table 3** Summary of different types of accidents (September 2011–April 2016)

| <i>Year</i>  | <i>Property/<br/>equipment<br/>damage</i> | <i>Alternate work<br/>injury (AWI)</i> | <i>First aid<br/>injury (FAI)</i> | <i>Loss time<br/>injury (LTI)</i> | <i>Medical<br/>treatment injury<br/>(MTI)</i> | <i>Total</i> |
|--------------|---|--|-----------------------------------|-----------------------------------|---|--------------|
| 2011         | 0   | 0                                      | 0                                 | 0                                 | 0   | 0            |
| 2012         | 7   | 1                                      | 1                                 | 0                                 | 2   | 11           |
| 2013         | 155                                       | 0                                      | 3                                 | 3                                 | 4   | 165          |
| 2014         | 164                                       | 2                                      | 0                                 | 5                                 | 5   | 176          |
| 2015         | 179                                       | 2                                      | 7                                 | 1                                 | 4   | 193          |
| 2016         | 75  | 0                                      | 3                                 | 0                                 | 0   | 78           |
| <i>Total</i> | <i>580</i>                                | <i>5</i>                               | <i>14</i>                         | <i>9</i>                          | <i>15</i>                                     | <i>623</i>   |

Considering the importance of inspection in ensuring proper health and safety at the workplace, the project HSE team was requested to provide a record of all internal and external inspections carried out during the project period. The ultimate purpose of the enforcing authorities is to ensure that duty holders manage and control risks effectively, thus preventing harm. The term ‘enforcement’ has a wide meaning and applies to all dealings between enforcing authorities and those on whom the law places duties (employers, the self-employed, employees and others). The purpose of enforcement is to:



- ensure that duty holders take action to deal immediately with serious risks
- promote and achieve sustained compliance with the law
- ensure that duty holders who breach health and safety requirements, and directors or managers, who fail in their responsibilities, may be held to account.

The inspection record shows that there were a total of 2392 HSE inspections carried out during the project period (September 2011–April 2016). The number of internal inspections conducted by the project HSE team consists of one HSE advisor and five HSE officers were 2376. The contractor head office HSE team conducted a total of 12 inspections. There were four inspections conducted by different government agencies out of which two were carried out by Civil Defence authority in 2013, One by Ministry of Manpower in 2014 and the last one was by Ministry of Environment and Climate Affairs in 2015. Table 4 shows the record of HSE internal and external inspections conducted from 2011 to 2016 on this particular project.

**Table 4** Summary of internal and external HSE inspections on the project (September 2011–April 2016)

| <i>Year</i>  | <i>Internal inspections by project HSE team</i> | <i>External inspections by contractor head office HSE team</i> | <i>External inspections by government authorities</i> | <i>Total</i> |
|--------------|---|--|---|--------------|
| 2011         | 0   | 0  | 0   | 0            |
| 2012         | 461   | 4  | 0   | 465          |
| 2013         | 791   | 2  | 2   | 795          |
| 2014         | 535   | 3  | 1   | 539          |
| 2015         | 406   | 3  | 1   | 410          |
| 2016         | 183   | 0  | 0   | 183          |
| <i>Total</i> | <i>2376</i>                                     | <i>12</i>  | <i>4</i>  | <i>2392</i>  |

## 5 Analysis and discussion

The HSE policy of the construction organisation define the procedure for incident reporting, which requires the workplace manager and HSE in-charge to determine whether a specific incident requires further investigation or not. The process of reporting an incident by the workplace manager and HSE in-charge include collection of necessary information to determine what happened, where and who was involved. To understand the causes of different accidents that occurred on the project, the project team was requested to provide the incident investigation reports for detailed analysis and study. A total of 44 different incident reports were provided by the HSE team of the project. These reports were initially assessed against the model developed for tracing the root causes of accidents. It was found that only 22 reports had sufficient information to be used for tracing the root causes. Thus the valid accidents data used are 50% of the total accidents reports received from H&S team of the project. Out of 22 reports, nine incident reports were classified as property/equipment damage, one as AWI, two FAI, and five as LTI. A different set of questions were developed and applied to each incident. The model was validated by top management, including the HSE advisor, construction manager and

project director of the construction organisation. All the valid incidents reports were reviewed against these questions and a conclusion was made on the main or root causes of each incident.

After reviewing the incident reports against the set of questions shown in Table 2, eight incidents were matched to one root cause. The remaining incidents (14 incidents) were having more than one main root cause (Table 5). In 2012, seven incidents completed reports were provided by the project HSE team. Two incidents matched to one root cause of ‘worker’ and another to ‘management’. The remaining four incidents in 2012 had more than one root cause.

**Table 5** Summary of accident classification and root causes of accidents investigated

| <i>Year</i>               | <i>Accident classification</i>  | <i>Root cause</i>                                      | <i>Total</i> |
|---------------------------|---------------------------------|--|--------------|
| 2012                      | Property/equipment damage       | Environment + Management                               | 7            |
|                           | AWI                             | Worker   |              |
|                           | Property/equipment damage       | Worker   |              |
|                           | FAI                             | Environment + Management                               |              |
|                           | Property/equipment damage       | Worker + Management                                    |              |
|                           | Property/equipment damage       | Management   |              |
|                           | MTI                             | Equipment + Worker + Management                        |              |
| 2013                      | Property/equipment damage       | Worker + Environment                                   | 8            |
|                           | Property/equipment damage       | Worker + Management                                    |              |
|                           | MTI                             | Equipment + Worker + Management                        |              |
|                           | Property/equipment damage       | Worker + Environment + Management                      |              |
|                           | LTI                             | Worker   |              |
|                           | MTI                             | Worker + Management                                    |              |
|                           | MTI                             | Worker + Management                                    |              |
| Property/equipment damage | Equipment/Material + Management |  |              |
| 2014                      | LTI                             | Equipment/Material                                     | 2            |
|                           | LTI                             | Worker   |              |
| 2015                      | Property/equipment damage       | Equipment/Material + Worker                            | 5            |
|                           | FAI                             | Worker   |              |
|                           | LTI                             | Worker   |              |
|                           | MTI                             | Equipment/Material + Worker + Environment + Management |              |
|                           | LTI                             | Worker + Management                                    |              |
| <i>Total</i>              |                                 |  | <i>22</i>    |

From eight valid accident reports of 2013, one incident was matched to ‘worker’ as a root cause while the remaining seven incidents had more than one root cause. In the year 2014, there were two valid accidents reports available. One incident had the root cause of ‘material/equipment’ and one incident to the root cause of ‘worker’. The total valid

accidents reports for the year 2015 were five out of which two incidents matched one root cause of 'worker', the remaining three incidents were having more than one cause as shown in Table 5.

Considering individual causes, for five incidents, 'equipment/material' was one of the root causes. For 17 incidents, 'worker' was one of the root causes of accidents. 'environment' was one of the root causes for five incidents; 'management' was one of the root causes for 13 incidents; and equipment/material was one of the root causes for six accidents.

## **6 Conclusions**

The proposed model for identifying the root causes could be a useful tool for construction organisations in Oman to know the root causes of accidents on their projects. This will help them to develop strategies towards reducing the number accidents and thus reduce the cost associated with accidents. By using this model, construction organisations will be able to pinpoint the key areas which cause most of the accidents. The proposed model identifies the main causes of accidents in construction that arise from equipment/materials, workers, environment, and management. Although the model is used only on a road construction project, it can be adopted and can be used on other construction projects. This investigation has revealed that a significant proportion of accidents (41%) arise from the 'worker'. Furthermore, it is found that Management factor contribution is 31%, equipment/materials contribution is 14% and the environment contribution is 12%. Different types of accidents are discussed and investigated in the research to identify their root causes. Understanding the main causes of construction accidents will aid construction organisations in directing their resources to high risk areas to improve their safety performance.

This work has described results of research where a model has been developed and applied to help identify the principal root causes of accidents on a major highway construction project in the Sultanate of Oman. The causes of accidents in construction will vary from project to project and from sector to sector in the construction industry. Exposure to the risk of construction hazards will also vary depending on whether the project is a new build or involves maintenance operations. The model developed in this study could be applied to accidents in other sectors including building, civil engineering, process plant construction, etc. It is essential that the model developed in this study is tested using accident data from other sectors in order to generalise the applicability of the model and the findings on the root causes of accidents in construction. Knowing the root causes of accidents in construction is one thing, however, further research need to be conducted how to eliminate all the causes of accidents in construction and how to achieve the goal of zero accident in construction projects.

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