TOWER CRANE ACCIDENT PROFILE

Prepared for:

Jabatan Keselamatan dan Kesihatan Pekerjaan
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Prepared by:

UKM PAKARUNDING

TOWER CRANE ACCIDENT PROFILE

Project Title:

A STUDY ON IMPROVEMENT OF TOWER CRANE SAFETY MANAGEMENT IN THE CONSTRUCTION SECTOR

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CHAPTER 1

REVIEW OF CRANE ACCIDENT TRENDS

The construction industry has been identified as being one of the most dangerous and largest industries in the world, based on studies on the rate of work-related fatalities, workers' compensation, injuries and deaths (Chong & Low 2014). The construction industry also involves the heavy usage of cranes, especially tower cranes, to help expedite the construction of buildings. In the construction industry, considerations for safety and health requirements are widely recognised as a useful approach for managing occupational safety and health because an emphasis on these factors can eliminate or reduce hazards at the workplace (Saifullah & Ismail 2012; Zakaria et al. 2012).

In relation to endangerment to the safety of workers, high-risk activities, including working at heights and hoisting work, have been identified as dangerous work that can lead to accidents in the construction sector. However, there are no rules and industry practices specific to the construction sector that have additional provisions to be adhered to by employees responsible for safety, especially for work in high places and hoisting work (Rahman & Hassan 2008).

Starting in 2000, there have been more than 1125 cases of accidents involving tower cranes all over the world, and these involved 780 deaths and an increase in injuries. There also many accidents are not reported, and the actual distribution might be double the figure. In 2009 alone, there were 188 accidents with 78 fatalities, while in 2010, there were 154 accidents with 113 fatalities (http://www.towercranesupport.com). The statistics with regard to the number and the causal factors for the accidents are shown in Figures 1.1 and 1.2.

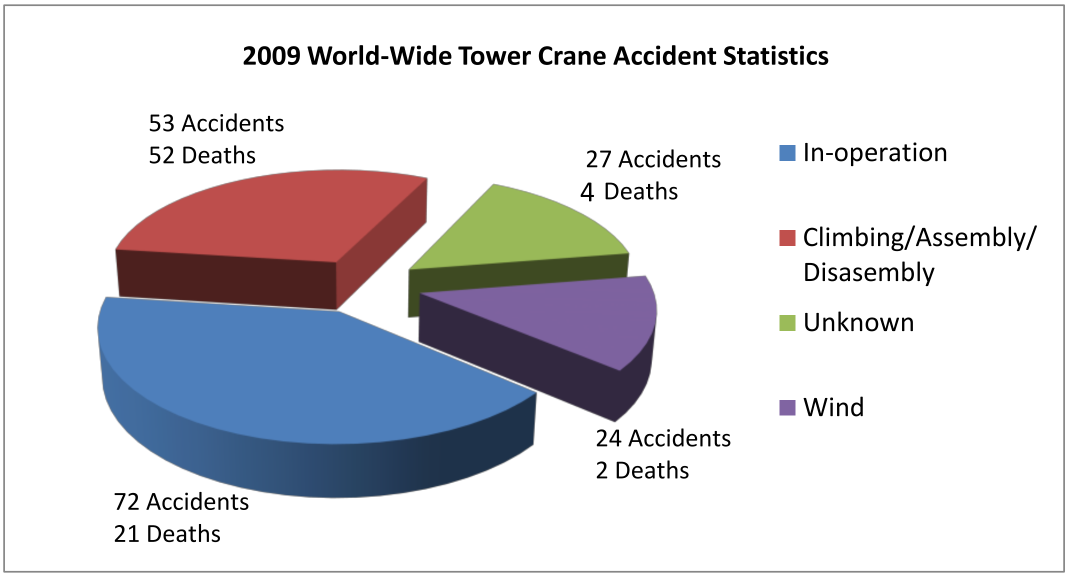

Figure 1.1 Statistics on the number of tower crane accidents in the world (http://www.towercranesupport.com)

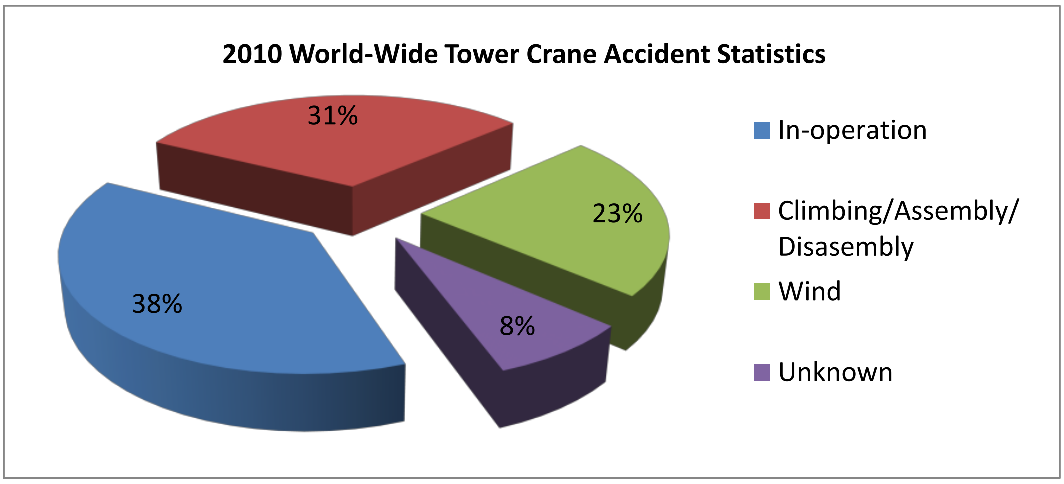

Figure 1.2 Statistics on the percentage of the factors responsible for tower crane accidents (http://www.towercranesupport.com)

In 2009, most of the tower crane accidents occurred during the operation (72 accidents and 21 deaths), erection/climbing/dismantling works (53 accidents and 52 deaths), due to wind (24 accidents and 2 deaths), and finally for unknown factors or others (27 accidents and 4 deaths). Similar trends also occurred in 2010, with most of accidents occurred during crane operation with the value of 38%, crane erection/climbing/dismatling was fpund to be at 31%, wind factor was at 23%, and another 12% with unknown factors. In addition, safety measures during the tower crane operation by means of erection/climbing/dismatling should be taken into account in order to ensure safety in the construction site, hence, to reduce the similar accident occurrence.

Employees working in the construction industry especially are exposed to greater risks compared to those in other industries (Bakri et al. 2006). To avoid accidents, the causes of workplace accidents must be identified, such as faulty machines, personal factors, environment, and mechanisms or equipment that can lead to accidents. In Malaysia, generally, cases in relation to accidents at the workplace have been increasing every year. For example, in 2003, the number of accidents involving the loss of life was about 5.41% or 907 cases from 81,003 cases, i.e. 1073 deaths from 77,742 accidents. Therefore, it is very important to maintain the safety of workers by having a good management system to ensure a safe environment for workers by legal means or non-legal approaches in the workplace (Arifin et al. 2012). In addition, the designs and materials for tower crane components or parts used, repaired or replaced should be tagged in order to assured the crane designs (and also their specific materials) that were used in the construction site are follow the manufacturer's specifications, and safe to be used.

While, for the structural design of the tower crane shall comply with the code of practice that is being used in several countries such as AS2550.20, AS1418.4-Cranes-Part 4 di Australia, DIN 15018-1 (1984-11)-Cranes; steel structures; verification and analyses, EN14439: The harmonised European product standard for tower cranes, ANSI/ASME B30.3: Tower cranes, and GB/T 5031-2008: Tower cranes. The contents of these codes give a more detailed description of the design requirements and guidelines for handling cranes in a safe manner. However, most countries have enacted standards and codes of practice based on the existing EN and ANSI codes.

CHAPTER 2

TREND OF TOWER CRANE ACCIDENTS

2.1 Malaysia

The Act and the standard operating procedures (SOP) involving cranes are based on the Occupational Safety and Health Act 1994 (Act 514) and the Factories and Machinery Act (Amendment-2006), and there are no specific acts or codes of practice related to the safe use of tower cranes in Malaysia. The guidelines that have been adopted are the Guidelines for the Registration of Persons with the Chief Inspector of Factories and Machinery as Tower Crane, Passenger & Material Hoist, Working Platform and Gondola Competent Persons, MS ISO 4306-1:2014 Cranes-Vocabulary-Part 1: General and MS ISO 4310:2014 *Cranes-Test code and procedures*.

Based on the scenario in Malaysia from 2000 onwards, Kuala Lumpur, Selangor, Johor and Penang are among the states with the highest number of tower cranes. From the crane distribution data obtained from DOSH, there are 10,677 mobile cranes, 4099 Derrick cranes and 1434 tower cranes. On another scope, 2741 tower crane operators were registered with DOSH and are actively work in the construction sites. Majority of the tower crane numbers at 1120 are used in both Federal Territory of Kuala Lumpur and Putrajaya, Selangor and Johor (DOSH 2017). With the increment of tower crane numbers in Malaysia, as yearly recorded, the rate of accidents may increase if both security and rules/codes of crane standards are not complied. Overall, Malaysia has 82% of the total imports from China, 6% from France, 4% from Malaysia, 3% from Italy, 2% from Germany and 3% from other countries, i.e. Spain, Australia, United States, Singapore, Japan, Korea, Netherlands, South Korea and Thailand.

With the number of tower cranes increasing in Malaysia every year, the accident rate may go up if the safety factors and the standard regulations/codes on the use of cranes are ignored. Referring to a study by Chong and Low (2014), from 2000 to 2009 as many as 69126 accidents occurred in the construction industry sector, and out of this total, as many as 653 cases involved cranes. 70 accidents were reported from year 2000 until 2017, and the cases are found to be increased every year, as shown in Figure 2.1, and some accident information are listed in Table 2.1. From the 70 accidents, 34 cases involved luffing tower cranes, 14 cases for hammerhead and 22 cases were unidentified (data unavailable).

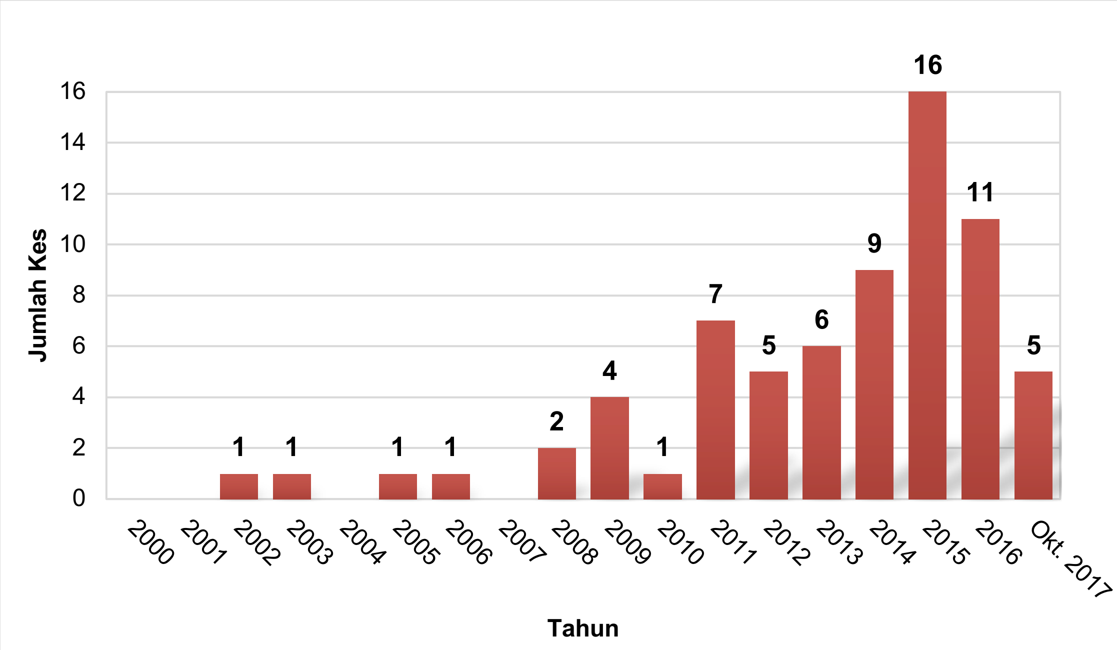

Figure 2.1 Statistics of accidents involving tower cranes
(Abdullah & Wern 2010; Laporan JKKP)

For year 2000, 2001, 2004 and 2007 the data on tower crane accidents can not be obtained. For example, an accident involving a collapsed crane in 2013 in Seri Kembangan was due to structural failure in the crane because of overloading, while the latest accident (April 2016) occurred at the Bangsar (detailed information are discussed in Chapter 5.4), caused by failure on the luffing angle limit switch. Detailed information regarding the accident in year 2016 will be discussed further in Chapter 5. In 2015 alone, 14 accidents were reported, and among the causes of the accidents were twisting of the tower crane's jib, snapping of the hoisting rod, detachment of the slewing unit of the crane and so on. Referring to the DOSH reports and the accidents that have occurred, there are several causes for the accidents. The percentages for the causes of these accidents are shown in Figure 2.7.

(a)

(b)

Figure 2.2 Occurrences of toppled crane in (a) Seri Kembangan, 2013 (http://www.starproperty.my) and (b) Bangsar, 2016 (http://www.lipstiq.com)

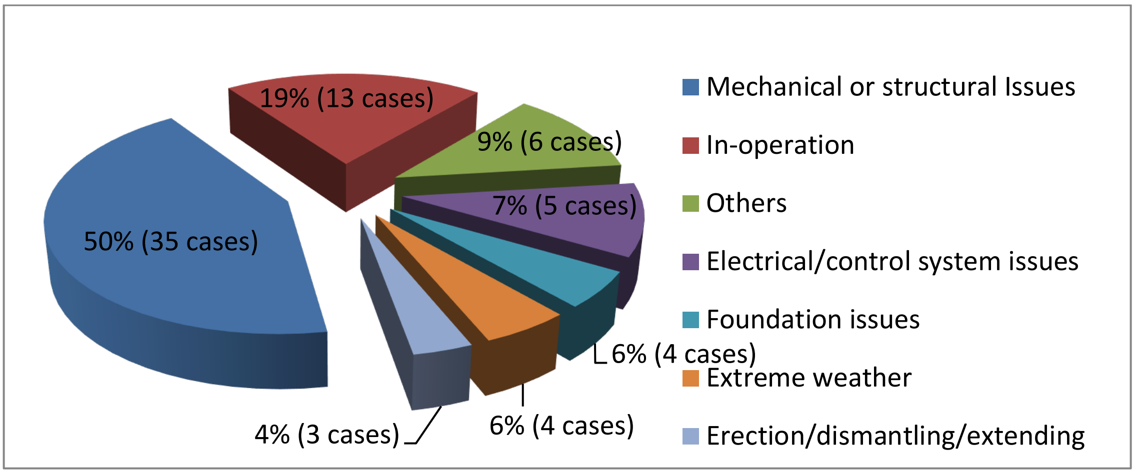

Figure 2.3 The percentage factors that cause accidents tower cranes (Abdullah & Wern 2010; Fail siasatan JKKP; http://www.dosh.gov.my)

Table 2.1 Details of several accidents involving tower crane

Year	Location	Type of Crane	Details of the Accident	Causes	Year of Manufacture	Country
2008	Persiaran Surian, Sek 39, Mukim Petaling Jaya, Selangor	Luffing	Concrete filled bucket and boom fell on concrete casting pillar during concrete filling at second floor. Luffing rope snapped off due to abrasion caused by relative movement between outer and inner strand. An operator and two construction worker injured.	Luffing rope snapped	2007	Malaysia
2009	Kuala Lumpur	Luffing dan hammerhead	Accidents of 2 tower crane which is the Hammerhead and Luffing. Both crane operated close to each other. Hammerhead counterjib crashed and pull the tie rod of Luffing crane until it bend and snapped. No inury reported.	Failure of planning and control of crane operation traffic	2007	China
2011	Taman Setia Tropika, Mukim Tebrau, Johor	Hammerhead	Crane main jib involved has bent at 20 meter during lifting of 20 tonne of reinforcing bar. No injury reported.	Damage at jib (Substandard material)	1996	China
2011	Bukit Tunku, Mukim Batu, Kuala Lumpur	Luffing	Luffing boom fell suddenly. During incident, 2 victims were under the crane. Consequently both died at the location due to severe ingury at head.	Luffing winch wire rope exerted from drum and snapped at the end of the rope. Imprfection of luffing system (winch, motor, gear, brake)	2008	Malaysia
2011	Selangor	Hammerhead	During crane operation of mirror lifting at 2 feet from the lorry, overload occured. Overload limit switch has been activated and stop lifting activities. The operator illegally reset the operation system. Suddenly slewing table and operator cabin detached and fall down to level 33. Boom and counterweight also fell off. An operator was injured.	Overload	1990	China
2011	Georgetown, Pulau Pinang	Hammerhead	Incident occured when crane in free standing condition. Suddenly it topple over a shoplot reside by occupant. 3 civilian injured and 1 died.	Crane foundation failure	2008	China
2012	Seksyen 89, Jalan Madge, Kuala Lumpur	Luffing	Crane fell over – Pile Cap (foundation) crane detached. Crane fell during lifting activities. One operator and construction worker injured.	Crane foundation failure	2001	Malaysia
2013	Taman Tasik Prima, Puchong Selangor	Luffing	Crane was lifting BRC steel (1 tonne). During lifting, suddenly crane boom fell slowly. Load position was found to be exceeding the permissible position (50m). The actual position was 52 to 53 m. No injury reported.	Overload at exceeded permissible distance	2012	China
2013	Sungai Buloh, Petaling, Selangor	Luffing	Before the incident, crane's counter jib was modified. Jib then snapped into 2, however no luffing, hoisting and pendant rope snapped. Load of 200kg was lifted before the incident. Connection pin was not installed correctly to the cotter pin. The maximum load for crane boom is 1.2 tonne at 50 m. No injury reported.	Jib fracture, connection pin was not installed correctly.	2012	China
2013	Seri Kembangan, Selangor	Hammerhead	Sub-contractor helper was operating crane without authorization to transfer iron. He was not authorized. Crane lifted load exceed the specification. Boom fractured at hinge point and mast pillar (counter jib weight impacted the mast). 1 operator injured.	Overload, boom fractured (misuse)	2013	China
2013	Bandar Sunway, Daerah Petaling, Selangor	Hammerhead	Failure at boom during lifting (industrial disposal bin) with unknown weight. Boom bent and fracture, resulting fracture of slab due to impact of boom and wire rope. No injury reported.	Corrosion at main boom especially at troley	1991	France
2015	Site Velocity Phase 2, Jalan Peel, Kuala Lumpur	Luffing	Tower crane fracture. No injury reported.	Unknown	2010	China
2015	Hotel Strong Force, Ipoh Perak	Luffing	Crane used to lift wooden sheet at level 12. During boom lifting at speed level 2, boom direct move backward and causes malfuntion. Boom failed to decelerate by luffing until it reached 72°. Luffing boom limit switch was not adjusted properly which causes diconnection of boom to limit switch eventhough te angle was maximum. No injury reported.	Crane operator careless during adjusting and installation of safety limiting device	2014	China
2016	Jalan Raja Chuka Jalan Bukit Bintang, Kuala Lumpur	Luffing	Crane rig of 300 kg mass fell from above the rooftop)at 100 m and resulting the death of the lady driver. Passer by witness crane to life fractured load before falling on the car. 1 civillian died.	Failure at lifting limiter to lift and lower hook.		China
2016	Jalan Bangsar, Seksyen 96, Kuala Lumpur.	Luffing	Crane was lifting "L" shape iron of 1.5 tonne at jib angle of 82 degree (based on meter reading) and jib fell at the opposite direction where the end of jib extended to the adjacent roadside. No injury reported. Crane main structure and a lorry was damaged. No injury reported.	Luffing exceeded limited angle degree.	1994	Italy
2016	Taman Len Sen, Cheras, Kuala Lumpur	Hammerhead	Incident occured during lifting 900 kg load at 40 degree angle (at trolley of 30-40 meter). Suddenly boom fractured and load fell on the building at upper level. Distance of load from the floor is 4 feet. The maximum load is 3000 kg. – Crane was not installed with load indicator. No injury reported.	Pin at boom fractured / detached. Overload	1982	Frane

Source: Abdullah & Wern 2010; Fail siasatan JKKP; http://www.dosh.gov.my; http://towercraneaccidents

Based on Figure 2.3, out of the 70 cases of crane accidents that occurred, 43% were due to mechanical or structural issues, namely, damage to the following components:

- damage due to bent jib/boom
- snapped crane cable
- broken pin/bolt (slewing table)
- snapped luffing rope
- damage to the pin jib/boom
- problems with the gear/brakes
- problems with the hoisting drum
- snapped hoisting rope
- crane mast

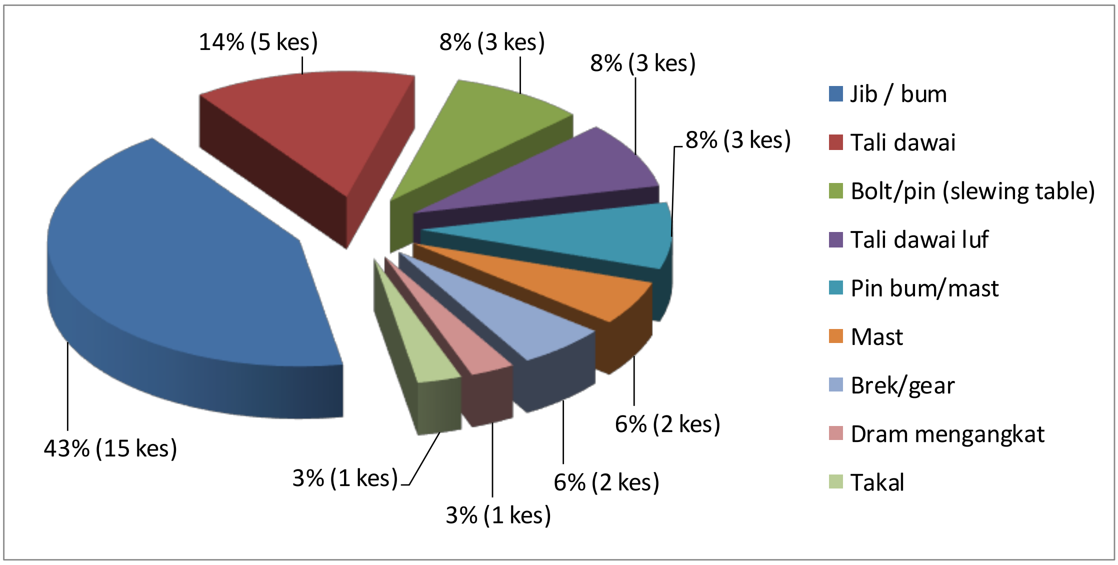

Figure 2.4 Components that fail during crane operation

The second factor for crane accidents, 21% of which occurred during operations, was failure/negligence on the part of the crane operator, signalman, management and so on. The third factor was electrical issues or control systems, namely, 10%, which was caused by failure of the control system of the crane such as the lifting limiter (3 cases), hoisting system (2 cases) and failure of the luffing system (1 case). In addition, among the other factors that contributed to crane accidents were the failure of the crane base, i.e. 5% (3 cases), while 4% (2 cases) were due to the erection/mounting/dismantling of tower cranes, 5% (3 cases) were due to extreme weather (wind and lightning), and 12% (7 cases) were due to other factors/unknown causes. Among the factors that influenced safety during the installation/dismantling of tower cranes (In Jae, 2015) were:

(i) the inadequate knowledge and skills of the persons installing/dismantling;
(ii) inadequate instructions or manuals regarding safe work procedures;
(iii) damaged tower crane parts that may have been due to poor storage conditions;
(iv) inadequate supervision at the work site; and (v) poor working conditions such as time and space constraints

Other than that, study made by Marquez et al. (2014) conclude that safety issues were mainly caused by human factor. Most crane failure were related to operation, operation fitness or crane operator responsibility (Tam & Fung 2011). Inadequate training dan operator fatigue result in unsafe tower crane operation environment (Aneziris et al. 2008; Fan 2010). Furthermore, unidentified imperfection in crane design were classified as ‘normal accidents’ eventhough crane design is essential since the imperfection can be repeated by constant manufacturer. When the crane enters the market, there is no effective safety measure to detect the structure weakness (Swuste 2013).

Besides that, various root cause leads crane failure. However most cases are due to extreme weather, structure weakness, crane foundation weakness, overload and error during crane structure installation (Panchal & Dodiya 2013; In Jae 2015). In addition, in the context of harmful factor related to tower cranes need to be consider (Raviv et al. 2016) although Malaysian climate rarely cause of accident of tower crane. Most risk occured are related to crane foudnation, steel structure, bolt connection, pin link, rope and safety limiting devices. All these errors related to mechanical safety (Deng Li et al. 2006).

In connection to that, DOSH officials have suggested a number of safety measures in order to reduce accidents such as ensuring all cranes are operated by competent and registered crane operator in which they are to operatecrane in prescribe method and obliged to correct procedure as state in the manual. Lifting activities must be done correctly to avoid extreme force. Contractor is also required to perform risk assessment upon all activities. Crane owener must ensure all limiting devices are functioning and schedule inspection must be performed on crane structure, especially critical component such as boom, counter jib, slewing cable, hoisting rope, wire rope, hoisting brake and others. Inspection must be done according to standard technical procedures and obliged to good engineering ethics.

According to a report issued by DOSH (2010), with the increase in tower crane accidents, DOSH came up with a new procedure for the approval of tower crane designs. This procedure was approved by the department and is being practised currently, especially for tower cranes and mobile cranes. This procedure specifies that every used crane unit that is more than 10 years old that is to be registered in Malaysia must undergo a special assessment examination conducted by a third firm of authorised auditors accredited by DOSH. The crane will be evaluated in terms of its structural analysis (life cycle) to determine the duration of its use before the iron structure experiences fatigue or failure. The duration of its use will not include the time when it is in storage. The remaining lifecycle is known as the permissible operating period. After that time frame, the tower crane concerned must either undergo a special inspection or be disposed of. With the enforcement of this procedure, tower crane accident cases can be optimally reduced.

In order to enhance the safety factor in the construction industry, the Construction Industry Development Board (CIDB) in collaboration with DOSH, developed the Occupational Safety and Health in the Construction Industry Plan 2005-2010 (CIDB Portal). This step is fully supported by the Malaysian government, where all parties are aware of the importance of reducing the accident rate. The function of this proposed master plan is to guide all stakeholders in the construction industry in enhancing activities for the safety and health of workers. The National Safety and Health Committee in the Construction Industry has identified and focused on six matters, namely

Enforcement and Legislation, Training and Education, Promotions, Incentives and Disincentives, Standards, Research and Development and Technology (Abdullah & Wern 2010).

2.2 Hong Kong

The construction industry is one of the contributors to the economy of Hong Kong, where it contributes approximately 4.5% to the gross domestic product and about 6.8% of the workforce in Hong Kong (*Occupational Safety and Health Council* 2008a). Nevertheless, the safety performance of the construction industry in this country has raised concerns. Table 2.2 shows the number of accidents involving all industries as well as the accident rate in the construction industry from 1997 to 2006. It was found that the rate of accidents is yearly decreased due to the engagement by Department of Labour (Hong Kong) in safety and health promotion in the workplace through education, legislation, enforcement, promotion and training. In addition, the employee Occupational Health and Safety Council has also managed to increase the awareness of employees and employers regarding safety in the workplace.

In 2006, the Hong Kong Department of Labor published the paper entitled 'Legislative Council Panel on Man Power Hong Kong's Occupational Safety Performance' to the Hong Kong Board of Legislators by proposing new initiatives to create and maintain a safe work culture at the site. Among these initiatives were to promote the safe lifting equipment, enhancing the scope of inspection and enforcement of lifting operations, conducting safety audits and the "Construction Industry Safety Award Scheme" sponsored scheme to improve the safety system at site. The Hong Kong Labor Department is working closely with related organizations, such as the Occupational Safety and Health Council (OSHC), the Construction Industry Council (CIC), trade associations, trade unions, professional bodies and other government agencies to foster the Safety and Health Work through enforcement, promotion and publicity.

Table 2.2 Number of industrial accidents and the accident rate in the construction industries in Hong Kong

Year	Number of Industrial Accidents	Accidents Rate for every 1000 workers (Percentage)
1997	18,559	227.4 (22.74%)
1998	19,588	247.9 (24.79%)
1999	14,878	198.4 (19.84%)
2000	11,925	149.8 (14.98%)
2001	9206	114.6 (11.46%)
2002	6239	85.2 (8.52%)
2003	4367	68.1 (6.81%)
2004	3833	60.3 (6.03%)
2005	3548	59.9 (5.99%)
2006	3400	64.3 (6.43%)

Source: Occupational Safety and Health Council 2008b

Furthermore, the construction industry in Hong Kong has recorded the highest death and accident rates compared to other industrial sectors. As mentioned by Beavers et al. (2006), fatalities in the construction industry mainly involve tower cranes. Table 2.3 shows the list of accidents involving tower cranes in Hong Kong from 1998 to 2007. Based on Table 2.3, 9 tower crane accidents were recorded, and these accidents occurred almost every year. The date, place and detailed information regarding the accidents are mentioned in the table. In addition, Figure 2.5 shows the news of tower crane accidents for 2007, 2011 and 2015.

Table 2.3 Tower crane accidents in Hong Kong from 1998 to 2007

Date	Place	Details of accident
18 Oct. 1998	Wong Tai Sin	2 workers fell 15 m onto a building platform while operating a tower crane.

23 Feb. 1999	Sau Kei Wan	A worker fell from the 5th floor after being hit by a tower crane winch when hoisting iron.
13 Oct. 2000	Aberdeen	80 pieces of concrete bricks fell from a tower crane and struck the workers.
5 July 2001	Lantua Island	A worker fell 10 m from the cabin of a tower crane while conducting inspection work.
2 Aug. 2001	Kowloon Tong	Wooden beams being lifted by a tower crane came loose unexpectedly and struck 2 workers.
6 July 2002	West Kowloon	3 workers were struck by an iron beam that fell from a tower crane, which was being dismantled.
7 July 2005	Kwai Chung	Tower crane toppled over and struck the operator.
10 July 2007	Causeway Bay	2 construction workers were killed and 5 others injured when a tower crane toppled over during demolition of a building.
17 July 2007	Kwun Tong	A worker died after being struck by iron that fell from a tower crane.

Source: City University of Hong Kong 2008b

(a)

(b)

Figure 2.5 News on tower crane accidents in Hong Kong (a) Accidents in 2011 (http://www.towercranesupport.com) and (b) Accident in 2007 ((http://www.towercranesupport.com)

The number of fatalities from tower crane accidents in Hong Kong is still low compared to other developed countries such as the United States, where 137 deaths were recorded from 1992 to 2006 (Kang & Miranda, 2007). Meanwhile, in Japan as many as 41 fatalities were recorded in 2006 (Kawata, 2007). Table 2.4 shows that the main causes of accidents involving tower cranes in Hong Kong from 1998 to 2005 were workers falling from a height, getting hit by moving objects, getting struck by objects and being trapped in rubble. Being struck by objects is a serious accident because it resulted in six fatalities.

Table 2.4 Main causes of accidents involving tower cranes in Hong Kong from 1998 to 2005

	Fall from a height	Hit by a moving object	Struck by a falling object	Trapped by a falling object
Number of accidents	2	4	5	1
Number of deaths	3	4	6	1

Source: Occupational Safety and Health Council 2008a

According to a study by Vivian and Ivan (2010), four main factors affect the safety of tower cranes in Hong Kong, i.e.:

(a) Negligence when operating the tower crane

The main cause of death is due to negligence such as being in a high power area and lifting a load that exceeds the capacity of the crane (Shapiro et al. 2000; Beavers et al. 2006).

(b) Insufficient training

Workers who have not undergone sufficient training will not be able to identify or anticipate hazards that appear around the workplace (Abdelhamid & Everett 2000; Shapira & Lyachin 2009).

(c) Practising sub-contracting in tower crane operations

Only a few contractors own tower cranes and most of them are leased or controlled by private operators (Neitzel et al. 2001). According to the Hong Kong Confederation of Trade Unions, the layered sub-contractor system is common in Hong Kong for the operation of tower cranes. This is due to the low wages that are paid to tower crane operators, while their working hours are long and there are exchanges or transfers of operators that ultimately affect safety during the construction process (Ng 1997). Figure 2.9 shows the sub-contractor system for tower cranes in Hong Kong.

(d) Pressure to make progress in implementation

A tight construction schedule is the main factor preventing the practise of safety during construction work in Hong Kong (Mohamed 2002). Delays in the construction process can be stressful, and can lead to faster than normal implementation of the work process, while compromising on safety. This will result in cranes, adjacent objects, workers and staff nearby to be exposed to greater risk (Shapiro et al. 2000).

According to a survey conducted by Vivian and Ivan (2010) of workers involved in tower cranes in Hong Kong, the main company does not have a good safety system in place for the operation of tower cranes. The workers as well do not have any in-depth knowledge of a code of practice. The inspection of cranes is sometimes neglected because of the hurried transfer of the tower cranes between construction sites. Complex communications also result in directives not being understood properly, thus affecting the safe handling of the cranes.

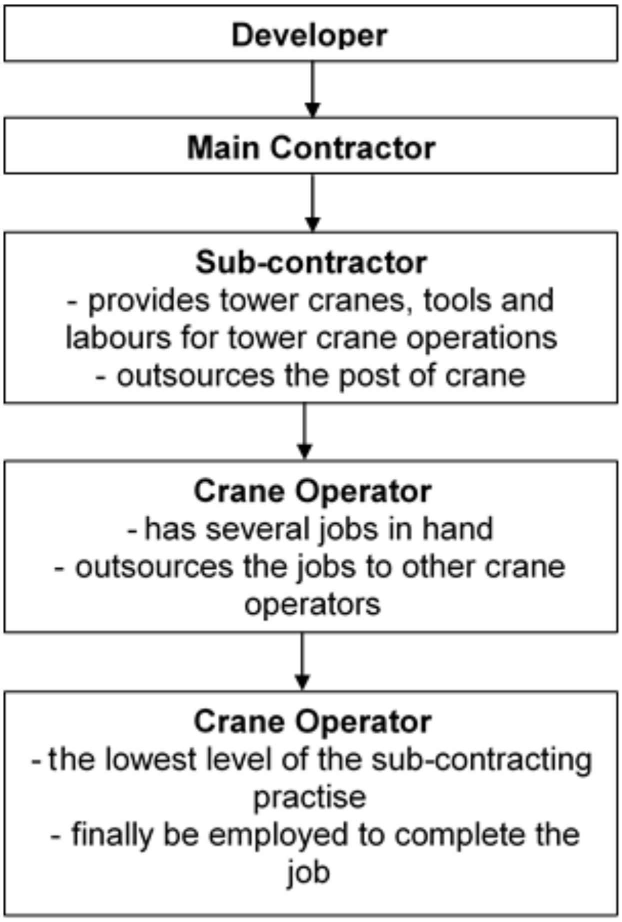

Figure 2.6 Practice of sub-contractors for tower cranes in Hong Kong (Vivian & Ivan 2010)

2.3 Australia

Based on the Worldwide Tower Crane Accidents Report (Isherwood 2010), there were 89 accidents involving structural failures in tower cranes from 1989 to 2009. According to the study, the factors causing these failures and accidents are shown in Figure 2.7.

In Australia, only one case of an accident was mentioned in this report, i.e. in 2005 (Figure 2.8). However, the report on this case was very limited. This accident, which reportedly occurred on 3 February 2005, was caused by strong winds, which caused the jib to collapse by folding. This report also mentioned that no further information was available about the case, especially about the angle of the jib when the incident occurred. This incident was categorised as an "Extreme Weather" factor.

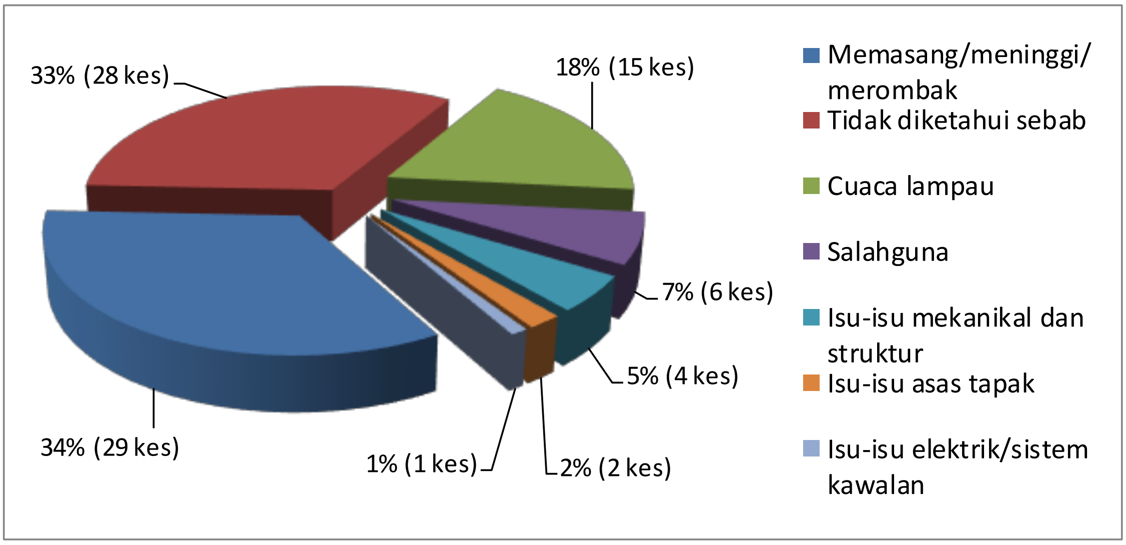

Figure 2.7 Factors causing crane accidents (Isherwood 2010)

Figure 2.8 Cases of crane accidents in Australia in 2005 (Isherwood, 2010)

According to a specific blog on crane accidents, http:// towercraneaccidents.blogspot.my, which reported on tower crane accidents throughout the world for 2008 until 2012, there were two cases involving Australia, i.e. in 2008 and 2009. The incident in 2008 involved a crane in

Sydney, Australia, which was reportedly in a poor condition at the construction site because of the unstable position of the counter-jib (leaning) that very likely caused the accident. This resulted in the temporary closure of the adjacent buildings, comprised of an apartment block and a hotel, due to concerns that the crane structure may fail and crush into the affected buildings. Due to this incident, a special investigation was carried out directly on the crane to ensure its level of safety and all operations were put on hold for a month to make way for a safety inspection. No accidents have been reported for this crane, except that the relevant authorities have to pay attention to the stable operation of the crane before any mishap occurs. This incident was also reported in The Sydney Morning Herald (Figure 2.9).

smh.com.au
The Sydney Morning Herald

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'Leaning' Sydney crane declared safe

December 29, 2008 - 3:19PM

A "leaning" crane on a building site in Sydney's east has been declared safe, after WorkCover and police agreed it was not dangerous.

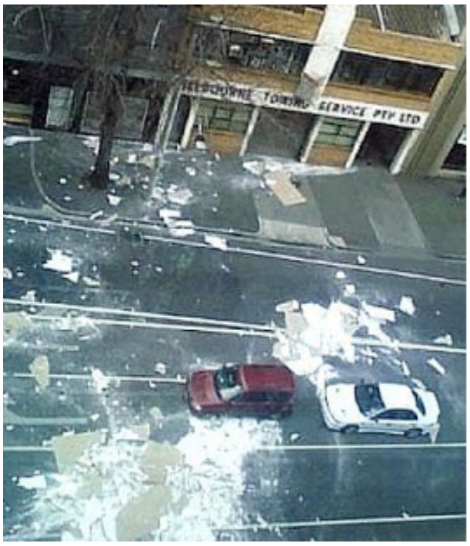
Residents at five heritage-listed apartment blocks and a boutique hotel in Springfield Avenue, Potts Point, were evacuated about 11.15am today due to fears the large construction crane might fall.

The alarm was raised by a resident, who told emergency service operators the crane was "leaning".

Advertisem

Figure 2.9 Online newspaper clipping (http://www.smh.com.au/news)

The incident in 2009 occurred in Melbourne, Australia, where the crane failed to lift a load and almost caused it to smash onto a car (Figure 2.10(a)). This article did not explain in detail how the incident occurred. Crane accidents are often caused by rigging failure, such as what happened in New York in 2007. In this case, it is important to ensure that the rig is appropriate for carrying a certain load and meets the standards. In this incident, it was reported that the load was at a height of 180 feet when the accident occurred. It was also reported that this accident was due to error on the part of the workers at the construction site, who only changed the rig chain randomly, without specifically assessing whether the type of rig was appropriate for the load. This article also emphasised the aspects of supervision and in-depth knowledge on the maintenance and use of tower cranes.



(a) (b)

Figure 2.10 News on accidents in Melbourne (a) accident incidents (b) rigs (http://towercraneaccidents.blogspot.my)

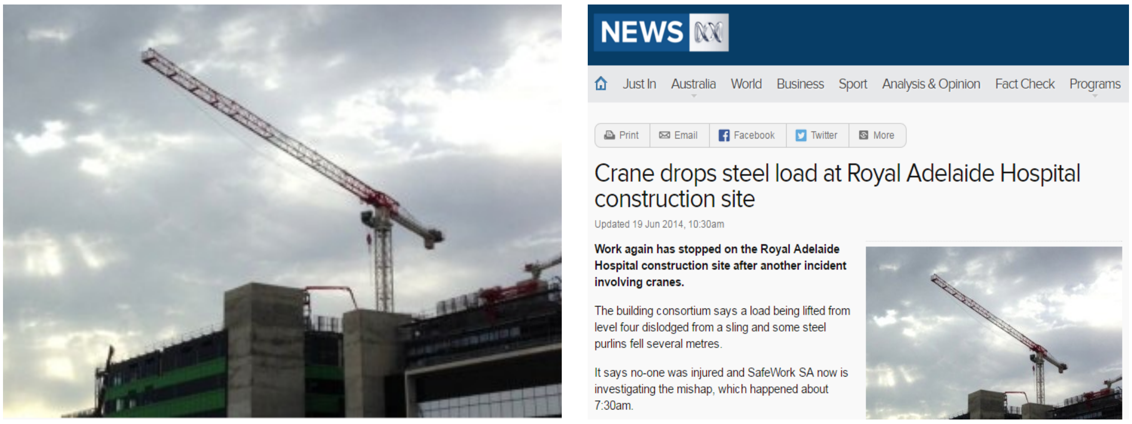
The Crane Accidents blog (http://www.craneaccidents.com/tag/tower-crane/) reported on an accident that occurred on 26 February 2016 in Hornsby, Sydney, Australia. The fire and rescue personnel reported that this incident was not caused by the wind. There was no detailed report on this incident. The picture of this crane failure is shown in Figure 2.11.

Figure 2.11 Crane accident in Hornsby, Sydney (http://www.abc.net.au)

In August 2015, the luffing jib of a huge tower crane fell and crushed into the elevator shaft of a building in Melbourne, Australia as it was climbing up the tower (Figure 2.12). Local reports stated that the failure of the hydraulic jacking component caused the crane structure to fall.

Figure 2.12 Crane accident in Melbourne (http://www.abc.net.au)

In June 2014, an incident involving crane failure occurred at the construction site of the Royal Adelaide Hospital in Adelaide, Australia. The load, which was supposed to be raised from the fourth storey, fell from a height of 7 meters onto the concrete floor (Figure 2.13). Due to this incident, all cranes were stopped from operating to examine the question of safety. An unofficial statement from Construction Union slammed the construction consortium for this accident, claiming that this disaster occurred because the consortium took shortcuts to complete this project as it was reported that the project was behind the originally planned schedule.



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Crane drops steel load at Royal Adelaide Hospital construction site

Updated 19 Jun 2014, 10:30am

Work again has stopped on the Royal Adelaide Hospital construction site after another incident involving cranes.

The building consortium says a load being lifted from level four dislodged from a sling and some steel purlins fell several metres.

It says no-one was injured and SafeWork SA now is investigating the mishap, which happened about 7:30am.

Figure 2.13 Crane accident in Adelaide (http://www.abc.net.au)

In June 2012, an accident involving a tower crane was reported at a construction site in Sydney's city centre (Figure 2.14). Witnesses saw the arm of the crane swaying before it broke and crushed into the roof of a building adjacent to the University of Technology Sydney. There were no fatalities. It was reported that this accident occurred when the cable supporting the boom caught fire and resulted in failure. WorkCover New South Wales conducted an investigation to determine the cause of this accident. However, they also criticised the construction company for failing to conduct the required maintenance.

Figure 2.14 Crane accident in Sydney City Centre (http://www.sbs.com.au)

In June 2012, a crane accident occurred in Perth, Western Australia involving a luffing jib, which fell and crushed through the roof of a hospital. This incident was caused by strong winds blowing at a speed of 140 kph (Figure 2.15). Figure 2.16 shows the average number of crane accidents that occurred in Australia from 1999 until 2016.

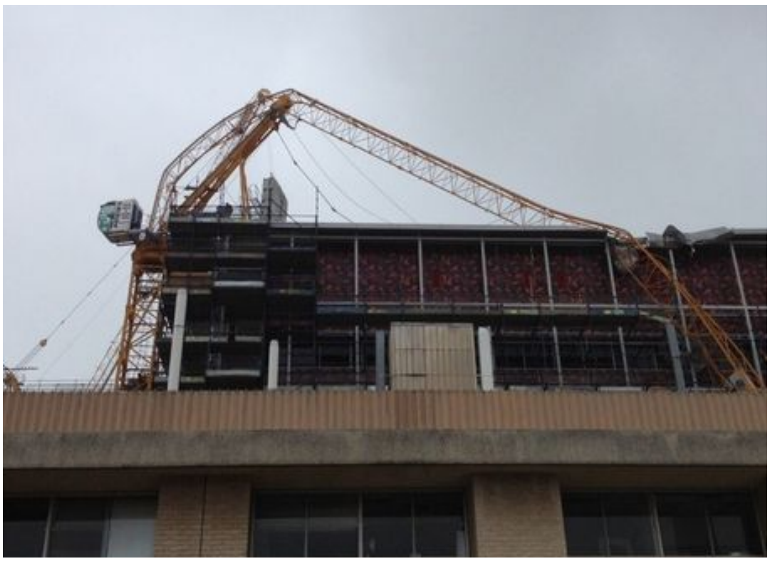


Figure 2.15 Crane accident in Perth (http://www.vertikal.net)

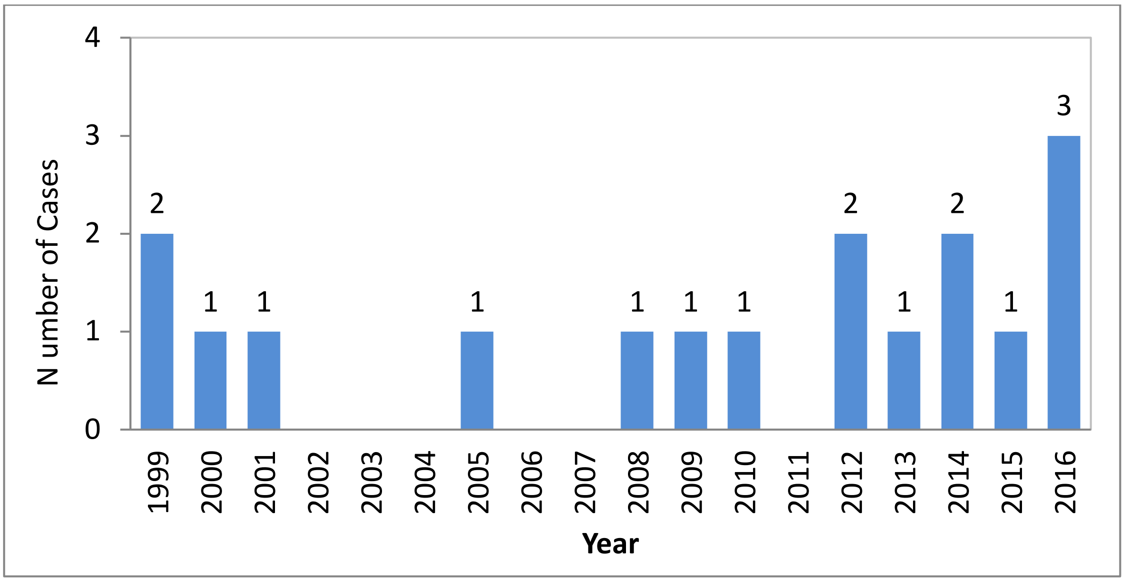


Figure 2.16 Average number of crane accidents in Australia from 1999 to 2016 (Isherwood 2010; http://www.craneaccidents.com; http://towercraneaccidents.blogspot.my)

The regulations and standards regarding safety and the use of cranes in Australia can be referred to in the Australian Standard Specification C.B.2-1938- Crane and Hoist Code-Australian Capital Territory. Every company, user or worker that wishes to install or use a crane, hoist, plant or scaffolding must comply with the standards AS 1418.1-2002 General Requirements, AS 1418.2-1997-Cranes hoists and winches. Part 2: Serial hoists and winches, AS 1418.3-1997-Cranes, hoists and winches. Part 3: Bridge, gantry, portal (include container cranes) and jib cranes, AS 1418.4-2004-Cranes, hoists and winches. Part 4: Tower cranes, AS 1418.7-1999 Builders' Hoists and Equipment, AS 2549-1996 Cranes (including Hoists and Winches), and AS 2550 Cranes, Hoists and Winches-Safe Use Set. Further clarification regarding the regulations and standards used in Australia will be discussed in Chapter 7.

These standards are applicable for various crane requirements, including those relating to the:

(a) classification and position of the load;

(b) structure;

(c) balance;

(d) lifting mechanism;

(e) access from a permanent platform;

(f) speed limit; and
(g) release access.

In terms of a code of practice, it may be a legal or non-legal requirement. The legal code of practice is defined by legislation. No legal code of practice is defined by industry regulators and relevant bodies.

2.4 United Kingdom

Since 2000, there have been a number of high profile incidents in Great Britain involving tower cranes, where as many as eight persons (including a civilian) lost their lives and most were seriously injured. These incidents gave rise to public concern for further improvements, and safety studies had to be conducted with regard to tower crane operations (Abdelhamid 2000). Health and Safety Executive (HSE) took the appropriate enforcement action by publishing a report on the investigation into the collapse of the tower crane and released a report on the reasons for the incident as well took precautions after the incident (Aneziris 2008). The Construction Products Association (CPA) published several technical Information Notes regarding the safety of tower cranes. At the Strategic Forum for Construction, the Safety Working Group for tower cranes produced several best practice guidelines for the safety of tower cranes.

In addition, other works are also being carried out. After consulting with registered tower crane owners in the building industry, the HSE took various measures to improve the safety of tower cranes (Shin 2015).

- Raising the efficiency requirements for crane erectors and dismantlers;
- Considering the adequacy of design standards for cranes;
- Research into the effect of wind on certain types of cranes;
- Research to increase understanding as to the causes of tower crane incidents at the international level;
- Promotion of best practice guidelines in the industry; and
- Visits to tower crane companies and construction sites to gauge the implementation and effectiveness of industrial supervision.

Several studies on fatalities from crane accidents have been carried and data have been gathered based on the past 25 years. Most of these studies involved two main categories, namely Conceptual and Empirical (Beavers 2006). Research show that 85% site worker believe if they work with tower crane in the construction site, they are always in dangerous situation, even there have another accident risk. They need to be always cautious and follow the construction site safety procedure while working with any type of crane (Begum et al. 2010).

Ten incidents throughout have been identified as involving tower cranes in the United Kingdom and Ireland in between 2000-2010 involving 9 deaths and 25 injuries (HSE Report 2000; Margaret Sharkey 2012). The data until year 2010 have been identified and the causes of eight cases have been accurately identified for categorisation. The causes of eight cases have been accurately identified for categorisation. One incident has been categorised in the unknown group, while another incident is still under investigation and the details have not been released. Table 2.5 compares the contribution of the incidents in each category (leaving out the unknown cause category) between the UK and the rest of the world as show in Figure 2.17.

Table 2.5 Comparison of accidents in the U.K. with other countries

Category	United Kingdom	Other Countries
Erection/dismantling/extending	3	26
Extreme weather	3	12
Foundation issues	0	2
Mechanical and structural issues	1	3
Misuse	1	5
Electrical and system control issues	0	1
Total	8	49

Source: Isherwood 2010

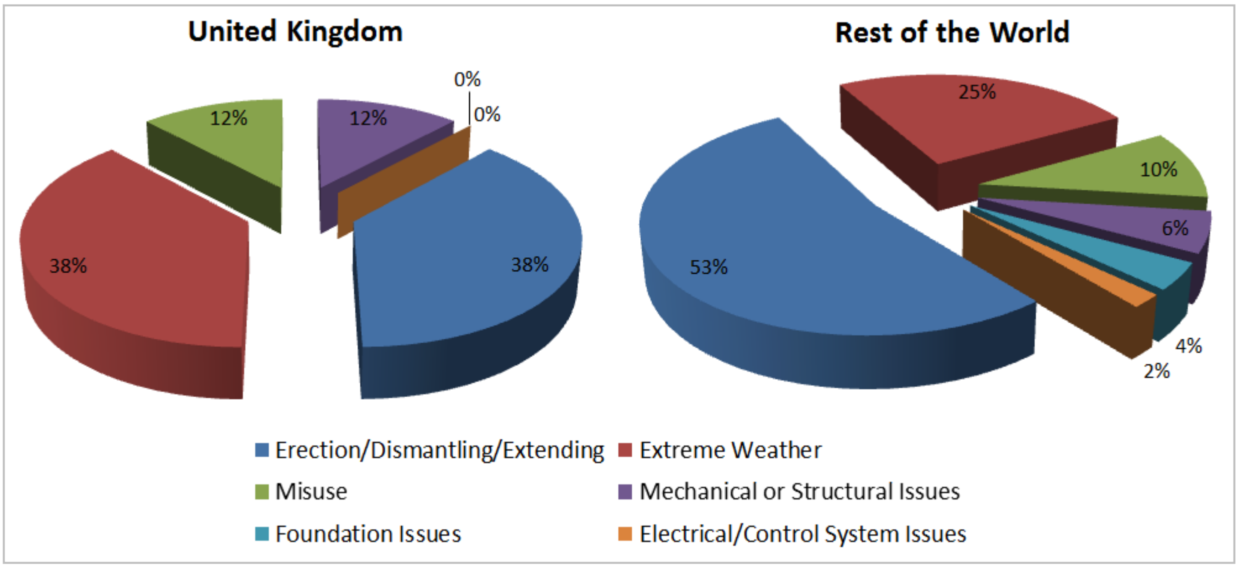


Figure 2.17 Percentage comparisons of reasons for accidents in the U.K. and other countries (Isherwood 2010

Although the number of incidents in the UK is much smaller, making the statistics less accurate, the general trend of the incidents in the UK is almost similar to that of the whole world, where the two dominant conditions, namely erection/dismantling/extending and extreme weather, have been associated with 76% of the eight incidents. This shows that the statistical incidence in the UK is in line with that of other countries in the world.

In addition, U.K. also impose fines and action to companies which involved in accidents and deaths related to tower cranes. Table 2.6 shows the list of companies and fines imposed by the U.K. authorities from 2000 until 2010.

Table 2.6 Among of the companies involved with the accidents and fined

Date	Incident	Company	Fatalities and other serious injuries	Fines & costs
May-00	Canary Wharf	Hewden Tower Cranes	Killed: Peter Clark,33, Martin Burgess, 31, Michael Whittard, 39.	No HSE prosecution - but Hewden Stuart said it cost the firm £500,000 after it shut down its entire tower crane fleet for safety inspections
Feb-05	Worthing	W D Bennett	Gary Miles, 37, Steven Boatman, 45 another worker severely injured	WD Bennett fined £125,000; subsidiary Eurolift £50,000. WD Bennett £264,299 costs.
Sep-06	Battersea	Falcon Cranes	Michael Alexa, 23, Jonathan Cloke, 37	
Jan-07	Liverpool	Falcon Cranes	Zbigniew Swirzynsk	no HSE prosecution
Mar-07	Liverpool	Sitewold Construction Bryn Thomas Crane Hire	Mark Thornton, 46	Bryn Thomas Crane Hire Ltd (in administration) £4,500 Frederick Scott – operator- £2,500. Judge Gilmour QC said an "appropriate" fine of £300,000 could not be imposed because Bryn Thomas in administration. Sitewold (ceased trading) £50 Benjamin Lee, Managing Director, £80,000 plus £18,478 costs
Jun-07	Croydon	Select Cranes subsidiary of Laing O'Rourke	Four workers narrowly escape death. One was seriously injured & three others trapped 45 metres in the air for seven hours. The operator trapped in the cab hanging from the side of the building had to be winched to safety by a rescuer suspended by cables from a second crane.	
Jul-09	Liverpool	Bowmer & Kirland; Bingham Davies	Ian Gillham, 55, multiple injuries and legs paralysed	£280,000 fine for B&K, £1,000 for BD Massive damage to property, Bingham Davies out of business.
Dec-07	Forest Hill London			
Jan-10	Preston	Pocklington		£15,000 fine

Source: Margaret Sharkey 2012

Among the other cases of tower crane accidents in the UK are:

(1) Canary Wharf, London, England

On 21 May 2000, a Wolff 320 B luffing crane collapsed as the mast was being extended. Based on HSE Report 2000, the actual cause of the incident was not exactly stated but the issues that were raised during the inquiry included:

- The possibility that the erection crew was exhausted and took shortcuts to rush through until the end of their working hours.
- Changes in the speed and direction of the wind while the crane was being supported on the climbing frame.
- The safety of the single hydraulic cylinder on the climbing frame of the mast.
- This incident was categorised under Erection/Dismantling/Extending conditions.

(2) Dublin, Ireland

On 1 February 2004, the jib from a Wolff saddle jib crane failed in two sections, but was prevented from falling to the ground by the jib tie bar (Figure 2.18). It was reported that the incident was caused by strong winds, and the report mentioned that there was a possibility that motor brake slew had jammed or was left in a neglected state. This incident was categorised under extreme weather.

Figure 2.18 Incident of overturned tower crane in Dublin, Ireland (http://www.vertikal.net/en/news/story/741)

(3) Cardiff, Wales

On 9 July 2004, the jib from a Raimondi LR60 luffing crane was severely damaged by strong winds and was blown back into the 'A' frame. During the investigation by HSE, it was found that the mechanical slew motor brake had two defects. The setting mechanism was defective, causing it to slip so that the brake was being applied unknowingly, and the braking torque applied was about ¼ of what was stated. This incident was categorised under Extreme Weather.

(4) Worthing, Sussex, England

A BPR tower crane collapsed on 11 February 2005. During the collapse, it hit another crane causing damage, but that crane remained in position with a buckled jib. The investigating authority was the HSE and it was found that the collapse was due to a loose mast bolt which was finger tightened before the crane was dismantled. The crane turned around and added to the load that was applied, and the loose part snapped, causing the crane to collapse. This incident gave rise to issues concerning the competency of the operator and the training that is provided in the crane industry in the UK. This incident was categorised under Erection/Dismantling/Extending.

(5) Battersea, London, England

On 26 September 2006, the failure of the slew-ring bolt caused the upper parts of the crane (jib, slew turret, counter-jib and counterweights) to fall to the ground. The crane involved was a BPR 222, which was about 27 years old. This incident was categorised under Mechanical or Structural Issues.

(6) Holborn, London, England

The jib of a luffing crane buckled and collapsed on 19 October 2006 (Figure 2.19). It is believed that the crane collided with another crane on the same site. This incident was categorised under Misuse.

Figure 2.19 Tower crane accidents in Holborn, London
(http://www.vertikal.net/en/news/story/3122)

(7) Liverpool, Merseyside, England

On 15 January 2007, a Jaso J138PA luffing crane collapsed (Figure 2.20). The HSE investigation showed that the crane was operating with a steep jib, which was close to the minimum permissible radius. The wind speed approached the maximum permissible speed of 20 m/s (HSE Report, 2007). It is believed that the sequence of events that led to the incident was as follows:

- The jib, which was facing the direction of the wind, was blown backwards towards the spring stop on the 'A' frame.
- During this process, the luffing rope became slack and escaped from one or more grooves on the top of the 'A' frame.
- This disrupted operations and the jib of the crane could not be lowered using a luffing system. However, the driver of the crane, who was in direct control, proceeded to lower of the jib, and a large section of the luffing rope escaped from the luffing winch drum and was hanging down in a loop behind the crane.
- At one point, the luffing rope that was stuck at the top of the 'A' frame broke free and the jib was released. This caused the load to be caught at the mast.
- The moment it was released, the jib fell through a large arc (estimated to be about 38º) and was suddenly arrested by the luffing system.
- The sudden arrest of the falling jib shocked the bolt on top of the crane, which was connected to the mast. The increased bending/tensile caused the top part of the crane to fall from the mast.
- This incident was categorised under Extreme Weather.

(8) Croydon, England

On 2 June 2007, a Terex Comedil tower crane, owned by Select, was being extended. The crane collapsed during the climbing operation on top of the Croydon Park Hotel. Subsequent investigations by the HSE revealed that the bolt connecting the climbing frame to the crane structure was loose or was not in use during the climb. The climbing crane was not bound to the structure and the mast broke, causing the crane to collapse. This incident was categorised under Erection/Dismantling/Extending.

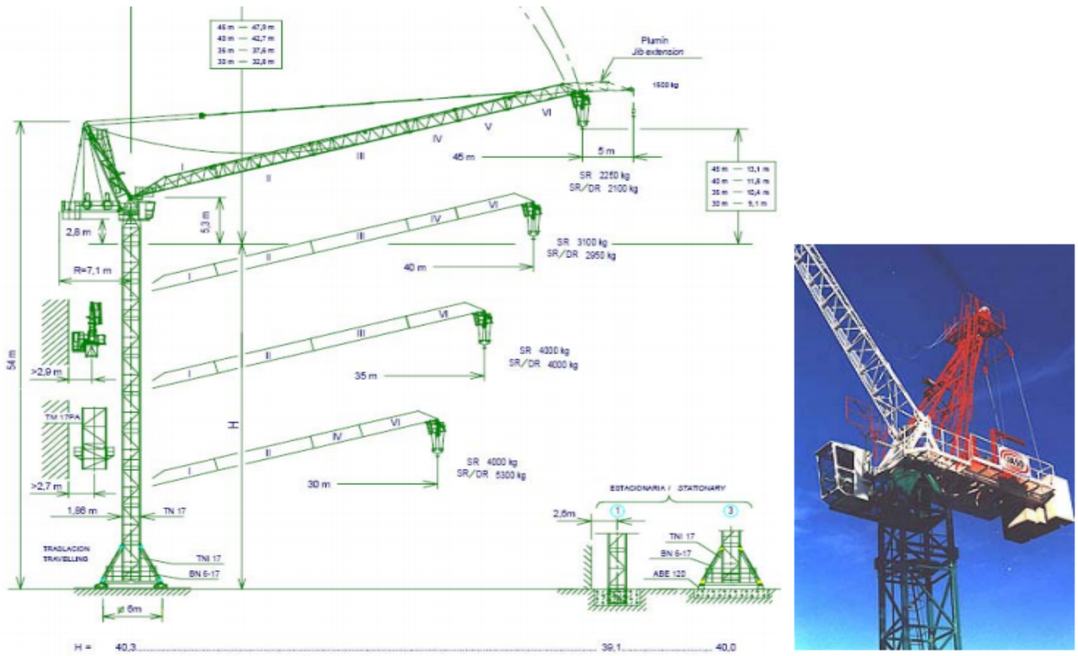


Figure 2.20 Luffing jib crane involved together in accident (HSE Report 2007)

(9) Forest Hill, London, England

The jib from a Raimondi LR 60 luffing crane sagged and collapsed on 11 December 2007. No conclusive reason was given for the incident during the HSE investigation but the damage to the jib was consistent with the placing of an excessive side load on it while in operation. Another possible reason could be that the safety/erection rope snagged or obstructed the jib. This incident was categorised under Unknown Reasons.

(10) Liverpool, Merseyside, England

On 6 July 2009, a Wolff 500 B luffing crane, owned by HTC, collapsed on a block of flats. Further information cannot be released until current investigations are concluded, and legal proceedings may arise from the investigation.

In terms of tower cranes registration, some of the essential requirements regarding registration and documenting when and where of tower crane was erected on the site should be considered. Among of the information need to be recorded are:

(a) type, age and crane owner

(b) the last date of thorough examination (refer to Operations and Lifting Equipment Regulations 1998, LOLER)
(c) are the tests reveal defects that can cause serious risk of accident
(d) the re-registration after the crane dismantled and reassembled in other places

In addition, an efforts to improve crane safety should also need to be considered for improving the efficiency requirements for crane erectors and dismantlers, the consideration of the adequacy of the design standards, understanding of the causes of tower crane accident at the international level, to promote best practice guide to the industry, and the initiatives taken to enhance safety awareness among the industry itself (Shin 2015).

Other that, the effect of the wind reaction on some types of cranes should also be reviewed to see the crane reaction against the wind during a free spin, and the too steep of jib angle can cause independent rotation occurs if incorrectly calculate where (http://www.safepractice.co.za);

(a) a small increase in wind speed can have a significant impact on the operation of tower cranes,
(b) wind power exerted on tower cranes and any suspended load can be quite large and affect the operation of the crane and the load,
(c) refers to the study of wind speed by CPA Tower Crane Interest Group, which recommended a maximum wind speed for operating the tower crane in U.K is 38 mph (16.5 m/s, 60 km/hr).

Based on the cases of accident, the HSE United Kingdom took a vital approach to identify some actions that should be imposed for crane designers, manufacturers, suppliers and consumers, which is needed to reduce the accident risk in the future. In February 2003, HSE published a discussion paper that discussed on the use of risk to assess external climber cage. The outcomes have been shared with the chairman and members of the British Standards Committee on Cranes (MHE / 3/11). Subsequently, the reported information was considered towards the preparation of BS 7121 *Code of Practice for Safe Use of Cranes - Part 5 Tower Crane for Consumers, and*

Recommendations for European Standard for Manufacturers. The HSE party considers the Machinery Directive (as amended by Directives 91/368 / EEC, 93/44 / EEC and 93/68 / EEC) is applicable to the supply of climbing gear for tower cranes.

2.5 Singapore

In Singapore, tower cranes and mobile cranes are being used actively in the construction industry, and overhead towers and gantry cranes are being used in the manufacturing and shipping industries. The use of cranes can help to increase productivity, but care should be exercised because it involves large equipment or components and complex operations. Nevertheless, crane accidents can adversely affect the safety of workers and the public. To ensure the safety of all parties, the cranes must be maintained and handled properly and securely, and hoisting activities must be planned and managed well in accordance with standard operating procedures (SOPs) to reduce the risk of accidents.

Since 2006, fatal accidents involving cranes in Singapore have increased from 2 to 10 cases in one year. These dangerous incidents have given rise to stable improvements, with most of them being due to the greater awareness of the parties concerned of the need to report the occurrence of any incident. From 2009 to 2011, the number of registered tower cranes increased from 541 to 612, and the number of tower crane operators increased from 1458 to 2045 (http://www.wshc.sg). This annual increase in the number of tower cranes could lead to an increase in crane accidents in the absence of strict regulations. Fatal accidents involving hoisting equipment including collapsed cranes, and workers or swinging objects falling from a height are shown in Figure 2.21. Figures 2.22 - 2.23 show the statistics of fatalities and hazardous incidents in relation to cranes, while Figure 2.24 gives an example of a tower crane accident that occurred in Singapore in 2013. Referring to initial investigations, the accident occurred when the luffing jib of the tower crane snapped, causing serious injury to one person.

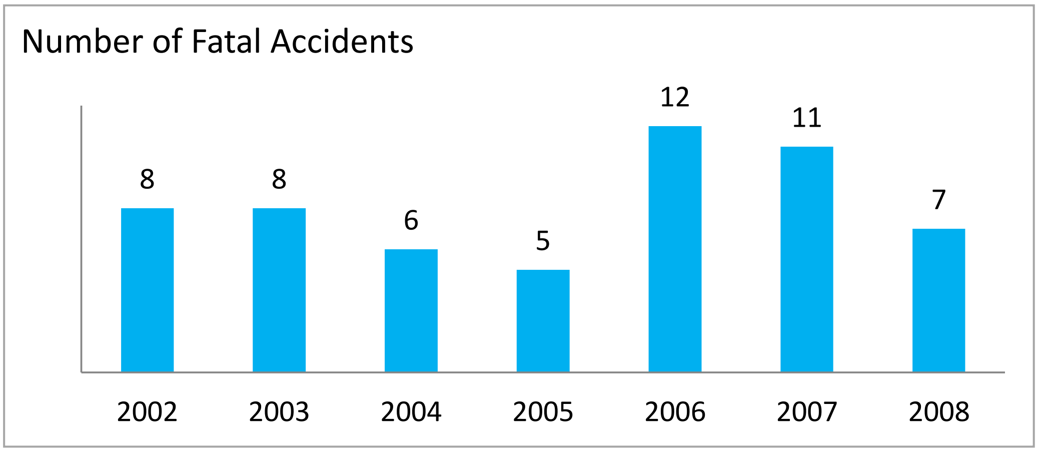


Figure 2.21 Fatal accidents caused by hoisting cranes/equipment for the period 2002-2008 (http://www.wshc.sg)

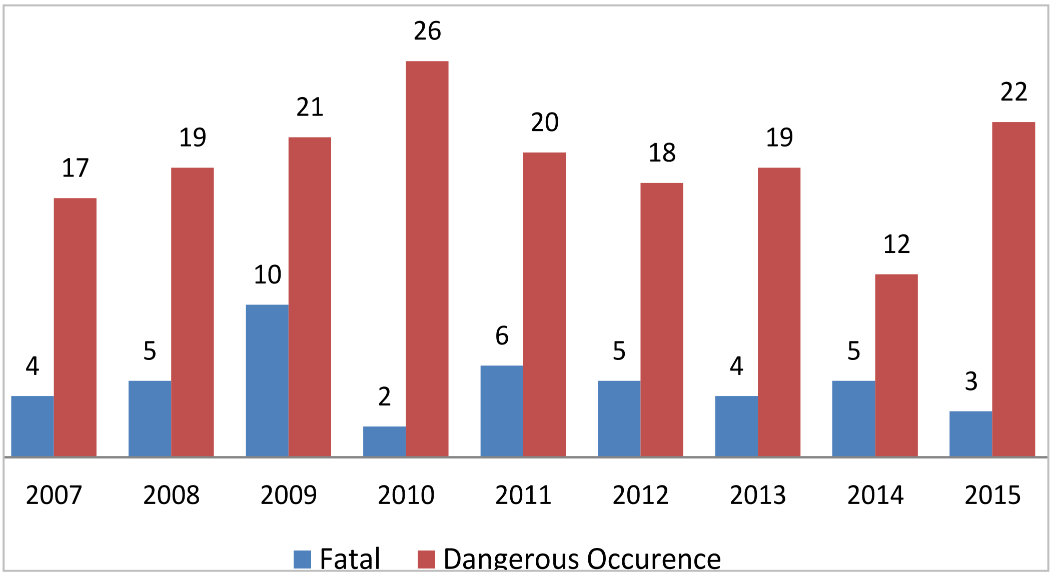


Figure 2.22 Number of fatalities and dangerous incidents in relation to cranes for the period 2007-2015 (http://www.wshc.sg)

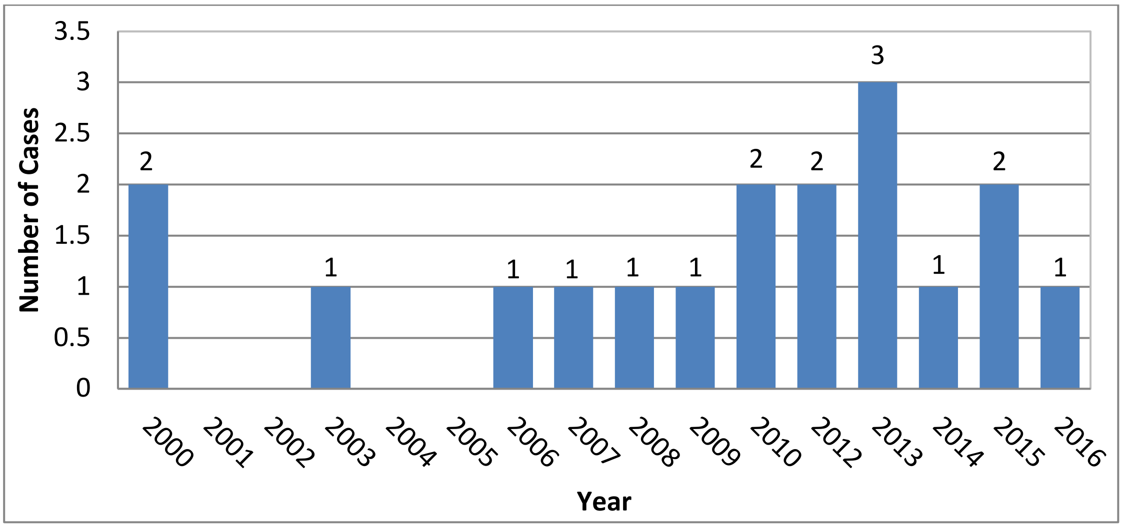


Figure 2.23 Statistics of accidents involving cranes (Satishkumar s/o Kurusamy 2015; http://www.craneaccidents.com)

Figure 2.24 Cases of tower cranes collapsed in Singapore in 2013 (http://www.vertikal.net/en/news/story/18420)

In addition, efforts have also been made by the Singapore authorities to improve the safety of cranes. Realising the importance of this, the Singapore government established a National Crane Safety Task Force in 2009 to guide and coordinate crane safety at the national level (http://www.mom.gov.sg). At present, the task force is focused on addressing new issues in crane safety from the aspects of (i) improving the competency and capacity, (ii) raising awareness of key issues, and (iii) reinforcing standards and practices.

In Singapore, emphasis is being placed on involvement at all levels, from the manufacturing industry up to the crane operators, for the successful integration of Workplace Safety and Health (WSH). Among the agencies/stakeholders involved are the:

a) Government
b) Public services
c) Crane operators
d) Crane contractors
e) Crane manufacturing companies
f) Hoisting teams
g) Industrial associations
h) Qualified inspectors

In addition to the integration of the Workplace Safety and Health, the life-cycle approach for crane safety was used by the Singapore authorities to control the use and safety of cranes, i.e. from the level of imports/sales, installation, use and operations, dismantling, storage, maintenance and disposal. They have also reviewed and improved the WSH regulations for the regular control of the safety of cranes to ensure that the rules remain strong and relevant with changes in the operating conditions. They have also ensured compliance with crane safety by referring to various sources such as the Code of Practice, Standards, Technical Advice and Hardware (http://www.wshc.sg) to assist stakeholders in implementing the requirements and initiatives provided.

Among the codes of practice and standards used in Singapore to control the use and safety of tower cranes are Code of Practice for Safe Lifting Operations at the Workplace, (2011), CP 35: 1996 The Selection, Care and Maintenance of Steel Wire Ropes for Hoisting, CP 63: 2005 Code of Practice for the Lifting of Persons in Work Platforms Suspended from Cranes, Guidebook for Lifting Supervisors, SS531: Part 1 : 2006, Part 2 : 2008 and Part 3 : 2008 Code of Practice for Lighting of Work Places, SS559: 2010 Code of Practice for Safe Use of Tower Cranes, Worker's Safety Handbook for Crane Operator, 2011, Worker's Safety Handbook for Rigger and Signalman, 2011, BS 71. In addition, they also reffered the international standard i.e. ISO 9927-3: 2005-Cranes-Inspections, Part 3: Tower cranes and ISO 7296-1: Cranes-Graphic Symbols, Part 1: General. 21-5: 2006-Code of practice for safe use of cranes, Part 5: Tower cranes. Further clarification regarding the act and standards in Singapore will be discussed further in Chapter 7.

Generally, in terms of the regulations and trends related to the use of tower cranes, only tower cranes that comply with international standards and codes are allowed to be used in Singapore, and all new tower cranes have to be approved (www.mom.gov.sg). The regulatory requirements for tower cranes that can be adopted in Singapore have been divided into three categories, namely:

(1) New tower cranes

For new tower cranes, a relevant certificate of manufacture and certificate of compliance are required, and tower cranes that are manufactured according to international standards and codes can be accepted.

(2) Used tower cranes (imported for first use)

(a) All used tower cranes brought in from abroad and registered for use the first time must comply with the following:

i. The crane model concerned is of the type approved for use in Singapore;

ii. It must be accompanied with a recent inspection certificate (not more than 2 years) from the statutory inspection authorities of the last country where it was used;

(b) Used tower cranes from abroad that are 5 years old or more (starting from the date of manufacture) are subject to inspection by a third party inspection agency recognised by the Commissioner for Workplace Safety and Health (WSH);

(c) The following used tower cranes are not allowed in Singapore:

i. tower cranes from countries that do not have a statutory crane inspection body;

ii. tower cranes that are 15 years old or more (starting from the date of manufacture);

iii. tower cranes with a certificate of inspection issued by the last country more than 2 years ago.

(3) Used tower cranes (with an existing Lifting Machine (LM) certificate)

(a) Tower cranes, whose use in Singapore has been approved and registered, i.e. with an existing LM certificate, and those that are 8 years old or more (starting from the date of manufacture) must undergo an inspection by a third party prior to installation;

(b) Tower cranes that are 15 years old or more (starting from the date of manufacture) are not allowed unless the owner or user of the crane concerned obtains a letter from the manufacturer stating that the crane can be safely used for a long period of time. Tower cranes that are 20 years old or more (starting from the date of manufacture) are not allowed;

(c) Non-destructive tests should be conducted by a testing agency accredited by the SAC-Singlass within the scope of certain tests.

When analysing tower crane accidents, the Singapore authority (WSH) uses the 5M approach (Mission, Man, Machine, Medium and Management) (Crane Safety Analysis and Recommendation Report 2009), as shown in Figure 2.25. These guidelines are used to determine the factors that cause crane accidents. According to a study by the WSH (referring to the years 2007-2008), several improvements are required. These include (a) the need for laws to control the competency training and curriculum for hoisting operations in relation to recognised hoisting engineers/supervisors, riggers and signalmen, crane operators and crane contractors, (b) programs for the maintenance of cranes and hoisting gears, and (c) participation and outreach programs. Figure 2.26 shows the distribution of the 5M factors that contributed to crane accidents from 2003 - 2007. An important factor that contributed to crane accidents was Management and Man, while the contributions from Machine and Medium were low. It was also stated that Mission was not a contributory factor to the incidents. Therefore, the analysis should investigate the four main factors that have been highlighted.

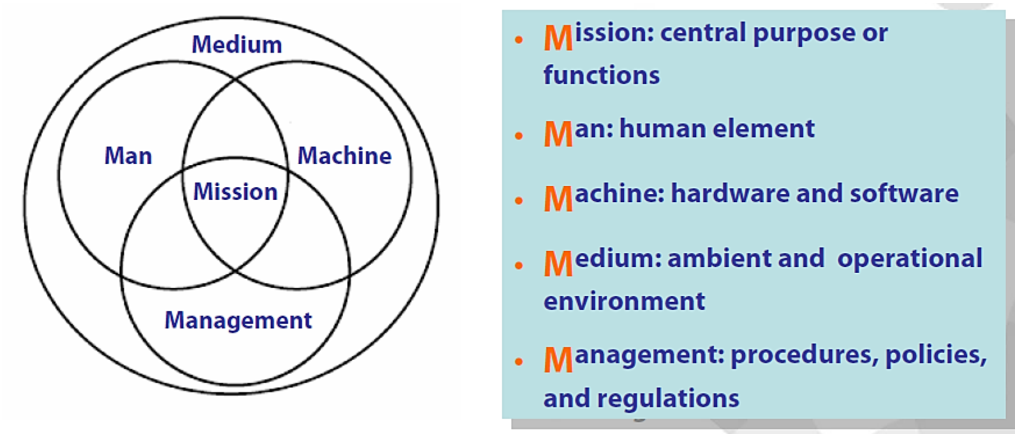


Figure 2.25 Analysis of accidents using the 5M approach (Crane Safety Analysis and Recommendation Report 2009)

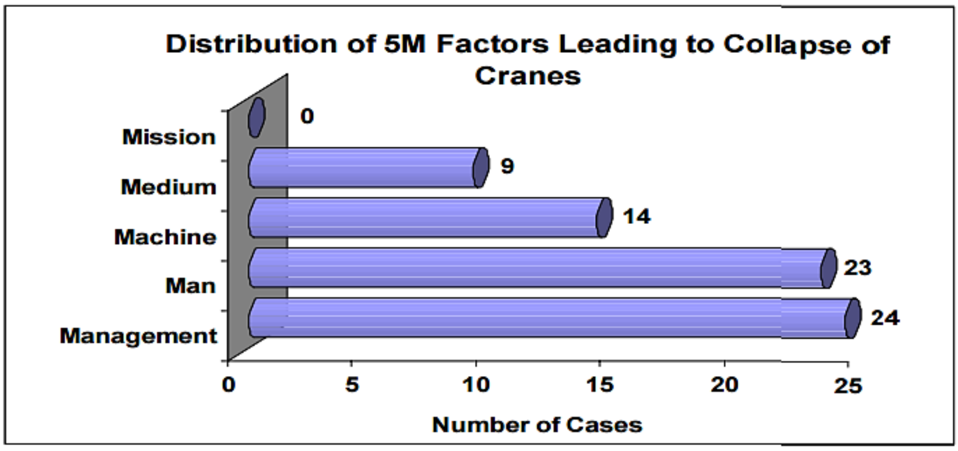
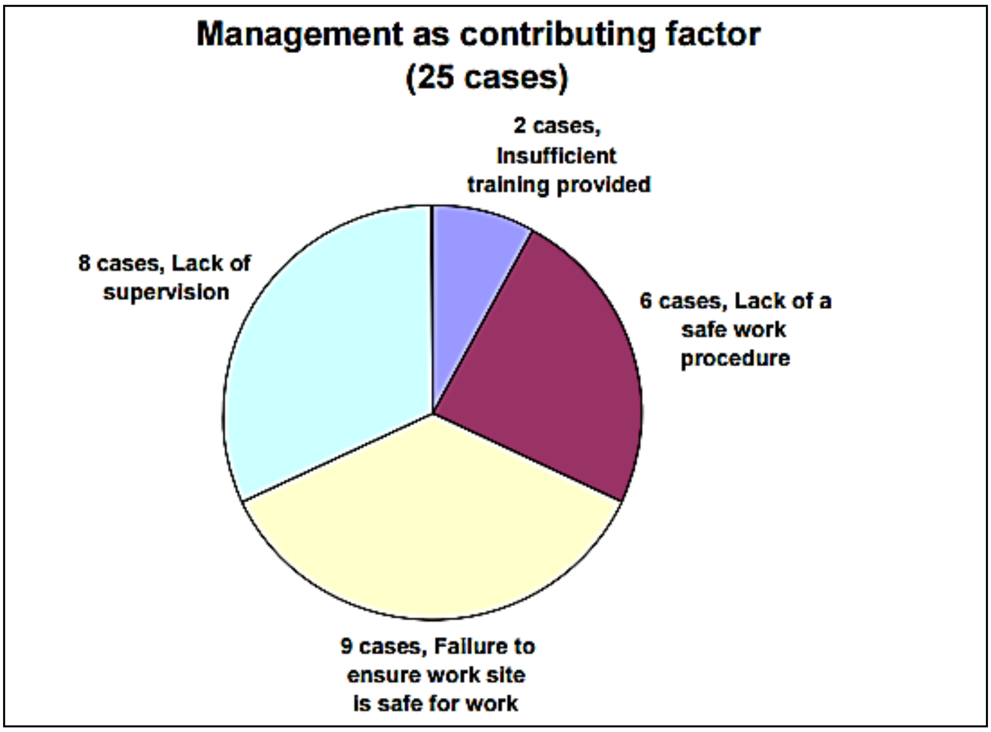


Figure 2.26 Distribution of 5M factors that caused crane accidents (Crane Safety Analysis and Recommendation Report 2009)

The Management factor was the biggest factor contributing to the collapse of cranes, i.e. 25 cases out of the 40 cases that were investigated. Figure 2.27 shows the breakdown of the causes or the improper management system that has contributed to crane accidents, among them being a lack of supervised monitoring, non-compliance with crane operation procedures and not ensuring safety in the workplace. The Man factor accounted for 23 cases of violations of regulations and acts, lack of knowledge and human error, as shown in Figure 2.28. Figure 2.29 shows the types of component failures that contributed to crane accidents, among them being alarms, brakes, wire ropes, alarm switches and crane structures.



Figures 2.27 Breakdown of management factors that contributed to crane accidents (Crane Safety Analysis and Recommendation Report 2009)

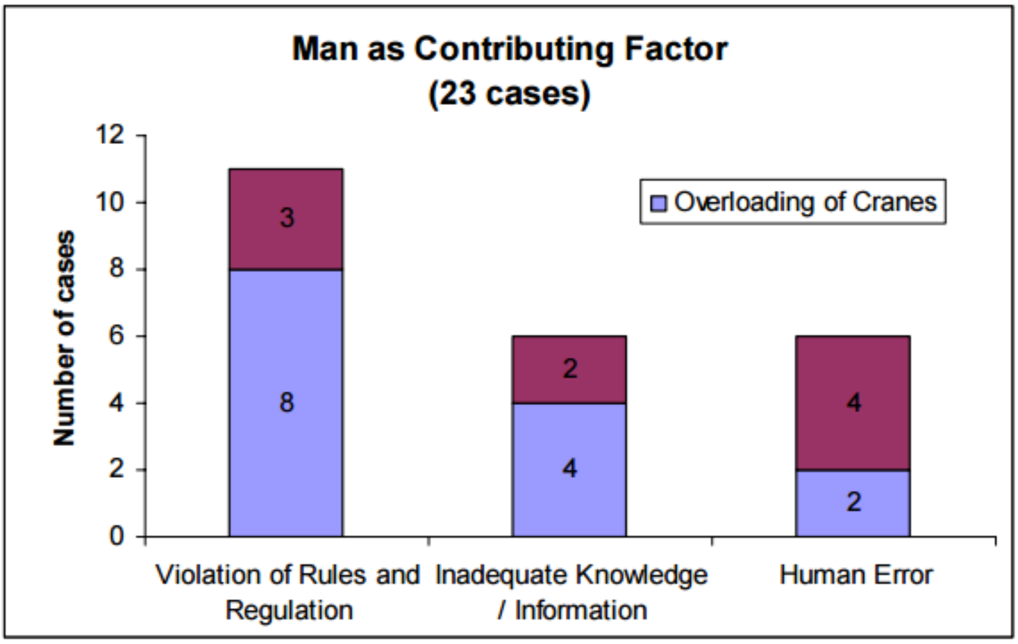


Figure 2.28 Overloading caused by human factors that contributed to crane accidents (Crane Safety Analysis and Recommendation Report 2009)

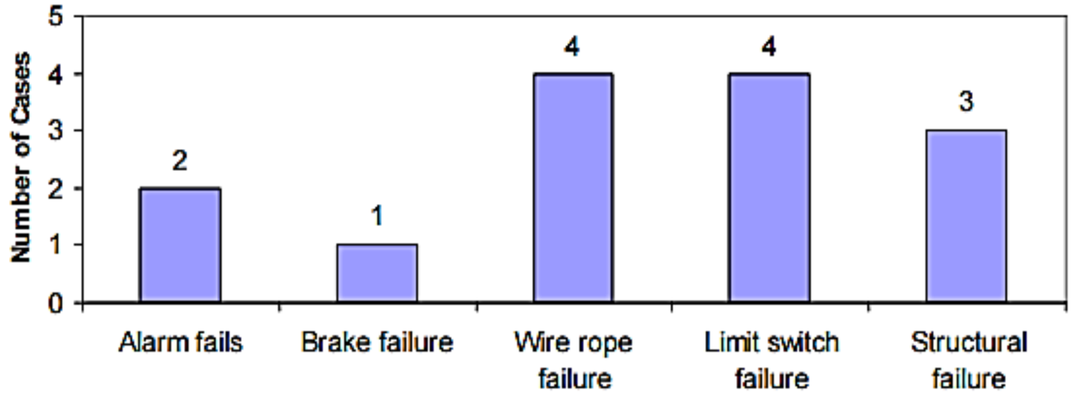


Figure 2.29 Types of component failures that contributed to crane accidents (Crane Safety Analysis and Recommendation Report 2009)

To enhance the safe operations of cranes, the National Crane Safety Task Force, Workplace Safety and Health (WSH) Council and the Ministry of Manpower (MOM) Singapore have come up with a number of proposals and joint initiatives to improve the safety of cranes, among them being:

(a) Improving the training curriculum for various compulsory courses for hoisting operations, especially for hoisting supervisors, crane operators, riggers and signalmen;

(b) Increasing outreach efforts, namely through the establishment of appropriate joint programs in efforts to reach out to top management, crane manufacturers and crane operators;

(c) Reviewing the code of practice, i.e. involvement in re-evaluating a relevant Code of Practice, especially the CP62 Code: 1995 Code of Practice for the Safe Use of Tower Cranes (led by SPRING) as well as improving the fact sheet on a Maintenance Program. The National Crane Safety Task Force will also continue to develop proposals and implementation plans, and will review the relevant laws and explore new technologies to improve the safety of cranes.

2.6 Germany

Generally in Germany, the construction industry has recorded a very high rate of injuries and deaths compared to other industries (Chong & Low 2014). Currently, cranes are being used extensively in mechanical, chemical and construction industries throughout the world. Tower crane failures are involved in almost 5% of all incidents related to cranes because most of them operate in crowded areas that are more prone to fatal accidents (Marquez et al. 2014).

With the growing economic development and increase in the number of cranes, accidents involving cranes have become more frequent. Mishaps resulting from the failure of cranes used in the construction of buildings have the potential to be very dangerous, and are often fatal (Zrnic et al. 2011). Figure 2.30 shows the number of accidents that occurred in Germany from 1999 to 2015, where the overall number of crane accidents recorded was 11 cases. The literature review indicated that the structures and processes designed to ensure safety in the industry are not satisfactory. Therefore, a study into the causes of this failure is vital for the industry and for the general knowledge of the workers, in particular.

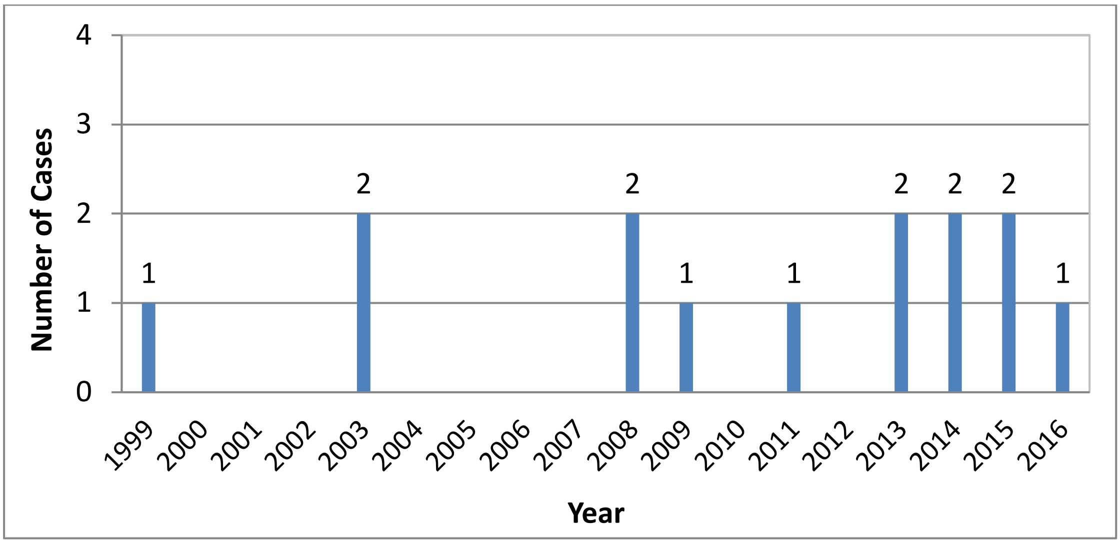


Figure 2.30 Overall tower crane accidents that occurred in Germany from 1999 to 2016

Figure 2.31 shows the four main categories contributing to tower crane accidents in Germany, namely the operation of tower cranes (building, opening and extending) (27%), mechanical and structural failures (46%), errors in the handling of operations by the operator (18%), and others due to unknown causes (9%). With reference to this analysis, it was found that mechanical and structural failures in tower cranes contributed to the highest number of accidents, i.e. as much as 46% of the total number of incidents. Meanwhile, the number of deaths and injuries recorded from 1999 to 2015 are shown in Figure 2.32, where 37% of the incidents were recorded as fatal accidents and the rest as accidents that inflicted injuries.

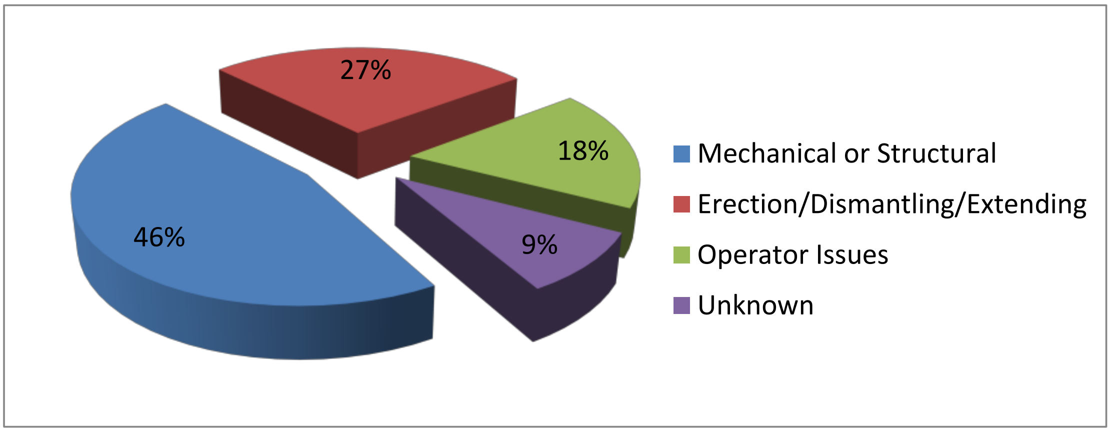


Figure 2.31 Causes of tower crane failures resulting in accidents in the construction sector

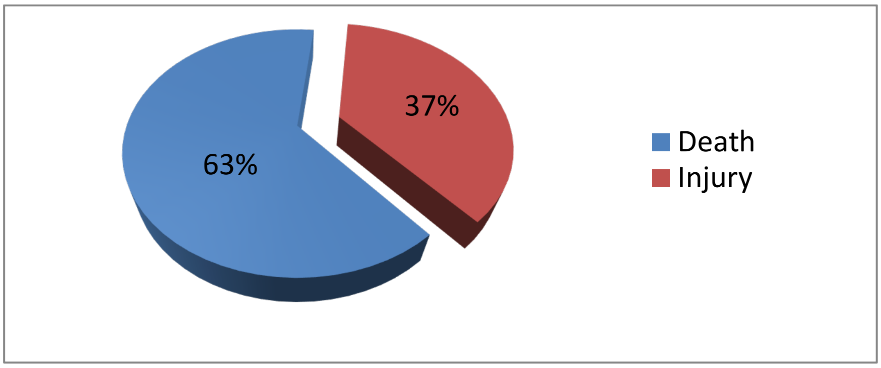


Figure 2.32 Total number of deaths and injuries recorded for tower crane accidents in Germany from 1999 until 2015

Tower crane collapse occurs when the load applied is much greater than what can be borne by the crane as set in the design specifications (Frendo 2013), i.e. when a heavy load is lifted on the geometry of the crane, or in unexpected wind conditions. In addition, when certain defects in the design of the crane have not been identified, the accident can be classified as a 'normal accident', i.e. something that is an important element in the design of the tower crane that can cause other tower cranes with the same design to meet with accidents. This was seen in the accident that occurred in Homburg, Germany, where a crane collapsed all of a sudden onto the Aldi supermarket, as shown in Figure 2.33, resulting in the death of one person and injuring five civilians. It was believed that this accident was caused by a failure in the component at the base of the crane.

Figure 2.33 Collapse of tower crane at the Aldi supermarket in Homburg, Germany (http://www.cbc.ca)

The entire structure of the tower crane consists of metal plates or beams that are welded together, especially at the jib, which is susceptible to fatigue failure when subjected to repeated loads (Bucas et al. 2013). This phenomenon contributes to several major changes in the structural integrity and capacity. Therefore, resistance to fatigue failure is an important aspect that should be taken into consideration by structural engineers of tower cranes. In addition, variations in the fabrication process, especially in the welding, affect the material and geometry of the structure. Thus, these geometrical variations make it difficult to predict the lifespan by reference to just a single case. An example of a tower crane accident resulting from metal fatigue failure could be seen in Germany, as shown in Figure 2.34. Fatigue failure was believed to have occurred at the support, which caused the jib to break into two. No deaths or injuries were reported in this incident. Therefore, fatigue damage must be taken into account in the modelling of complex structures through various analytical techniques.

Figure 2.34 Tower crane accident in Bavaria due to metal fatigue failure at the jib support (http://www.craneaccidents.com)

The control of the tower crane depends entirely on the skill and competency of the operator if it is to attain a higher level of performance and productivity. But there are still have accident cases reported and affect several factors involved with crane accident that can be identified, such as size of construction site of the company, safety policy not strong enough, project management and had an economic pressure (Tam et al. 2004). Tower crane accidents are also caused by human factors, including weaknesses in the working system, where standard operating procedures are not complied with and the work environment is uncomfortable (Brkić et al. 2015). Most crane failures have to do with operational errors as well as the performance and responsibilities of workers who lack the skill to handle tower cranes. Inadequate training and worker fatigue are some of the main reasons for unsafe practices in the operation of tower cranes. Several studies have been undertaken to prevent accidents caused by workers, and one of them is knowledge about human anthropometrics as a pre-requisite to understanding a good application for the work movement system between man and machine in biomechanical designs (Veljković et al. 2015). A survey that was conducted found that 23 body dimensions of 21 crane operators did not suit the anthropometrics of the workspace provided in the crane cabin. Through an anthropometrical analysis, this study highlighted the importance of increasing the comfort and facilitating interactions between crane operators in order to reduce the discomfort that can lead to tower crane accidents. This method can serve to improve safety and prevent injuries and even fatalities in relation to crane failure.

2.7 Summary

The statistics on crane accidents in the countries that were referred to show that most of the accidents occurred during the operation, installation and dismantling of cranes. It is important for the relevant parties to refer to more effective operational ethics to enhance the existing regulations. Most of the countries that were surveyed used a code of practice or guidelines on the safety of tower cranes at construction sites. Based on the countries that were studied, Singapore has fairly precise regulations in its code of practice on the use of cranes, where tower cranes are allowed to be used for a maximum of 15 years, and tower cranes that are 20 years of age or older cannot be used.

CHAPTER 3

ANALYSIS OF ACCIDENT TRENDS

3.1 Data on Tower Cranes in Malaysia

The use of tower cranes in Malaysia, especially in the construction sector, is increasing every year, based on the increase in the number of construction projects throughout the country. According to the records from DOSH until April 2017, there are as many as 1434 active tower crane units throughout the country, and these were manufactured between the years 1973 to 2017, as shown in Figure 3.1.

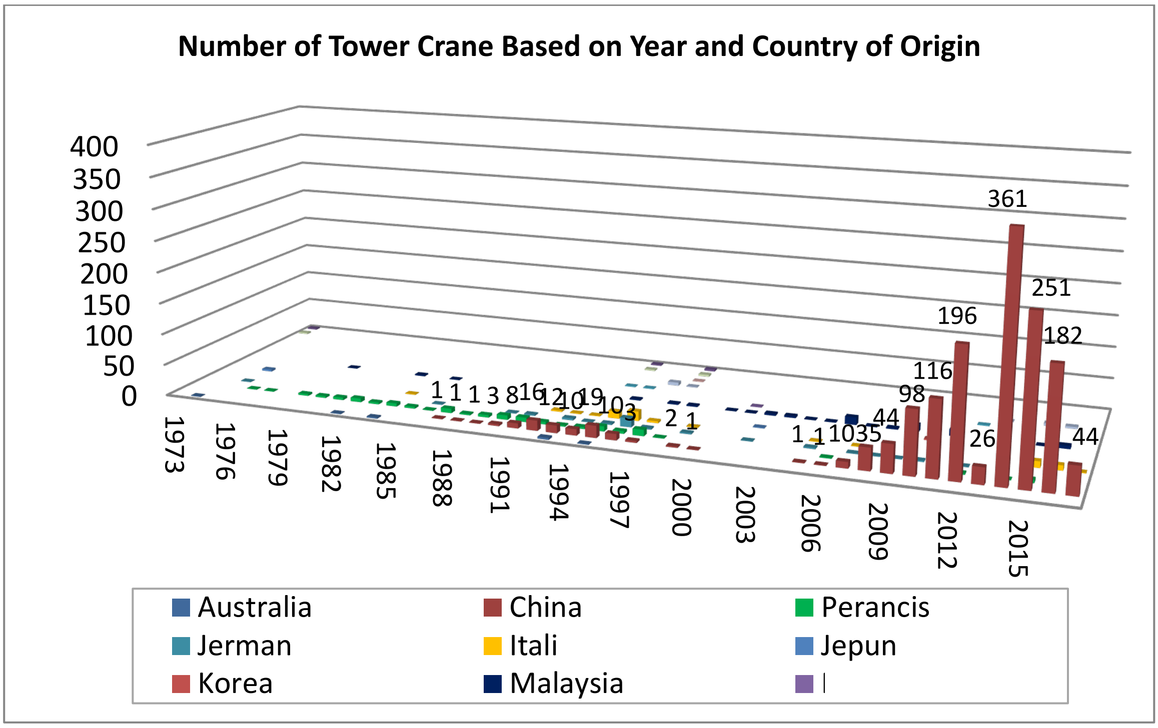


Figure 3.1 Distribution of registered and active tower cranes until 2017

Most of the tower cranes in Malaysia were imported from China, i.e. 1176 units, as this numbers increase annually, followed by 93 units from France, 55 units from Malaysia, 37 units from Italy, and 35 units from Germany. The rest were imported from other countries such as Australia, Japan, Korea, the Netherlands, Singapore, South Korea, Spain, Thailand and the United States, The distributions of this reported data are shown in Figures 3.2 and 3.3.

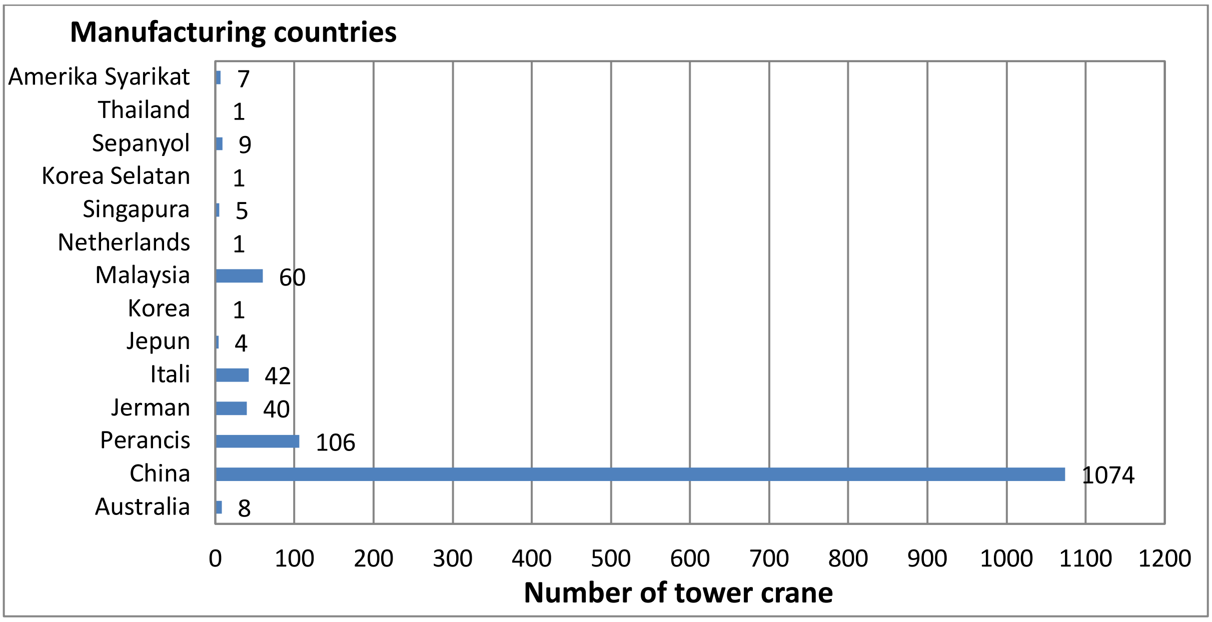


Figure 3.2 Number of tower cranes according to country of manufacture

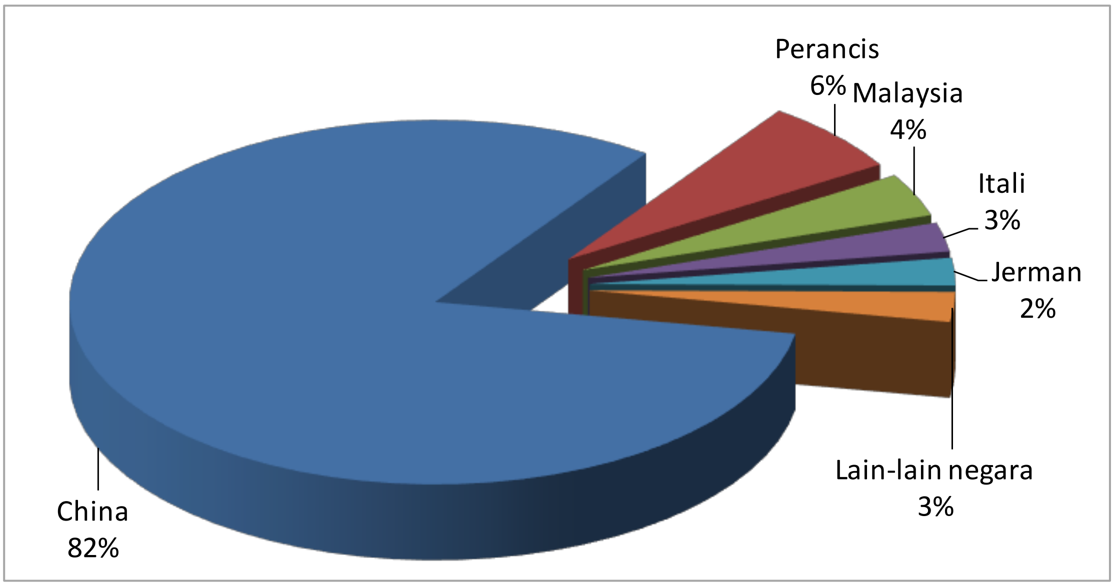


Figure 3.3 Percentage of tower cranes imported from foreign countries, including Malaysia

Based on data from the DOSH office in Putrajaya and the all DOSH state offices during the study, Selangor has the highest numbers of active tower cranes (at 358 units), followed by Kuala Lumpur/Putrajaya (463), Johor (299), Penang (161), Sarawak (36) and Sabah (49). From the total numbers of these type of cranes, 82% of them were imported China, 6% from France, 4% from Malaysia, 3% from Italy, 2% from Germany, and 3% from the rest other countries. It seems that more cranes were imported from China, as the price per unit is cheaper compared to other countries, and they are able to meet the needs by respective customers. Further details concerning the numbers of active tower cranes in Malaysia (until 2017) are shown in Figure 3.4. In addition, there is a bit difference in the data obtained from the DOSH Putrajaya and their state offices. It may due to errors or lack of complete data during the data input process.

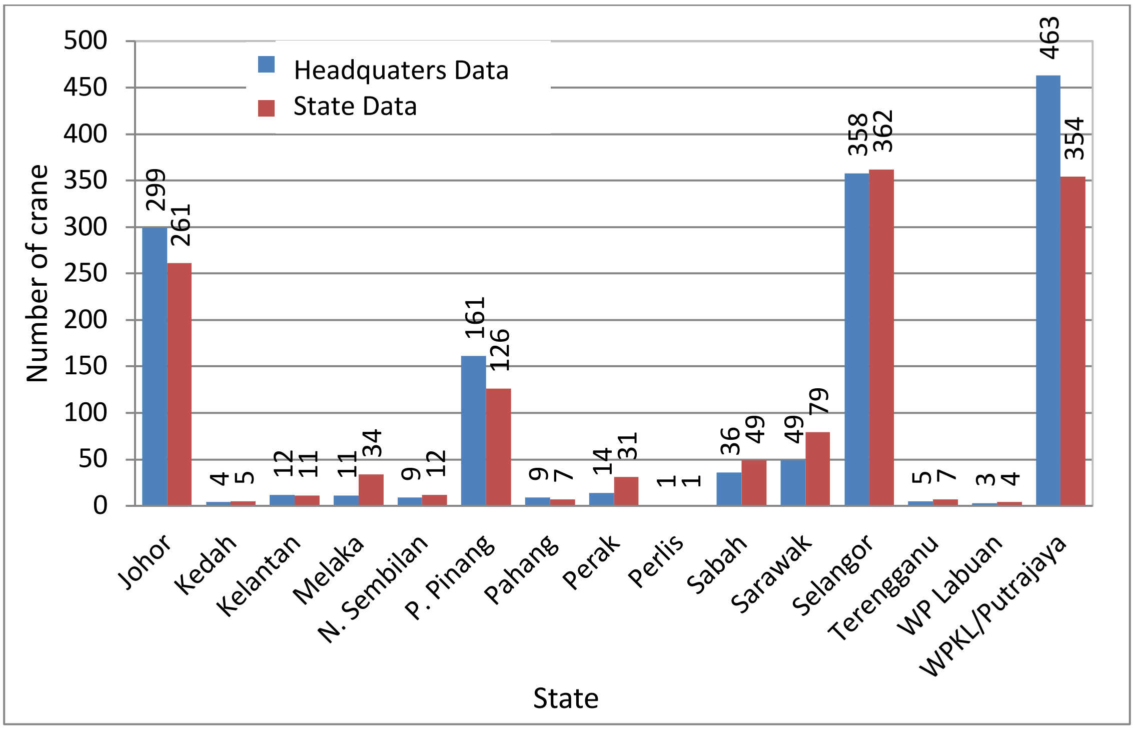


Figure 3.4 Statistics of mobile cranes and active tower cranes until 2016

If viewed from the perspective of the age of the tower cranes concerned in reference to their year of manufacture, almost 58% (775 units) are aged less than 5 years, 19% (257 units) are aged between 5 to 10 years, and 9% (122 units) are aged between 20 to 25 years. As for the tower cranes, 2.8% (37 units) are more than 30 to 40 years old, while 0.5% (7 units) are more than 40 years old, as shown in Figure 3.5. As such, most of the tower cranes being used in Malaysia currently are new, being less than 10 years old. However, the validity of the date of manufacture of the cranes concerned cannot be confirmed because every process for the design approval and registration is based on documents submitted by the crane owners to DOSH. The design approval for the crane must be obtained from DOSH, and written permission must be obtained from the state DOSH office prior to the installation of the crane at the construction site. A valid certificate of fitness, known as a Lifting Machinery Permit (PMA) is required for the machine to start operations.

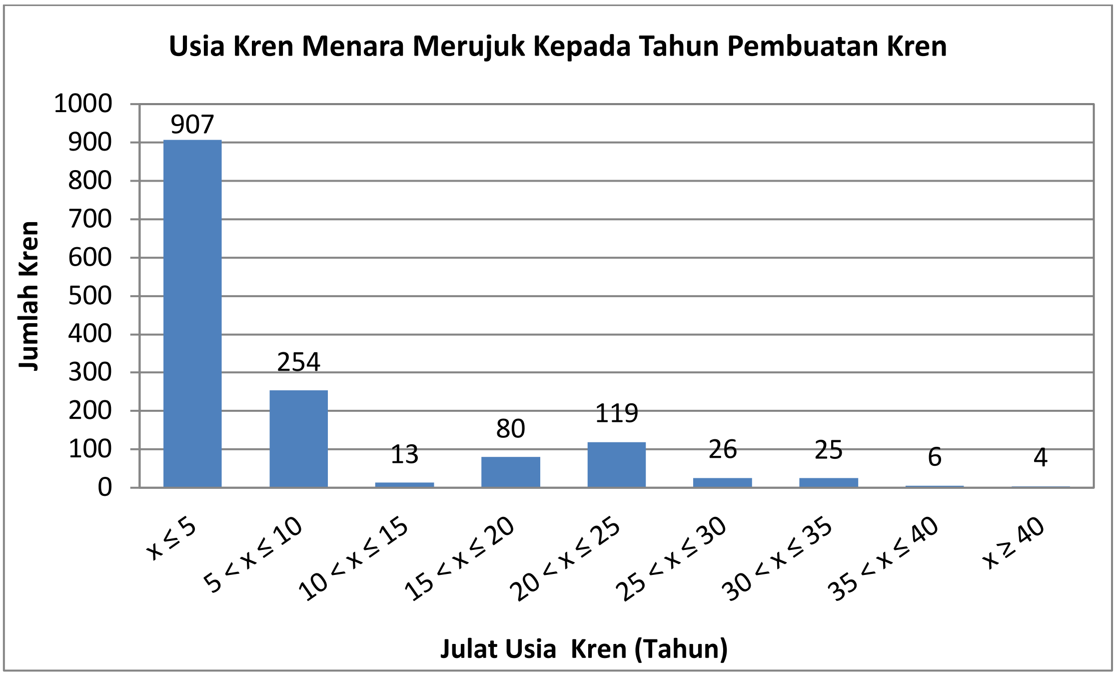


Figure 3.5 Age of tower cranes that are still active according to year of manufacture

According to the Factories and Machinery Act 1967, it is mandatory for tower cranes to be installed and maintained by competent companies that are registered with DOSH. In addition, the Occupational Safety and Health Act 1994 stipulates that the main contractor at the construction site is responsible for ensuring the safe use of the tower crane at the construction site. The installation, maintenance and dismantling of the crane must be carried out by a competent firm (FYK) that is registered with DOSH to handle the work. At present, there are more than 20 firms that are competent to handle the works associated with tower cranes. Nevertheless, there are also cranes that are owned by the main contractor and which are being maintained by them without the written permission of DOSH.

All matters pertaining to the installation, construction, and inspection of tower cranes must be well-documented and kept ready for presentation to the authorities when requested. In addition, only competent persons are allowed to operate the cranes, i.e., operators who have obtained a tower crane operator's licence from DOSH after passing a written and practical exam. Crane operators are also encouraged to carry out a pre-inspection/preliminary inspection at the start of each shift to ensure that the crane is not experiencing any defects or structural failures, and that its mechanism is safe for use.

In 1997, Malaysia produced a luffing tower crane, based on the design of Favelle Favco, Australia. Due to rapid economic expansion and developments in the construction sector, many tower cranes were brought in and owners preferred to purchase cranes from western manufacturing companies in view of the quality and durability of their products in the performance of heavy work. Prior to 1997, all types of tower cranes could be brought into Malaysia without any restrictions or the need to obtain permission from certain parties. However, after 1997, all tower cranes that are brought into the country are required to have an approved permit (AP) from MITI.

Apart from the Favelle Favco model from Malaysia, models from France, Italy and Germany such as Potain, Comedil and BKT are the choice of building contractors in Malaysia. The Potain FO/23B model, which is produced by Shanyang Co. Ltd., China is a popular choice among contractors because it is much cheaper and does not give rise to many maintenance problems, and the design of the crane's mast is the same as that of the French Potain, thereby facilitating the exchange process and alterations to the height of the crane. Apart from that, other crane models, such as the Manitowoc and Sichuan from China, are also popular in this country.

From 2010 to 2016 (Figure 3.6), the owners of 959 tower crane units had applied the permit-to-work approval from DOSH. However, the year for manufacture for another 26 units was unknown/not stated. Of that total, 56.4% were re-approved, 36.8% were given new approvals, 6.4% were rejected for unspecified reasons, 0.3% were given approval for modifications, and 0.1%

were issued with warning letters, and all the data is shown in Figure 3.7. According to the related regulation issued by DOSH, the operating licence or Lifting Machine Certificate (*Perakuan Mesin Angkat*, PMA) of each active tower crane must be renewed for every 15 months. For 2013 until 2017, 581 hammerhead tower cranes and 329 luffing tower cranes have been officially applied for approval / re-approval.

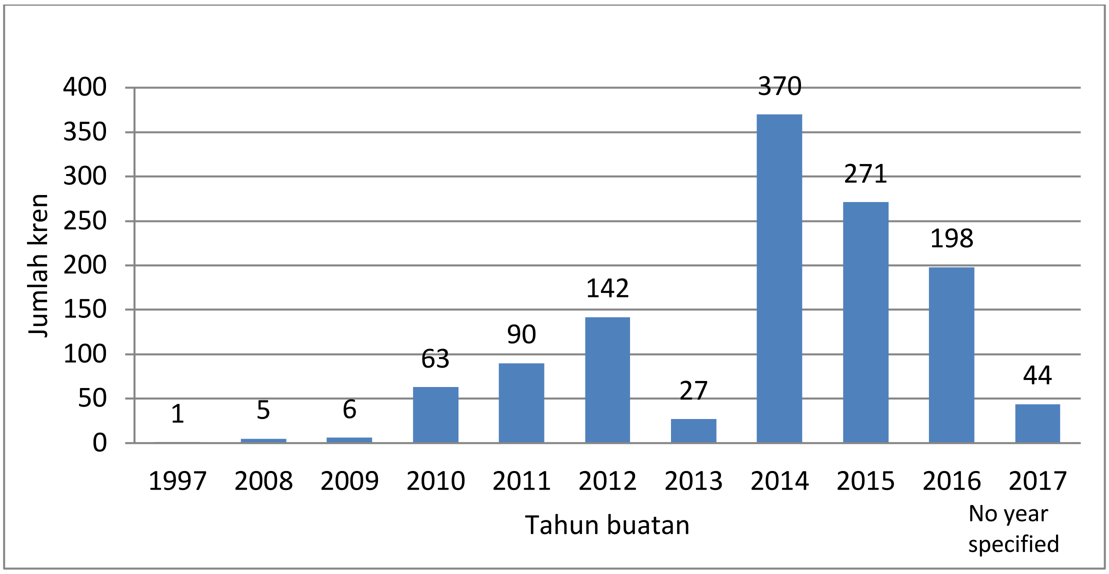


Figure 3.6 Number of tower cranes approved by DOSH until year 2016

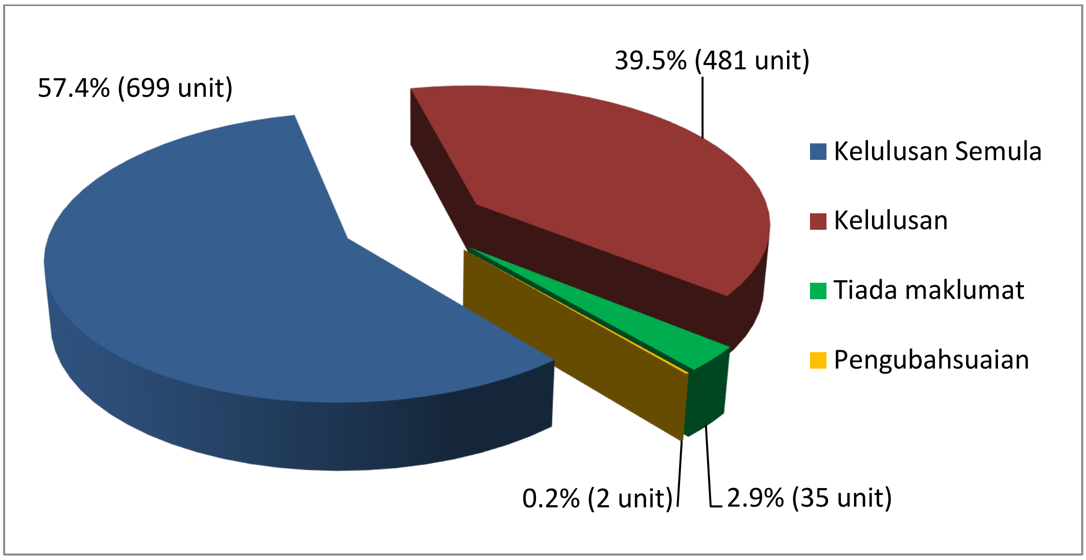


Figure 3.7 Percentage of applications for tower crane approvals

3.2 Comparison with Accident Trends in Other Countries

3.2.1 Current Trend of Accidents in Malaysia

The use of tower cranes in the construction industry involving high-rise buildings in Malaysia is no longer unfamiliar. On the whole, the construction of skyscrapers involves the use of hammerhead and luffing tower cranes. Many cases of accidents have been reported involving the use of luffing tower cranes. According to data provided by DOSH during a visit to state offices, 52 tower crane accidents were reported in the period 2002 to 2016. Among the factors reported as having been the cause of the accidents were the twisting of the crane's jib, the snapping of the hoisting rod, the detachment of the crane's slewing, and so on.

Overall, the accident cases that have been reported involved 22 fatalities, 14 injuries and 28 cases of dangerous occurrences over the last 15 years, as shown in Figure 3.8. The three states in Malaysia with the highest number of reported accidents are Selangor (16) with 3 fatalities, 5 injuries and 10 cases of dangerous occurrences, Kuala Lumpur (20) with 13 fatalities, 3 injuries and 11 cases of dangerous occurrences, and Johor (9) with a record of 3 fatalities, 3 injuries and 3 dangerous occurrences. Accidents have also been recorded in Penang (3), Putrajaya (1), Terengganu (1), Sarawak (1) and Perak (1).

Referring to the data provided by DOSH, as presented in Figure 3.9, the highest number of crane accidents, i.e. 13 cases, was recorded in 2015 compared to the subsequent years. One such case occurred in August 2015, where the entire boom and cabin fell from a height of about 23 meters as the crane was lifting and transferring garbage containers. According to DOSH, the accident occurred due to the failure of the bolts and nuts at the slewing ring, which caused the boom, slewing table and cabin to fall. In that incident, the crane operator was injured. In December 2015, a similar incident occurred in Perak, where the boom encountered a defect which could not be slowed down by luffing up, thereby causing the boom to rebound. The accident occurred during a lifting operation. The factor that contributed to this accident was the negligence of the crane operator with regard to the adjustment and installation of improper safety devices.

There have been 7 cases of tower crane accidents recorded until mid-2016. One such accident occurred in July 2016 in Johor, where the front boom snapped and the counter jib of the crane fell, as shown in Figure 3.10(a). The incident occurred when the operator was lowering sand from the 13th floor to the 10th floor of a building that was under construction. The crane swayed strongly and its front boom snapped, before the counter jib of the crane fell and got caught on the 13th floor of the building. The crane operator managed to escape with minor injuries to his forehead. The latest accident, as shown in Figure 3.10(b) took place on 25 August 2016 at Jalan Bukit Bintang, Kuala Lumpur, involving a hanger block tower crane that toppled over outside the construction area and smashed through a public vehicle, thereby causing the female driver to die on the spot. It was reported that the wire rope for the tower crane had snapped.

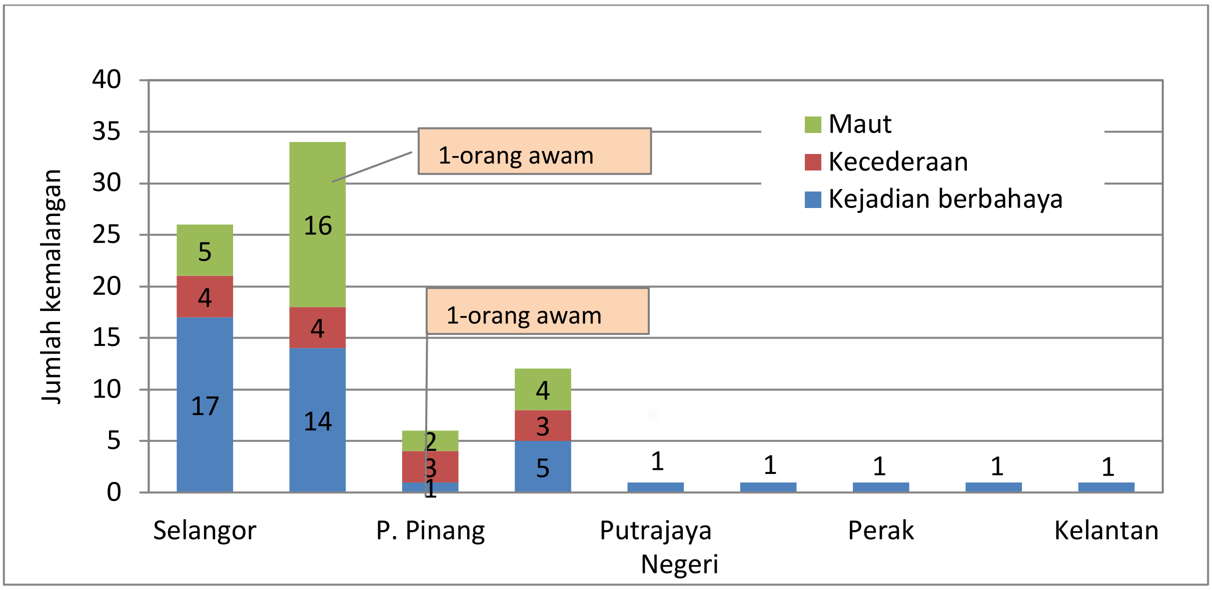


Figure 3.8 Reported cases across the country involving deaths, injuries and dangerous occurrences

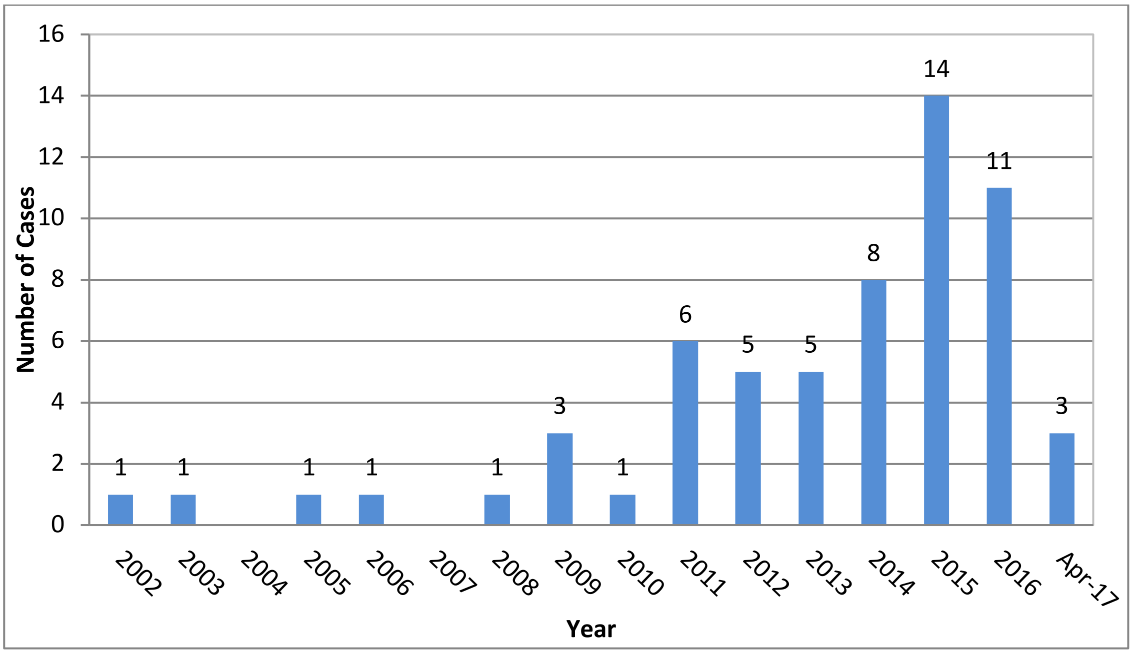


Figure 3.9 Number of cases involving tower cranes from 2002 to 2016

(a) (b)

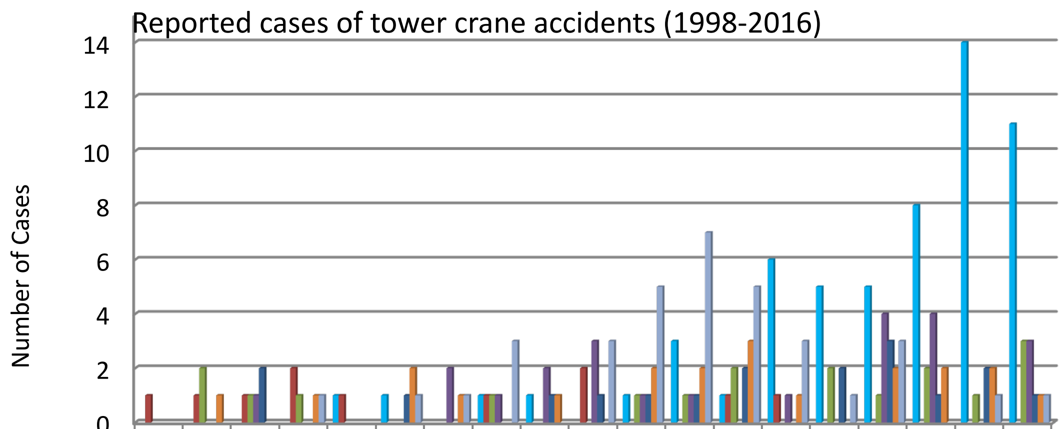
Figure 3.10 Crane accidents in (a) Johor (July 2016), and (b) Bukit Bintang, Kuala Lumpur (August 2016) (www.bh.com.my)

3.2.2 Comparison with Other Countries

A literature review was conducted to examine the trend of tower crane accidents in other countries from 1998 to 2015. As many as six countries were involved in this comparison of the number of tower crane accidents, namely Malaysia (2002-2015), Australia (1999-2015), Singapore (2000-2015), Germany

(1999-2015), Hong Kong (1998-2007), and the United Kingdom (2000-2009). The data on accidents for Malaysia were derived from information provided by DOSH, while for countries other than Malaysia, the range of years and the accident data were obtained from Chapter 2 (Literature Review).

According to the records that were obtained, as shown in Figure 3.11, tower crane accidents occurred as early as 1998 to 2000 in Hong Kong, Australia, Germany and the United Kingdom, and such accidents continued to occur year after year. For Australia, Germany and Hong Kong, the highest number of tower crane accidents recorded in a given year was only 2 cases a year, while for Singapore and the United Kingdom, there were only 3 cases. In addition, China also showed high incidence cases of 35 cases from 2001-2016. However, for Malaysia, the highest number of accident cases recorded was more than or equal to 5 cases a year, i.e. in 2011 (6 cases), 2013 (5 cases), 2014 (8 cases) and 2015 (14 cases). No data could be obtained from the literature on Hong Kong after 2011 onwards.



	"98	"99	"00	"01	"02	"03	"04	"05	"06	"07	"08	"09	"10	"11	"12	"13	"14	"15	"16
Malaysia					1	1		1	1		1	3	1	6	5	5	8	14	11
Hong Kong	1	1	1	2	1			1		2			1	1					
Australia		2	1	1				1			1	1	2		2	1	2	1	3
United Kingdom			1				2	1	2	3	1	1		1		4	4		3
Singapura			2			1			1	1	1	1	2		2	3	1	2	1
Jerman		1		1		2	1		1		2	2	3	1		2	2	2	1
China				1		1	1	3		3	5	7	5	3	1	3		1	1

Figure 3.11 Number of tower crane accidents from 1998 to 2016 in Malaysia, Australia, Singapore, Germany, Hong Kong, UK and China

Based on the literature review, although the information that was obtained for these countries was for different years, generally the trend showed that tower crane accidents were on the rise from 1998 to 2016 in these 6 countries. This upward trend can be seen in Figure 3.12, which shows the total number of accident cases for each year from 1998 to 2016.

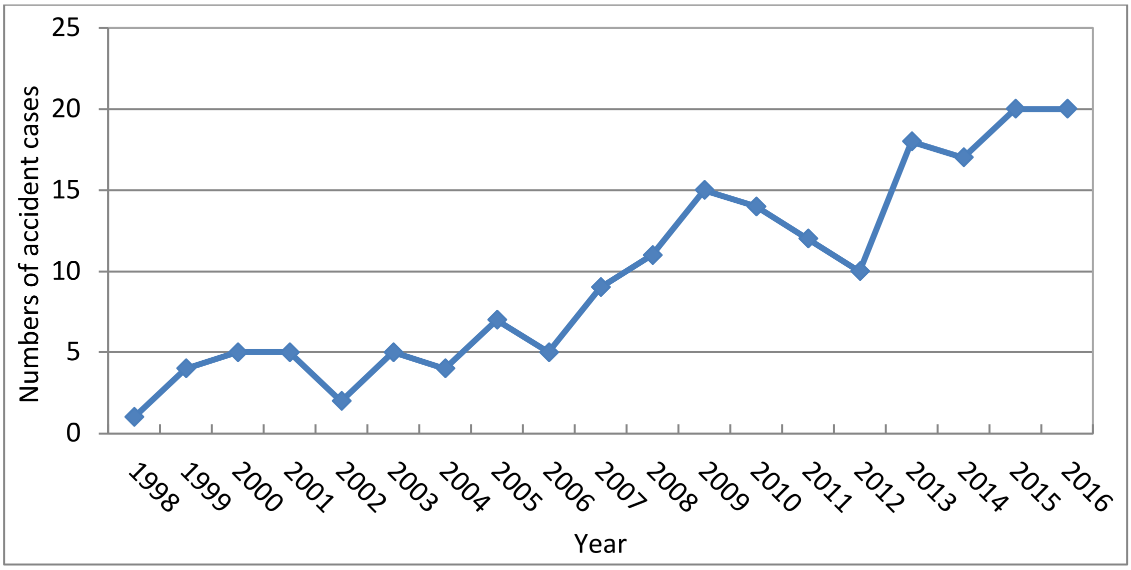


Figure 3.12 Total number of crane accidents by year from 1998 to 2016 for Malaysia, Australia, Singapore, Germany, Hong Kong, United Kingdom and China

Based on the limited information that is available (sourced from DOSH for Malaysia, and the literature review for other countries), a cumulative analysis was carried out on tower crane accident trends over the last 4 years, from 2012 to 2016, in four countries, namely Malaysia, Australia, Singapore and Germany, as shown in Figure 3.13. The trends in Hong Kong and the UK could not be analysed because no information was available for those years.

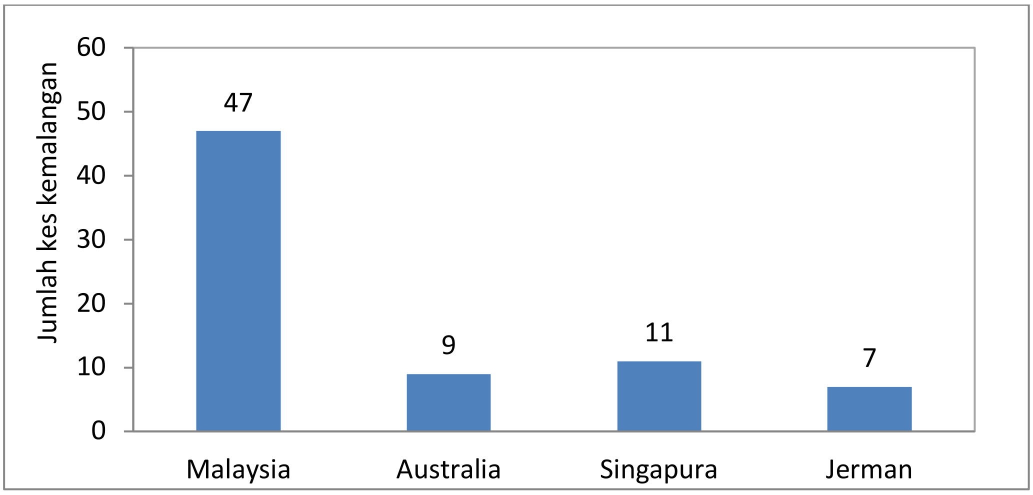


Figure 3.13 Total number of crane accidents from 2012 to 2016 in Malaysia, Australia, Singapore and Germany

From Figure 5.13, it is clear and very noticeable that Malaysia had the highest cumulative number of accidents involving tower cranes compared to the 3 other countries. A total of 34 tower crane accidents were recorded over the last 4 years compared to only 11 cases recorded in Germany and 8 cases each in Australia and Singapore.

3.3 Summary

The increase in the number of tower cranes at construction sites can lead to a rise in the number of accidents at these sites if safety measures and regulations pertaining to the use and operation of tower cranes are ignored. Malaysia had the highest number of tower crane accidents compared to other countries such as Australia, Singapore and Germany for the period 2012 – 2015 in view of the fact that these countries have a specific code of practice for the use and operation of tower cranes. Proper techniques and investigation models are also required to identify the causes of accidents in Malaysia.

CHAPTER 4

ACCIDENT INVESTIGATIONS

4.1 Introduction

The key to preventing a recurrence of the same incident is to understand the cause of an accident. Detailed investigations will lead to a better understanding of the behaviour of tower cranes and can indicate the need for additional research on the safety factors when tower cranes are in operation. The construction industry must be constantly reminded of the need for competent parties to conduct inspections of tower cranes.

The two main reasons for studying accident trends or near misses are:

i) Predicting accidents or potential incidents based on previous trends and taking measures to prevent a recurrence of such accidents.

ii) Anticipating risks and dangers that can be avoided or reduced.

4.2 Investigations

Every day there is news of a tower crane accident. These incidents cause damage to cranes, and more unfortunately, involve injuries and the loss of life whether of crane operators, construction site workers or the general public. When investigating a crane accident, the investigators will try to determine a number of factors:

- Whether the operation of the crane was in compliance with the limits and specifications of the producer/manufacturer of the crane;
- Whether the installation of the crane and adjustments to the crane were carried out by trained and competent individuals;
- Whether the crane was being operated by a qualified (certified) and trained operator;
- Whether a competent person had been assigned to inspect the crane before and during its use to ensure its safe operation, and whether a more comprehensive inspection of the equipment and critical parts had been carried out according to a fixed schedule;
- Whether the inspection schedule by a competent firm covered items such as the wire ropes, and also the welding of cracks and crane parts that were worn out or significantly damaged;
- Whether repairs to the crane or other modifications had been checked by a qualified person;
- Whether the crane had been placed on a stable surface in a safe work environment, especially one that is away from overhead power lines;
- Whether the access of the crane was limited to within its slewing radius;
- Whether the load capacity of the crane was not exceeded when lifting, and whether an accurate evaluation was made of the weight of the load;
- Whether there were workers working below the crane components while it was in operation;
- Whether the crane had a safety device to indicate the correct and safe level of operation of the crane;
- Whether a qualified signalman was available, when required, due to problems with the limited view of the crane operator;
- Whether equipment for protection against falling objects had been put in place for work at high-rise buildings;

- Whether materials had been tied up by a qualified and experienced rigger so that the items could not come loose and be a source of danger to workers around the crane.
- Whether the base of the tower crane and the support structure had been designed by a manufacturer/contractor/competent firm and had been reviewed by DOSH or a registered professional engineer.

4.2.1 Guidelines for Occupational Safety and Health Act (Act 514) Part VIII, Sections 32, 33 and 34

For situations involving accidents, dangerous occurrences, poisoning and diseases, refer to the matters stated in the Occupational Safety and Health Act 1994 (Malaysia), i.e. to Part VII, Section 32, 33, and 34. Specific regulations or guidelines pertaining to tower cranes are not mentioned in this Act. Suggestions concerning investigations and enforcement in relation to tower cranes are discussed in Chapter 8 (Sub-chapter 8.2.2). The explanation for Sections 32, 33, and 34 are as follows:

Section 32: Notification of accidents, dangerous occurrences, occupational poisoning and diseases, and inquiries

(1) An employer shall notify the nearest occupational safety and health office of any accident, dangerous occurrence, occupational poisoning or occupational disease which has occurred or is likely to occur at the place of work.

(2) Every registered medical practitioner or medical officer attending to, or called in to visit, a patient whom he believes to be suffering from any of the diseases listed in the Third Schedule of the Factories and Machinery Act 1967 [Act 139], or any disease named in any regulation or order made by the Minister under this Act, or occupational poisoning shall report the matter to the Director General.

Section 33: Director General may direct an inquiry to be held

(1) If, in the opinion of the Director General, an inquiry ought to be held into the nature and cause of the accidents, dangerous occurrence, occupational poisoning or occupational disease, he may cause such an inquiry to be held by an occupational safety and health officer.

(2) The Director General may appoint one or more persons of engineering, medical or other appropriate skills or expertise to serve as assessors in any such inquiry.

(3) Every person not being a public officer serving as an assessor in the inquiry may be paid an allowance at such rate or rates as the Minister may determine.

Section 34: Power of occupational safety and health officer at inquiry

For the purpose of holding an inquiry under this Act, an occupational safety and health officer shall have the power to administer oaths and affirmations and shall be vested with the powers of a First Class Magistrate for compelling the attendance of witnesses and the production of documents, maintaining order and otherwise duly conducting the inquiry, and all persons summoned to attend the inquiry shall be legally bound to attend.

4.2.2 Guidelines for Accident Inquiry (Director General's Circular Number 7 Year 2009)

The process for conducting an inquiry into an accident or dangerous occurrence, included one that involves tower cranes, is shown in Figure 4.1. This process explains the scope of the inquiry, starting from the receipt of the notification of the accident or instructions to conduct an inquiry until a complete report of the inquiry has been prepared. In carrying out an inquiry, there are activities that are placed under the field of duty of the DOSH state investigating officer, the officer from the DOSH Headquarters, the Forensic Engineering Division (FED) as well as the activities that must be carried out together according to the accident case that has been received.

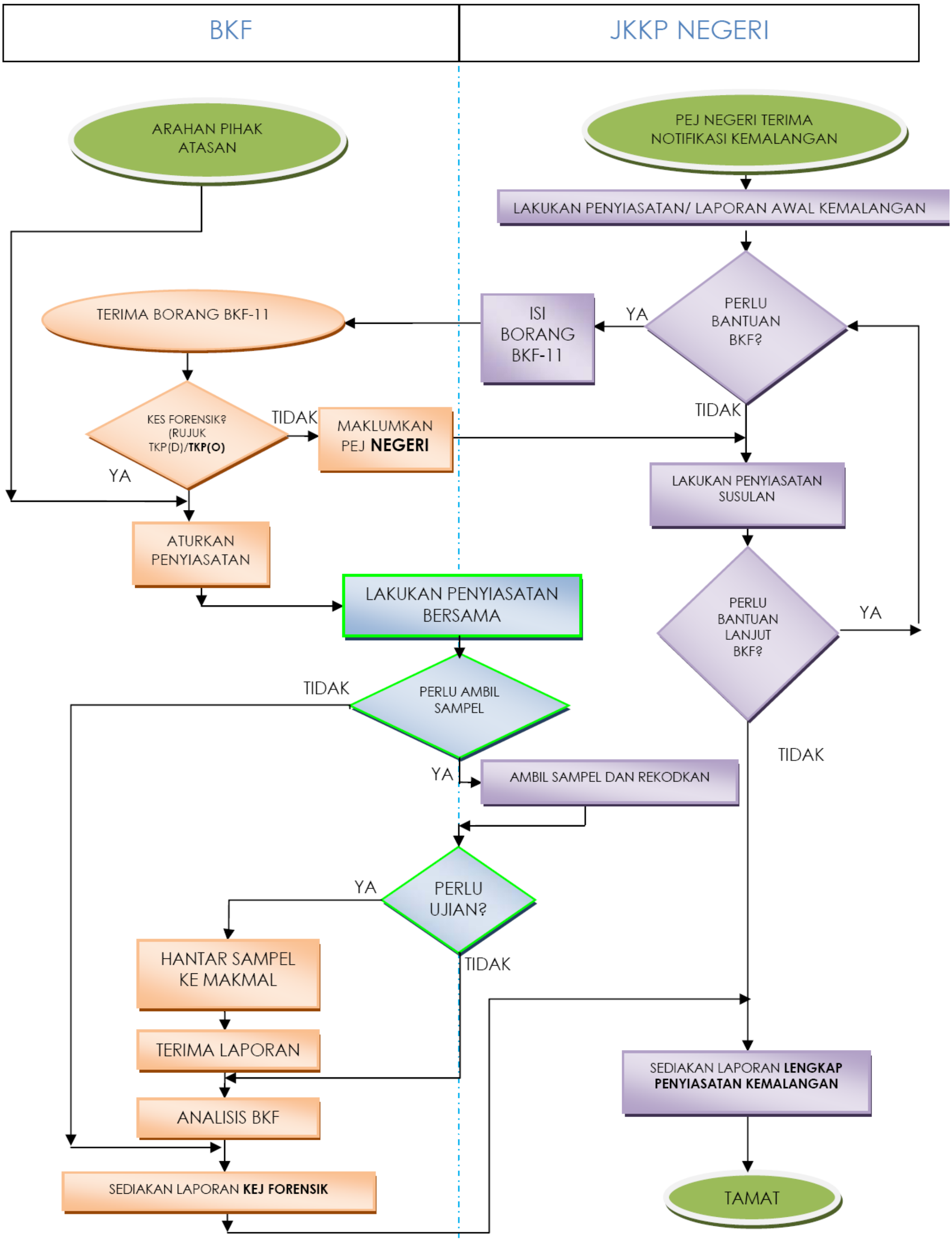


Figure 4.1 Procedures for accident investigation at the workplace (DOSH 2009)

Accident Investigation Process

i. The investigation begins with the receiving of an accident notification or instructions from the authorities to hold an inquiry;
ii. If the case of the instructions of the authorities, the FED should arrange for an inquiry with the DOSH state personnels involved;
iii. In the case of an accident notification, the DOSH state office should check whether the case requires the assistance of the FED or not. For accident cases requiring the assistance of the FED, the DOSH state office must complete the FED Form 9, and submit it to the FED;
iv. Reference will be made to the TKP(D) or TKP(O) to determine whether the it is a forensics case or not.;
v. For any cases involving the FED, investigations will be carried out at the accident scene together with the gathering of evidence;
vi. To coordinate and establish control over the gathering of case evidence, the state DOSH investigating officer will carry out the recording of activities and collect evidence for laboratory tests by the FED; and
vii. The inquiry report prepared by the FED will be submitted to the state investigating officer, and the respectice officer will prepare a complete report on the accident.

4.2.3 Accident Investigation according to the Guidelines on Investigation of Forensic Engineering Approaches

The accident investigation or dangerous occurrence at the workplace is conducted by the investigating officer in order to identify the following matters:

i. The main causes and factors affecting the occurrence of the accident
ii. Action that should be taken to prevent recurrence of accident occurrences to ensure compliance with the law
iii. Improvements to the existing DOSH guidelines and legislation
iv. Appropriate and applicable action if there is a violation of the law enforced by DOSH

Figure 4.2 shows the scope of investigation work for a tower crane accident. This process starts with the acceptance of an accident notification, then continue for conducting an investigation, and finally followed by the report preparation as the completion. In an early stage, DOSH state personnels, the parties at the construction site (operators, signalmans, riggers, safety officers, etc) and witnesses will play an important role to report and gather accident information, and they are all vital for the investigation. The investigations are to be carried out under the provisions of the Factories and Machinery Act 1967, the Workers Safety and Health Act 1994, Procedural and Investigation Inquiry and Incidents (PK-04) Procedures and Forensic Engineering Approach Guidelines.

The preparation for investigation is required by DOSH state officers before the identification of accident location, understanding the activities and also the processes that should be performed at the place of accident. DOSH state officers should identify the complete survey equipment as well as personal protective equipments that need to be carried. In addition, investigating officers should also identify the cooperation requirements of other relevant agencies based on the initial information received. Investigating officers should ensure that the team members are in good health and equipped with information and knowledge in handling accident cases.

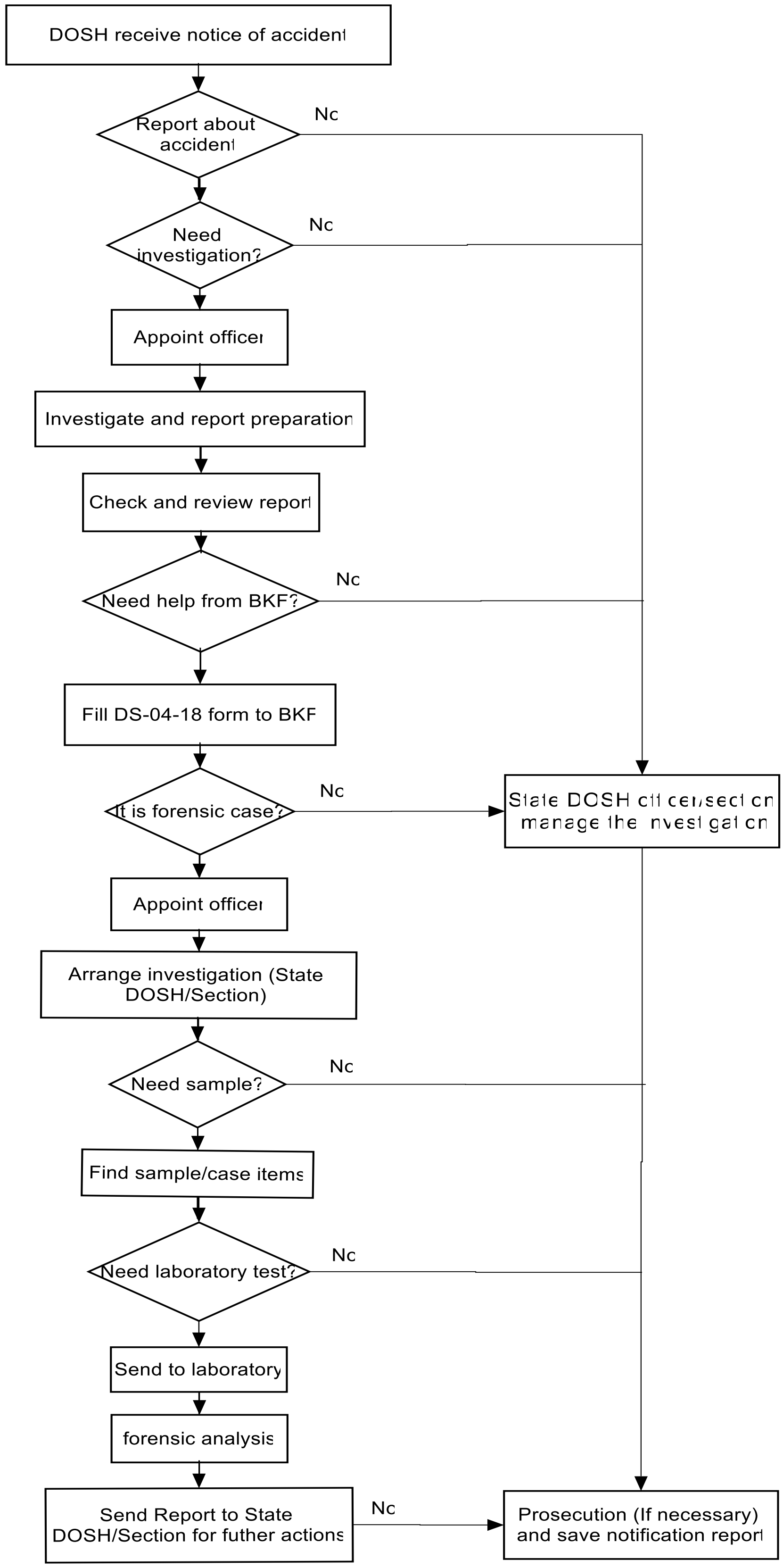


Figure 4.2 The process of investigation of the tower crane accident

(a) Accident Notice

The management/employer should notice the accident to the DOSH state office as soon as possible. The immediate notice from the management or employers are important to ensure that the state DOSH is prepared to carry out the investigation process as soon as possible to identify the cause of the accident. If the notice is related to the death, injury and dangerous occurrence, the DOSH central office at Putrajaya will manage the investigation. If the notice is not related to the (death, injury and dangerous occurrence) accident, the state DOSH officer will manage the report. Both reports need to be referred to the Procedures of Complaints and Incidents Survey (PK-04).

When the preliminary information on accidents is obtained, the investigations should be carried out sooner. The director of the DOSH state office should appoint an investigating officer with appropriate knowledge and experience. The investigating officers should hold the discussions with directors based on initial information received. Among the initial information needed is as follows:

i. Information from workplace registration files
ii. Occupants / workers at the place of accident
iii. Competent persons such as safety and health officials, crane operators, registered engineers and others
iv. Relevant agencies such as the Fire and Rescue Department, Royal Malaysian Police, Local Authorities and others.

Upon for obtaining the information, the investigating officer should appoint a member of the investigating team. The division of duties is carried out according to their respective expertise. The team members should be accompanied by investigating officers, assistant investigating officers, photographers and skecher. Investigating officers also need to hold pre-investigation meetings or discussions with team members for an initial description of the incident scenario, possible hazards at the place of accident and safety briefing. In addition, the investigation team members need to provide equipment, protective equipment and logistics as adequate, functional and calibrated as shown in Figure 4.3. An authority card, investigation books and log books of each team member should also be brought together during the process.

Jadual 1: Kit Penyiasatan Umum
[merujuk kepada klausa 5.1.3.2 (b) (iii)]

SENARAI PERALATAN PENYIASATAN UMUM	
Lampu Suluh	Pisau Pemotong Saku
Pita Ukur	Papan Klip/Papan Lakar
Kit Kamera	Kertas Graf
Kamkorder DVD	Cermin Pemeriksaan
Binokular Kalis Air	Beg Keterangan Kertas Bercetak
Pita Kuning Amaran Hazard	Kompas
Pembaris Keluli Nirkarat	Perakam Suara
Kaca Pembesar	Komputer Riba dan Jalur Lebar
Angkup	Kit Tandaan
Tolok Kimpalan	

Figure 4.3 List of general investigation equipment according to the Guidelines on Forensic Engineering Approach Guidelines

(b) Visit to the Accident Venue

If an accident occurs outside of construction site, local authorities and police will be involved in the investigation. If the accident occurs within the construction site then the case will be investigated by the investigating officer of the DOSH state. Investigating officer should be present at the scene as soon as possible to see the actual situation of the accident. The Prohibition Notice will be issued in the event of a major accident or life threatening under Section 48 of the Occupational Safety and Health Act 1994.

Investigating officers will examine, confiscate materials, articles or things which may be used as an evidence in the investigation. The investigating officers also have the authority to prevent the accident area from being disturbed and intruded. It can be done by close and control the accident area using enclosures, cones or other suitable equipment, as an addition to use existing barriers such as doors, fences and others. The investigating officer should also consider issuing a temporarily prohibition/prohibition notice if the accident area is hazardous. This method can be used to prevent injury or damage while protecting the evidence. Any information such as sketches, measurements, samples and pictures may be taken for further action.

In addition, the investigating officers need to collect information from related witness, including management/employer, operator, signalmen, rigger, employee or others, who are at the scene to know the accidental picture of the accident. They need to record the personal information or the witnesses, for example name, address and telephone number, and these are needed as a further contact for conducting interviews as soon as possible. Examination through visual components and screening should be done immediately through the initial review within the enclosure.

(c) Detail Investigation

After visiting the accident venue, the DOSH state investigating officer should conduct a detailed investigation for identifying the cause of the accident. Furthermore, the investigating officers need to identify whether the case would need assistance from the Forensic Engineering Division (Bahagian kejuruteraan Forensik, BKF). If BKF assistance is needed, the DOSH state officer needs to fill out the DS-04-18 form. On the other hand, the DOSH state officers should also conduct their own investigation.

The BKF division will evaluate the reported cases to be either brought forward for the forensic analysis/testing or not. If a forensic analysis is required, the director will appoint a BKF officer to arrange a detailed investigation with the DOSH state/division investigating officer. This action can be referred to the document of Procedure of Complaints and Incident Investigation (PK-04). The investigating officer should use the appropriate personal equipment according to the circumstances of the accident. The first step to be done in this detailed investigation is to divide the work for the recording and re-evaluation of the initial findings recorded in the Early Investigation Form at the Accident Place.

The evidence, photographs, videos and sketches should be taken as evidence records. The photographs criteria should be taken as a long distance, medium and close images at the location of the accident as well as an object, the images should be marked and pointed along with the equipment showing the size by placing the appropriate measuring device. Additionally, the victims and machinery should also be photographed if they are related to the purpose of the investigation. Example of the methods can be used for evidence collection are:

i. Start by taking photographs in public areas and then moving to a specific scene.
ii. Take photographs from various directions, some angles and photographs from close range.
iii. Create a photographs log containing the time and date the photographs was taken, the location, the name of the photographer and a brief description of the picture.

DOSH investigator officers also need to do sketches and measurements at the location or place of accident. Basic information such as accidental address, case reference number, date of accident, time and date of investigation, investigating officer's name and northern signage should be recorded in the sketch. The investigating officer also should mark the number of pages and signatures on each sketch. The position of the case should be marked with the coordinates in the sketch before it is removed. The distance between the accident scene and the nearby building or other related object is drawn.

The next step is the process to meet the witnesses, by calling them to meet and interview about the accident scenario, and it can be done at the accident venue. The findings of this step are dependent on the methods or means of interviews conducted by the investigating officer. After the session is completed, the inspection of the failure component need to be performed, and all evidences obtained should be taken for analysis.

Size measurement also should be done to obtain informations whether the work is done within the permitted distance or not. Based on the information obtained, the investigating officer can make an initial conclusion about the causes of the failure or accident occurring. This process is performed in order to identify whether the accident occurred due to human error (management / employer, operator, signalmen or other) or failure of component / structure.

(d) Materials and Structural Testing

If an accident occurs due to a component/structure failure, a follow-up test should be made whether the test is done by any NDT approach or the forensic testing (in the laboratory). Using the suitable tests, the actual causes of accidents can be hypothesised and found from the failure behaviour on the fractured surface of the components.

A case chain is a chronology and control over the movement of case items showing the chain, loot / pick up, transfer, analysis and disposal of case items. The principle of the case merchandise is to ensure that the integrity of the case matters submitted to the Court is assured and avoid reasonable doubts. The integrity and chain of the case begins from the loot/uptake until the disposal should be recorded and documented using the procedures and the prescribed forms. Information on case matters such as time, date, place, person responsible and evidence of case should be completed and signed by DOSH investigating officer.

The investigating officers should collect the identified case items and ensure the chain of goods is complied with. The investigating officer should also mark and label the case by using appropriate sealing. In addition, all the case materials (or evidence) must be sent to the storage or to the testing laboratory for further analysis.

(e) Forensic Testing in Laboratory

The laboratory forensic testing is performed to test samples or physical evidence obtained from the place of the accident. The chemical analysis was performed by conducting a spectrometer testing, which allows the present chemical elements to be identified. In addition, the broken or fractured surface analysis can also be performed using visual observations for large samples, microscopes for macro samples and Scanning Electron Microscopes (SEMs) for micro samples.

As an additional proposition, the structural integrity test at the construction site also can be done to determine the preliminary conditions of the crane component. Non-destructive testing (NDT) can be carried out to obtain information on crane structure conditions. The results obtained from this test will be applied to comparisons with the results of forensic testing in laboratories. This NDT test must be performed by competent person (*Orang Yang Kompeten*, OYK) with experience and knowledge to determine the appropriate NDT method for testing the crane components. The standards applicable to the NDT test are the standards of ASTM Nondestructive testing standards and CEN / TC 138 - Nondestructive testing.

The physics experiments on evidence such as fitting experiments, grinding & polishing, etching can also be performed. Using the tests, the physical condition of the evidence can be identified, such as the characteristics of materials failure by means of cracks, fractures, crookedness, perforation, etc.. The experimental determination of mechanical properties and computational analysis (stress testing, three points flexural test, hardness test, finite element analysis) are performed to determine the level of material strength. Thus, the material mechanical properties can be obtained and they are later can be compared to the standard properties of similar materials.

Electrical and electronic related analysis is also performed to check the circuit and the crane device used works well or not when used before the incident. This analysis can determine the causes of failure in electrical and electronic wiring or wiring that are usually caused by fire, short circuit and leaks in wiring systems.

(f) Forensic Analysis

As soon as all evidence (photographs, videos, sketches, measurements, interviews on witnesses, site tests and laboratory forensic tests) are collected, the analysis of the data obtained is done. The investigating officer is responsible for collecting and compiling all reports and documents pertaining to the accident into an investigation file. Each file needs to be classified as CONFIDENTIAL.

At this stage, investigating officers need to know and have strong evidence of how the incident occurred and what causes the incident. All the information and data obtained are compared to the right conclusions. All the causes considered will be supported by valid and relevant facts. This provided file for accident investigation that can be used as a reference for prosecution cases, policy studies and others.

(g) Report Preparation

After the forensic analysis as well as the evidence is completed, a report on the investigation should be provided. The purpose of this report is to suggest the actions that need to be taken to enhance safety levels so that the same occurrences are not repeated. This details report has specific recommendations and details the target group that will read the report.

The investigation results describe the entire activity of the actual investigation with the overall conclusion, and they are supported by reliable and proven information. A good report need to be consistent with the standards adopted, easy to understand and can also be used as a future and related reference. It should contain the following formats:

(a) Executive Summary which briefly explains the entire contents of the report.
(b) Introduction which includes:

- i. Objective of the investigation
- ii. Scope of investigation
- iii. Investigation team
- iv. Company background
- v. Position (map of location and building layout)
- vi. The process involved
- vii. Fact of events
- viii. Summary of accident
- ix. Venue of accident

x. Date
xi. Time
xii. Victims and parties involved
xiii. Chronology of accident events
xiv. Explanation on the event sequences according to the time of the event
xv. Explanation on the investigation process

(e) Observations and discoveries at accident sites such as hazards and risks (mechanical, chemical and electrical hazards). A thorough observation at the place of accident to determine the hypothesis, direction of the investigation, findings of the cause of failure and the evidence of the occurrence of the accident.

(f) Hypotheses of possible events that may cause accidents and determine the cause of the accident.

(g) The results of the investigation such as:

i. Records on accident sites such as photographs, sketches, measurements and interviews
ii. Analyse the relevant case items such as the seized goods list, the selection of test cases, the list of test cases and the case test results
iii. Discussions on the analysis of the results of investigations based on relevant evidence and references.

(h) Propose improvements to DOSH enforcement strategy, industry and other agencies involved (or other stakeholders in tower crane industries)

(i) The conclusion of the cause of the accident occurred

(j) References

Subsequently, the submitted report should be sent to the DOSH state/division office for further action. The prosecution process can be done where necessary and the final report is kept as a record of the accident case for future reference.

4.3 Search for the Basic Causes of Crane Accidents

It is not enough to investigate and see the direct and immediate causes. The root and basic causes must also be identified, because even if the accident was due to the negligence of the crane operator, the causes beyond that negligence must also be identified. The Ishikawa fishbone diagram in Figure 4.4 shows the categories and sources that can be identified as the causes of workplace accidents.

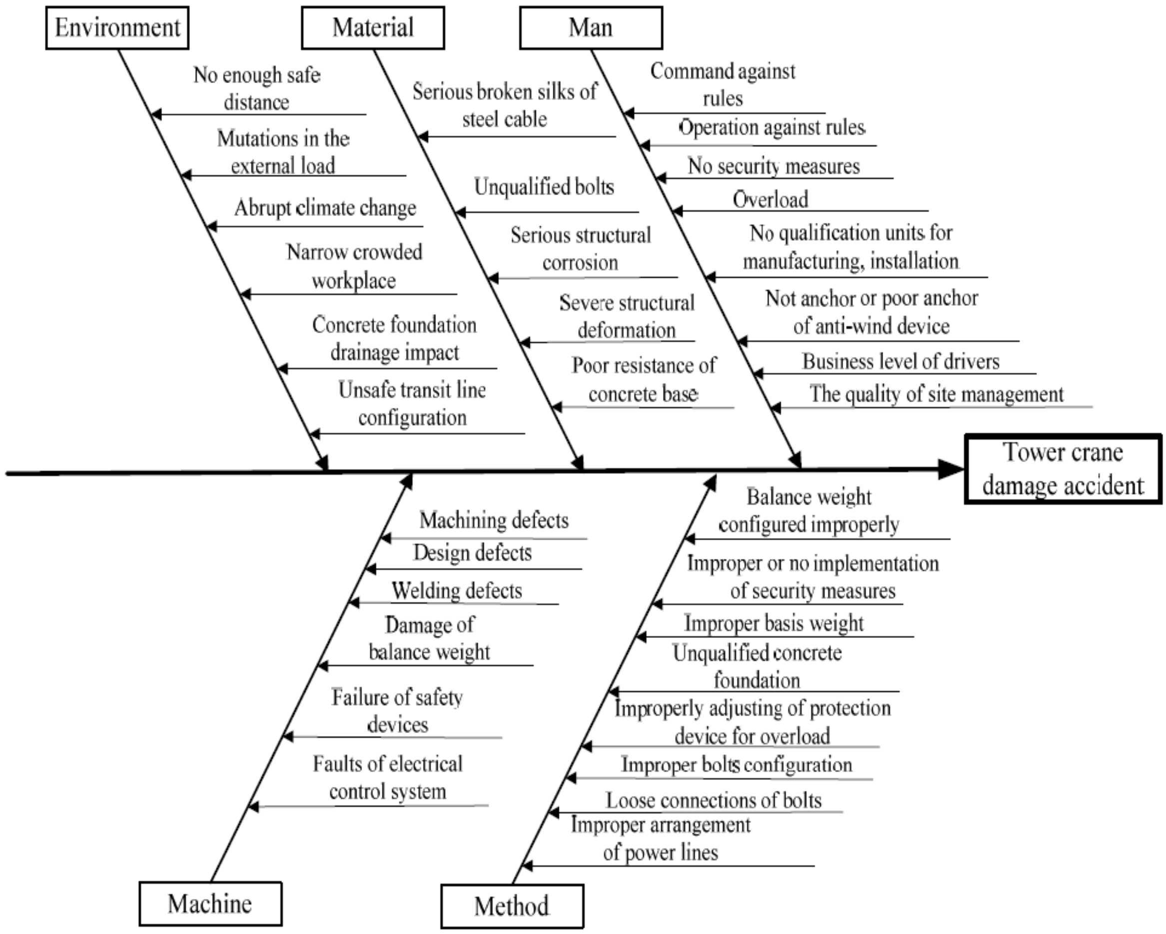


Figure 4.4 Ishikawa Fishbone diagram for tower crane accidents (Chunhua Zhao et al. 2012)

(a) Incident investigation

A Preliminary Incident Investigation must record the date and time of the occurrence. The location of the incident must be noted as the location where the accident occurred. What was the main activity that was being carried out when the incident occurred? The history of previous cases in relation to the incident must also be identified, especially those that involved similar specifications or a similar incident. Other additional information, including reports by members of the public and so on, must be recorded.

(b) Additional information for the investigating officer

Any additional information that can help the investigation officer to identify the cause of the incident must be noted. This additional information can include:

(i) Investigation at the site of the case

- Compliance with SOP.
- The working environment at the site of the case. Aspects to be looked at are in terms of congestion in the vicinity of the workplace, work space and so on.
- Other relevant factors that may have had an impact.

(ii) Summary of Events

Outline in detail the accident that occurred based on the sequence of events and the time (chronology).

(c) Conclusion

Major Factors that Caused the Incident. What were the main factors that caused the accident/incident to occur?

Factors that Contributed to the Incident. What were the other side factors (if any) that contributed to the occurrence of the accident?

(d) Measures for prevention/improvement

The preventive measures that have been undertaken are aimed at avoiding a recurrence of the same incident. If more than one preventive measure has been taken, a statement must follow the hierarchy of priorities, as contained in the Occupational Safety and Health Act 1994, namely:

- Elimination
- Replacement
- Isolation
- Engineering Control
- Administrative Control
- Use of PPE

(e) Summary by investigating officer

The summary can include the following items:

- The main cause of the accident based on the results of the investigation that was conducted.
- The action that has been taken to address/resolve the recurrence of such incidents. This can be in the form of a temporary action until truly effective preventive measures are implemented to eliminate/minimise the risk of accidents.
- Actions from the aspect of case management such as educating and notifying. If the outcome of the case is known, the results must be stated briefly.
- Other relevant and appropriate information to summarize the results of the investigation.

4.4 Examples of Tower Crane Accidents Investigation Model in Other Countries

4.4.1 New York, USA

Figure 4.5 shows the process of an investigation conducted by the Think Reliability conducting an investigation against the tower crane accidents in New York City on January 2016. It was found that the investigation process is divided into three levels, which are, problem, analysis and solutions. At the problem level, the main cause of the incident was identified so that investigation is more focused on the causes of the accident. The analysis approach was more focused on the effects and causes of the accident, and it was done so that the cause of the accident clearly identified. Finally, the solutions proposed by the investigative bodies are given based on the analysis performed. The actions to be taken by certain parties will be suggested. The effects of these actions are also described for the purpose of awareness to all parties.

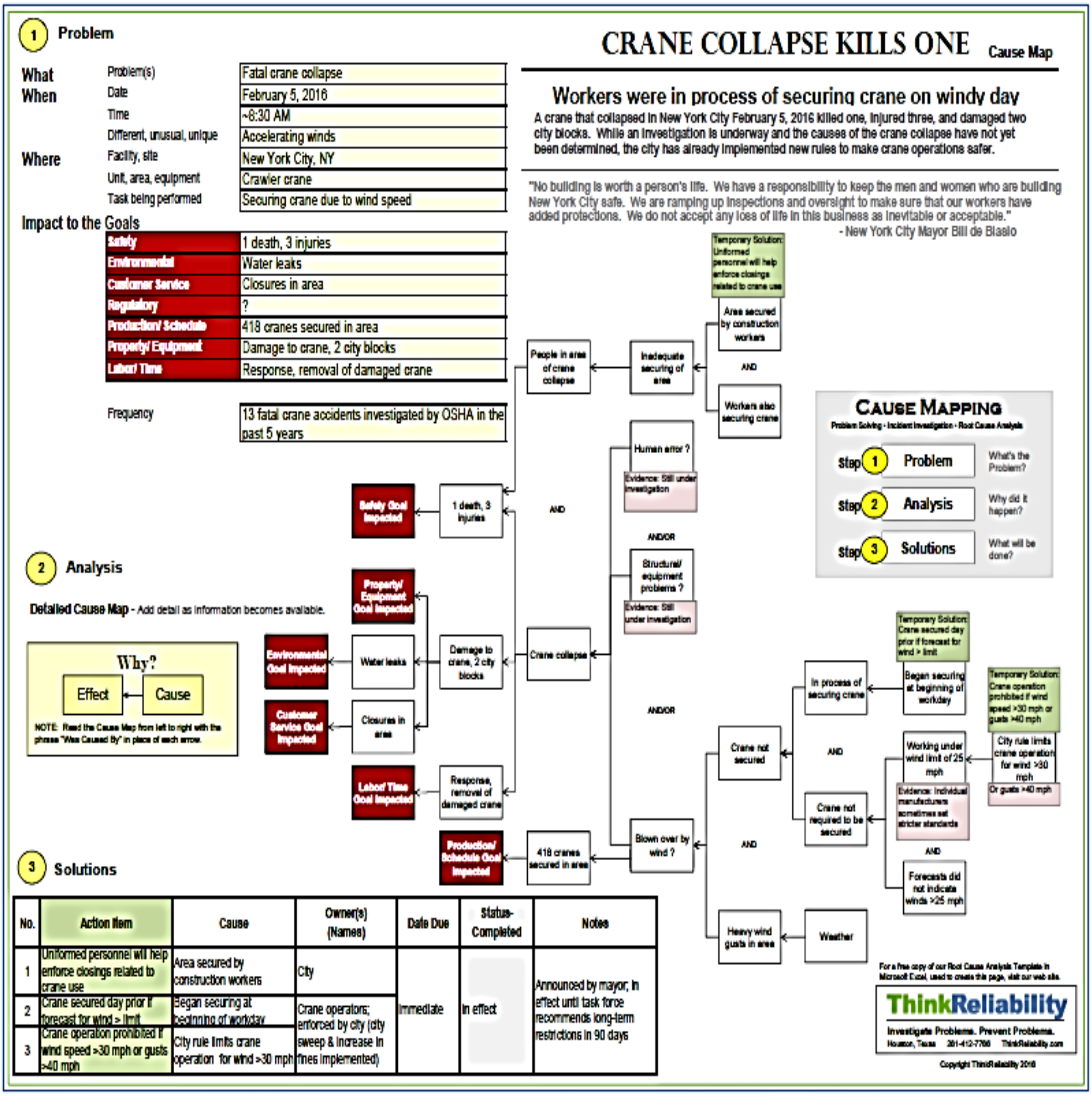


Figure 4.5 The cause map of the tower crane accident in New York City

4.4.2 Construction Site in Canada

Figure 4.6 shows the process of investigation of workplace accidents involving evidence, analyzing evidence and report preparation for further action. In the early stages, the specific preparation needs to be done to determine the scope of the investigation. This determination is needed to determine the factors that influence the accident such as the resources required to obtain preliminary information, tools and security investigations, investigations expectations will be obtained and the behavior that should be highlighted during the investigation. Next, a visit to the site of the incident was carried out to see what had happened. This includes the initial steps to be taken to control the circumstances of the accident. By doing interviews, preliminary information can be obtained and the scope of the investigation may be reduced. Once the informations obtained, the testing of physical evidence can be done and the evidence analysis can be carried out. Finally, a detailed report should be made to further strengthen the evidence derived from investigations conducted. After that, the next action can be taken to solve the case.

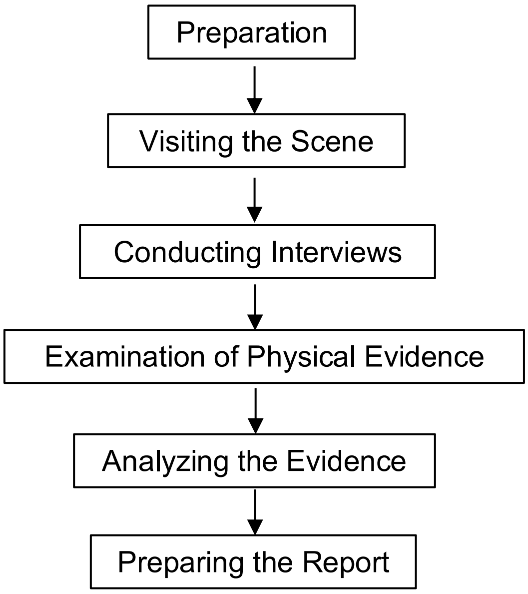


Figure 4.6 Incident investigation guide in the workplace
Source: Workplace Safety and Health Committee, 2003

4.4.3 Netherlands

According to a study conducted by Swuste (2013), available methods of investigation conducted by the "Dutch Safety Board (2013)" is almost similar to the method of investigation conducted in other countries. Figure 4.7 is a flow chart of the process of investigation and it started with the process of gathering information from interviews conducted at the site. This process should be done by the investigators to obtain preliminary information which is an important source for gathering all the evidence involved with the incident. Among the methods of information collection is usually done with the interview. Next, the interview result is divided into two parts, design and technical of the crane. In the design of the crane section, the stakeholder analysis is carried out, while under the technical section covers several types of operating parameters such as the use of excessive operation parameters, weakness on the construction site and excessive loading jib. Finally, a report was made to be assessed and the next actions taken for improvement in the future.

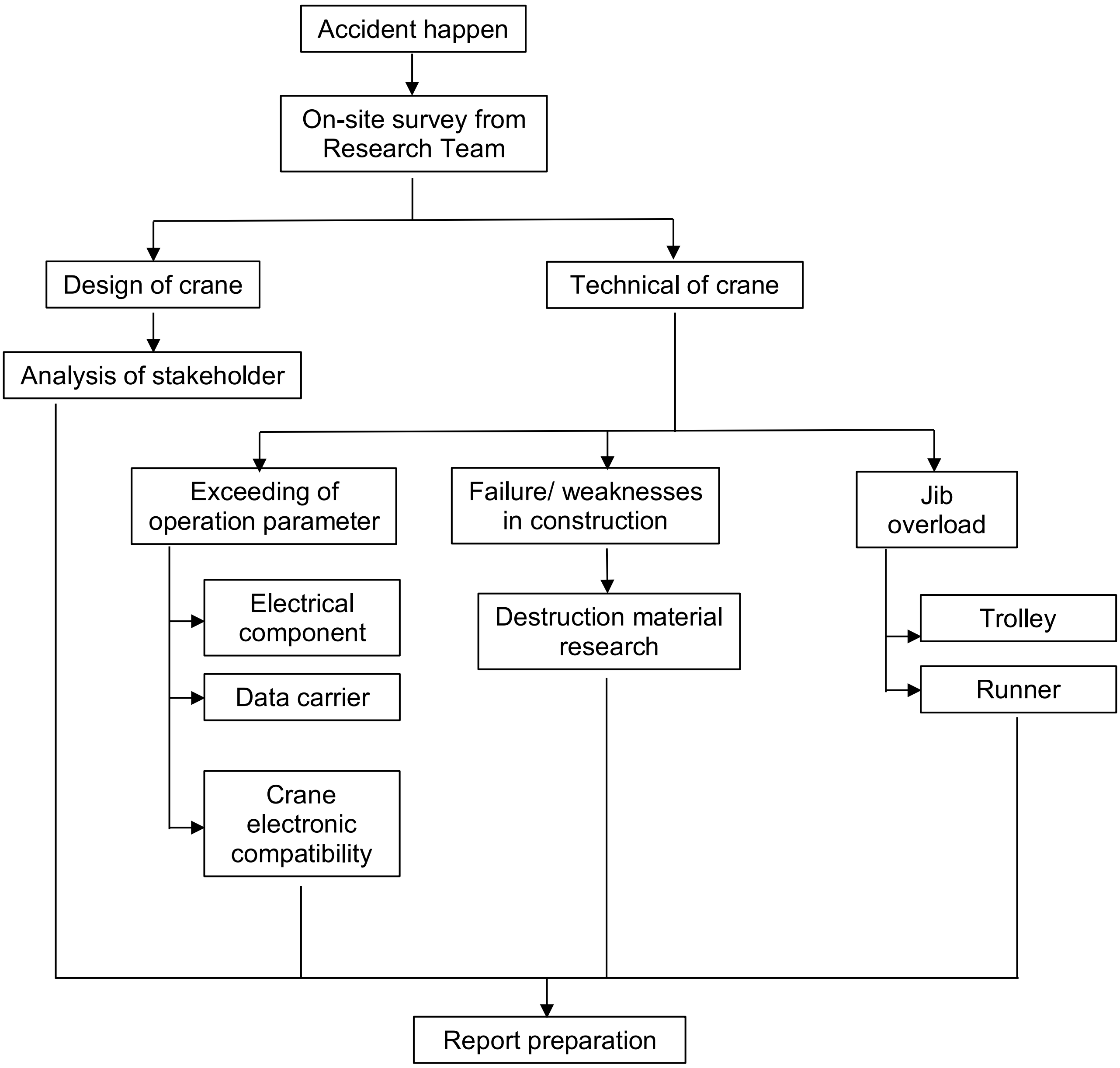


Figure 4.7 The crane accident investigation process by the Dutch Safety Board

Source: Swuste (2013)

4.5 Examples of Accidents Involving Tower Cranes in 2016

At the start of this Tower Crane Project by UKM Consultancy on 1 April 2016, there were 7 crane accidents. Two types of tower cranes were involved in these examples of accident cases, namely luffing and hammerhead cranes; and the accidents resulted in the injury/death of crane operators, construction site workers and the general public.

4.5.1 Bangsar, Kuala Lumpur (8 April 2016)

The incident occurred on 8 April 2016 at the construction site at Lot 422, Jalan Bangsar, Section 96, Kuala Lumpur. This project is owned by Etiqa Insurance Berhad. At approximately 11:50 a.m., the crane from the construction site next to Dataran Maybank toppled over, where the tip of the crane fell onto the Dataran Maybank highway. No casualties were reported. However, a lorry parked by the roadside was slightly damaged. There was no damage to the Dataran Maybank building. Maybank and Etiqa are operating as usual. The cause of the crane accident is still under investigation.

The Favelle Favco luffing crane was built in 1994. According to the logbook, this crane was first used at the site soon after it was given the approval in November 2015. According to the evidence given by the Site Manager, the operator was handling this crane. The crane was lifting iron brackets weighing 1.5 tonnes. As the jib was being raised to an angle of 82 degrees (based on the meter reading), it toppled over in the opposite direction (Figure 4.8(a)) and the tip of the jib fell onto to the adjacent road, causing damage to a lorry (Figure 4.8(b)). While the crane was in operation, a guard was also directing from below to ensure that there were no problems with the load. The operator mentioned that he heard a sound but still continued to operate the crane before it toppled in the opposite direction. During the visit to the site, the crane had been dismantled (Figure 4.9) with the permission of DOSH Kuala Lumpur because it was obstructing traffic on the outside. The investigation into the cause of the accident is still on-going.

Figure 4.8 Situation of tower crane accident in Bangsar

Figure 4.9 Frame of the crane that was dismantled at the construction site

4.5.2 Kuala Lumpur (16 April 2016)

A worker fell to his death from the 23rd floor when carrying out work to assemble an i-beam to the collar of the no. 3 tower crane at level 23. A Notice of Prohibition (NOP) was issued with regard to the operation of the tower crane. The cause is expected due to the negligence of workers in respect of safe work practices in the workplace during erection/extending/dismantling of tower cranes. The investigation on the cause of the accident is still ongoing.

4.5.3 Jelatek, Selangor (29 June 2016)

The initial hypothesis of DOSH is that the starter bar may have caught onto the column pile cap (iron around the bucket), as shown in Figure 4.10. According to witnesses, the crane boom gave way and fell. In the incident, the crane operator was lifting a bucket from the reservoir after soaking it to remove residual concrete in the bucket, when suddenly the boom experienced failure, where several trusses in the upper working arm broke. Next, the boom underwent free fall and hit the mast structure. The mast structure and the bottom working arm were bent, but no injuries and fatalities were reported in this accident. The investigation into the cause of the accident is still on-going.

Figure 4.10 Failure of crane in Jelatek (a) The broken crane, (b) used bucket stuck on crag

4.5.4 Johor Bahru, Johor (24 July 2016)

The crane swayed drastically and the front boom snapped before the counter jib of the crane fell. The tower crane collapsed and got stuck on the 13th floor, as shown in Figure 4.11. The crane operator escaped with light injuries. He said the incident occurred when he was lowering sand from the 13th floor to the 10th floor. As he was lowering the sand, the crane swayed heavily and the front boom snapped before the counter jib of the crane fell, causing the crane to topple over and to get caught on the 13th floor (news report).

On the day of the incident, the tower crane was transporting sand from the ground level to the 10th floor using a bucket, with a capacity of approximately 1m^3. When the load was at a height equivalent to level 5 and the trolley was positioned in the middle of the jib, the crane suddenly experienced failure. This failure caused the jib to twist backwards and the counter weight to fall to the ground. The operator suffered minor injuries when he hit against the cabin wall. According to the preliminary investigation and based on the circumstantial evidence, the accident was probably caused by the bucket being caught on the scaffolding, as:

- There were parts of the scaffolding that were damaged, and this scaffolding was located in the path of work that was going on to unload goods;
- The jib of the hammer head tower crane can only twist backwards if there is a force pushing the jib from below. This will only occur when the hoist ropes are snagged.

Figure 4.11 The snapped crane happen at Johor (2016)

4.5.5 Cheras, Kuala Lumpur (10 August 2016)

In this accident, the boom of the crane bent (Figure 4.12), but there were no fatalities. The used crane was purchased in Malaysia (repaired and serviced), and the mast structure, boom, slewing cable, swing ring, motor (original model) were first assembled at the site in January 2015. In the first test by DOSH in 1998, a load of 2100 kg was tested at 45 metres (radius). There were 2 operators (1 on standby) provided by the supply company. The operators had been trained at IKBN in Chembung (luffing crane course) and were operating a hammerhead crane. The operators had approximately one year of experience. The accident occurred when a load of iron weighing 900 kg was being lifted at a radial angle of 40 degrees (trolley positioned at 30-40 meters). Suddenly, the boom snapped and the load fell to the top floor of the building. The distance of the load from the floor was 4 feet. The maximum load was 3000 kg. The investigation into the cause of the accident is still on-going.

Suspected causes:

- The pin at the boom was broken/loose (pin was not found).
- Overloading (mistake by the signalman/rigger from the timber section, Indonesian, working for 8 months) and communication by way of walkie-talkie. The crane had also not been fixed with a load indicator.

The boom and the trolley of the crane were serviced every month. The last date on which the crane was reviewed by a competent firm was on 26 July 2016. The last service on 8 August 2016 was carried out on the following components/parts:

- Hoist speed
- Ability to slow down crane movement
- Estimate weight load
- Detect faulty crane operation
- Mast
- Cat head
- Counter jib
- Trolley

Figure 4.12 Bent crane boom

4.5.6 Kuala Lumpur (2016)

The crane that was involved in the accident was a luffing crane (Figure 4.13). Two connection pins between the counter jib platform and the slew table had snapped. This caused the counter jib platform to be disconnected or detached from the connection and to fall from its original position. However, it still remained connected to the part because there were two (2) other connection pins holding the structure of the counter jib platform together. The counter jib platform was dislodged and fell, dragging the 'A' frame structure and the boom of the crane backwards (in the direction of the counter jib). This caused overluffing in the crane boom, and the counterweight dropped to the construction floor. There were no injuries or fatalities in this accident.

(a) (b)

Figure 4.13 Failure of tower crane in Kuala Lumpur 2016 (a) Overluffing crane and (b) broken connection pin (http://www.dosh.gov.my)

4.5.7 Bukit Bintang, Kuala Lumpur (25 August 2016)

The crane model involved was a luffing STL230 model made in China. The iron hanger of the crane, which weighed more than 300 kg, fell onto the roof of a building (a height of more than 100 metres) and smashed into a car, causing the death of a woman (aged 24 years) (Figure 4.14). Bystanders claimed that they saw the iron hanger that was lifting a load snap, before falling and smashing into the victim’s car. The position of the crane was also in violation of the rules of safety as it was operating beyond the radius of the fence at the construction site. The crane operator and the signalman could not be traced. The accident may have been caused by the pass at the lifting limiter, which lowered/raised the hook, causing the hook to be raised until it broke off at the tip of the boom, and caused the wire rope to snap. The cause of the accident is still being investigated. The case is being investigated under Section 304A of the Penal Code for causing death by negligence. The parties involved can be prosecuted under the Occupational Safety and Health Act 1994, and the Factories and Machinery Act 1967, which allows for a prison sentence of 2 years or a fine of up to RM250,000 or both (source: Mingguan Malaysia, 28 August 2016, and Metro, 26 August 2016).

(a) (b)

Figure 4.14 Failure of tower crane in Bukit Bintang (a) Luffing crane STL230 model, (b) Iron hanger of crane which smashed into the vehicle

4.5.8 Petaling Jaya, Selangor (19 April 2017)

The tower crane model that was involved was a hammerhead crane manufactured in 1997 in Italy. The incident occurred at approximately 8.00-9.00 p.m. at the construction site of the Prasarana Tower at Jalan PJU 1A/46, off Jalan Lapangan Terbang Subang, Petaling Jaya, Selangor. The tower crane concerned toppled over while lifting a cement bucket at the 10th floor (Figure 4.16). The operator was a Malaysian citizen with a valid licence. Before the incident, the operator informed the site management (3 days before the incident) that he heard a 'ping' sound like something breaking. The initial cause was identified as a broken joint between the mast sections of the crane. This caused the mast to topple over, and to bend (at the second last mast before the slewing table), and then, to crush onto the floor of the building. The operator only sustained light injuries. There were no fatalities. The case is being investigated by DOSH

4.6 Earlier Case Studies of Accidents

Several studies were conducted previously by DOSH in collaboration with the Faculty of Engineering and Built Environment, UKM to examine and identify the causes of tower crane accidents. Through careful study and with the aid of computer simulations, the factors that caused these accidents could be determined and verified. Examples of such accident cases were (i) the crane accident in Kelana Jaya, Selangor, (ii) the hammerhead crane accident in Johor Bahru, and (iii) the cracked mast of the tower crane at Educity, Nusa Jaya.

4.6.1 Crane Accident Case in Kelana Jaya, Selangor

This accident involved a luffing crane that was operating in a residential high-rise building that was under construction in Kelana Jaya, Selangor on 27 April 2011, at 3.00 p.m. When the accident happened, the crane was not lifting any load. Figure 4.15 (a) shows the condition of the crane after the accident occurred, while Figure 4.15 (b) shows the same type of luffing crane under normal conditions. Checks at the site of the accident revealed that the 'A' frame and counter jig pendant had been severely damaged. Tests and analyses were carried out (Figure 4.16), and these were divided into four main stages, namely:

(a) Inspection of the components involved in the accident at the site

(b) Research into the failure and cracking of the components

(c) Lab tests

- Material composition test
- Microstructural observation
- Material performance test

(d) Analysis by Finite Element Method (FEM)

(a) (b)

Figure 4.15 (a) Crane that experienced failure, and (b) position of ‘A’ frame and counter jib pendant in normal state

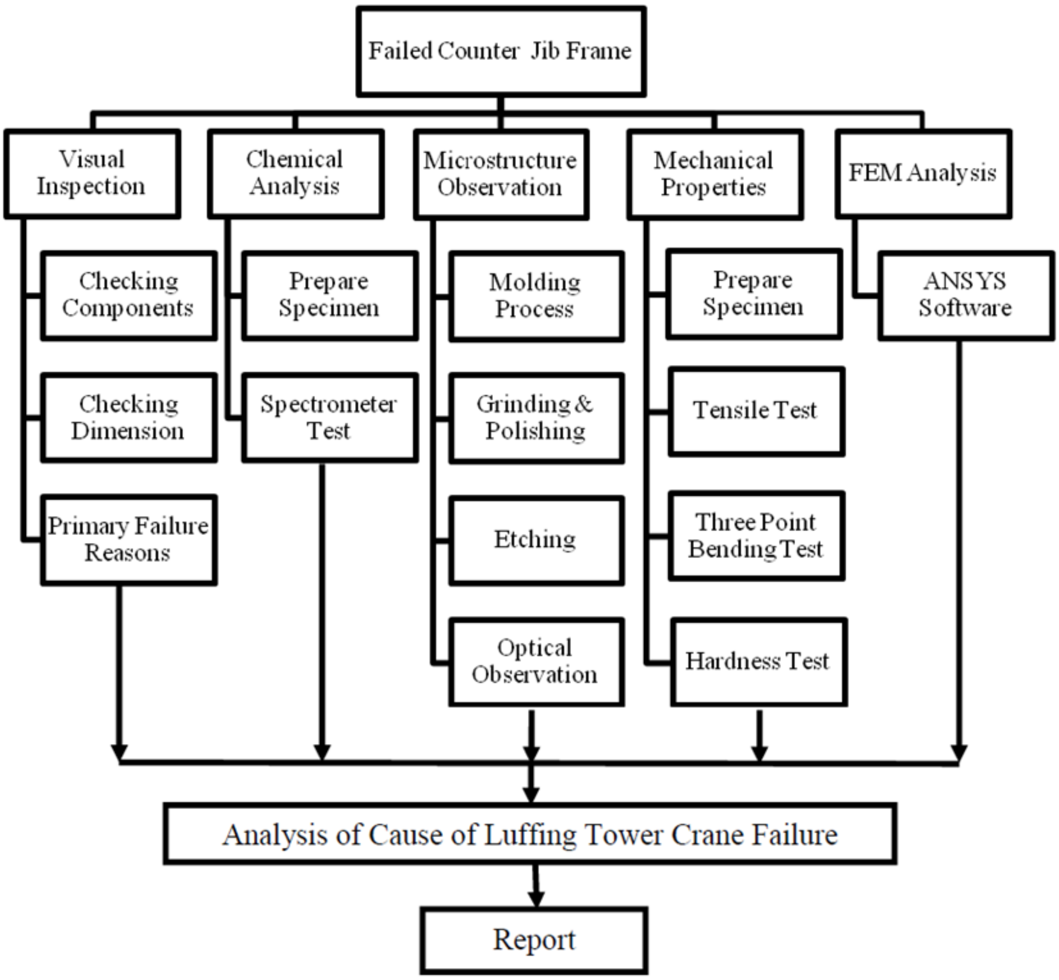


Figure 4.16 Flowchart of test for tower crane components

Based on the observations, it was found that there were severe cracks in the bent section of the counter jib frame. This was an indication that the welding that was done on that section had affected the structural strength of the frame. This is because the part that had been welded was fragile and was most vulnerable to rust. As for the damage to the counter jib pendant, it was probably due to overloading after the counter jib frame failed to function. Overloading at the pendant caused it to crack and fracture. Normally, the part that is the first to experience damage is the weakest part of the structure.

4.6.2 Hammerhead Tower Crane Accident in Johor Bahru

The second case was an accident involving the failure of a hammerhead tower crane (see the schematic diagram in Figure 4.17), which was operating at a construction site in Johor Bahru on 21 November 2011 at 4:45 p.m. In that incident, the centre part of the tower crane jib (jib bottom) was said to have bent and fallen slowly when lifting a load of approximately 2 tonnes.

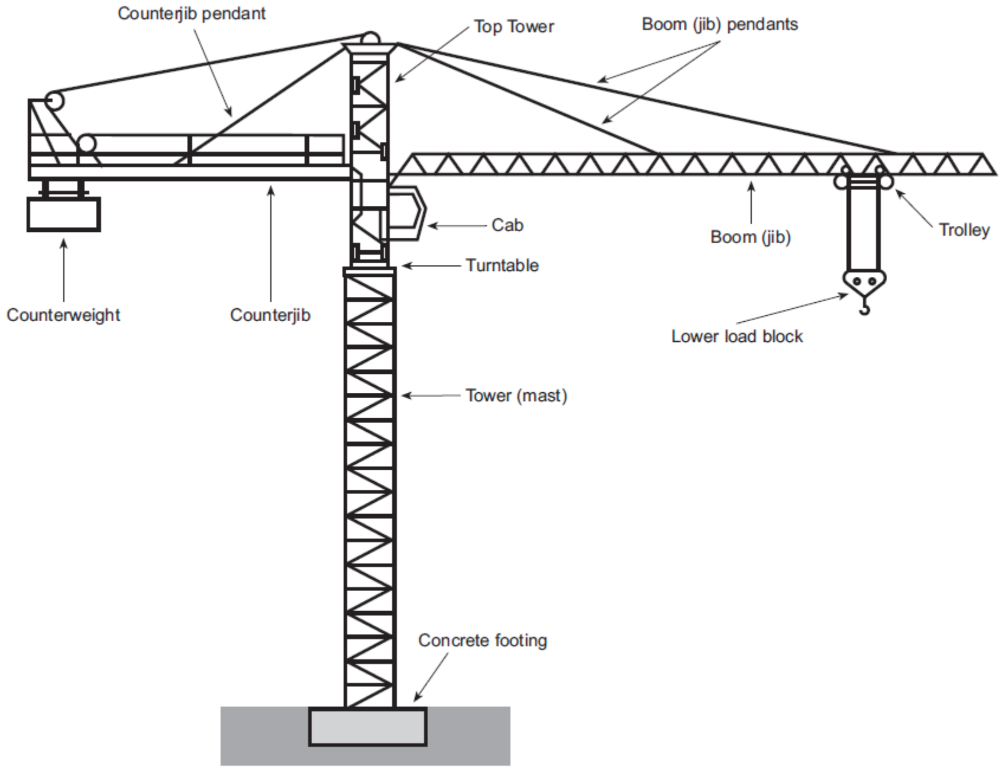


Figure 4.17 Schematic diagram of hammerhead tower crane (Neitzel et al., 2001)

The following tests and analyses were carried out in the laboratory on those components/structures that experienced failure:

- Analysis of the chemical composition;
- Analysis of the microstructure;
- Mechanical tests including tensile tests, bending tests and hardness tests;
- Failure analysis.

The results of the tests and analyses showed that there was a difference in the properties of the material taken from the perfect jib structure (not bent) and the material from the bent and rusted jib structure This showed that the material/structure used when installing the tower crane was different, thereby giving a different structural strength. The different material/composition had a high potential of contributing to the failure of the hammerhead tower crane that was involved in the accident.

4.6.3 Cracked Tower Crane Mast at Educity, Nusa Jaya

The third case study involved a crane used by Nusa Jaya Sdn. Bhd. for the construction of high-rise buildings, where cracks were discovered in the mast supporting the crane (Figure 4.18) prior to the accident. The component that experienced the cracks was analysed and a simulation was performed to obtain a true picture of what happened and why.

The results of the preliminary analysis from the tests and simulation that were carried out revealed that:

- The steel that was used was carbon steel, which contains manganese and has a composition that is similar to that of standard AISI 1524 steel or SAW HSLA 950C steel. The hardness test also showed that the hardness of the steel used was almost the same as that of the standard material.
- Steel has a typical carbon steel microstructure, namely ferrite and pearlite. Its ultimate yield strength and tensile strength are also in accordance with the standard mechanical properties of materials. The observation of the cracked surface indicated that ductile fractures occurred in the steel, even though the cracked surface had undergone corrosion.
- The stress analysis using the finite element method indicated that the mast underwent cyclic stress due to the rotation of the boom and the load that was lifted by the crane. Therefore, the cracks that occurred on the mast were due to cyclic stresses that exceeded the ultimate yield strength and tensile strength of the steel that was used.
- The stress analysis for the hollow steel reinforced with a supporting plate showed that the stress was highest (344 MPa) on the lower surface of the steel. The connection between the plate and the steel also showed a high stress of 330 MPa.

Figure 4.18 Hollow steel crane buffer

4.7 Summary

A detailed accident investigation provides a better understanding of the tower crane behaviour and also to indicate the need for additional research on the current safety use of the tower crane operation. The construction industries should always be reminded on the importance to conduct a tower crane inspection by any competent and qualified personnels. The search for cause or crane accident factors can be done through several approaches, such as Ishikawa fish bone diagram, problem solving analysis and failure analysis. In addition, the relevant tests on the failure area (broken/fractured surfaced) is important for ensuring the cause and effects of damage mechanisms of the tower crane materials and structures. Finally, the experiments in the laboratory are needed to determine the chemical composition of materials, microstructural analysis on the crane materials (also at the failure area) and mechanical testing (tensile tests, bending tests and hardness tests).

CHAPTER 5

FAULT TREE ANALYSIS

5.1 Introduction

A fault tree analysis is carried out after taking into account the findings of each process in the life cycle of the tower crane, starting from the importation/purchase, design approval and licensing, installation/dismantling, operation, inspection, maintenance and storage. Every process in the life cycle of the tower crane contributes in a different way to failures and accidents. There are five key elements that contribute to crane failures and accidents, namely the i) human element, ii) machine element, iii) medium element, iv) management element, and v) mission element. The details of each element are presented in Figure 5.1.

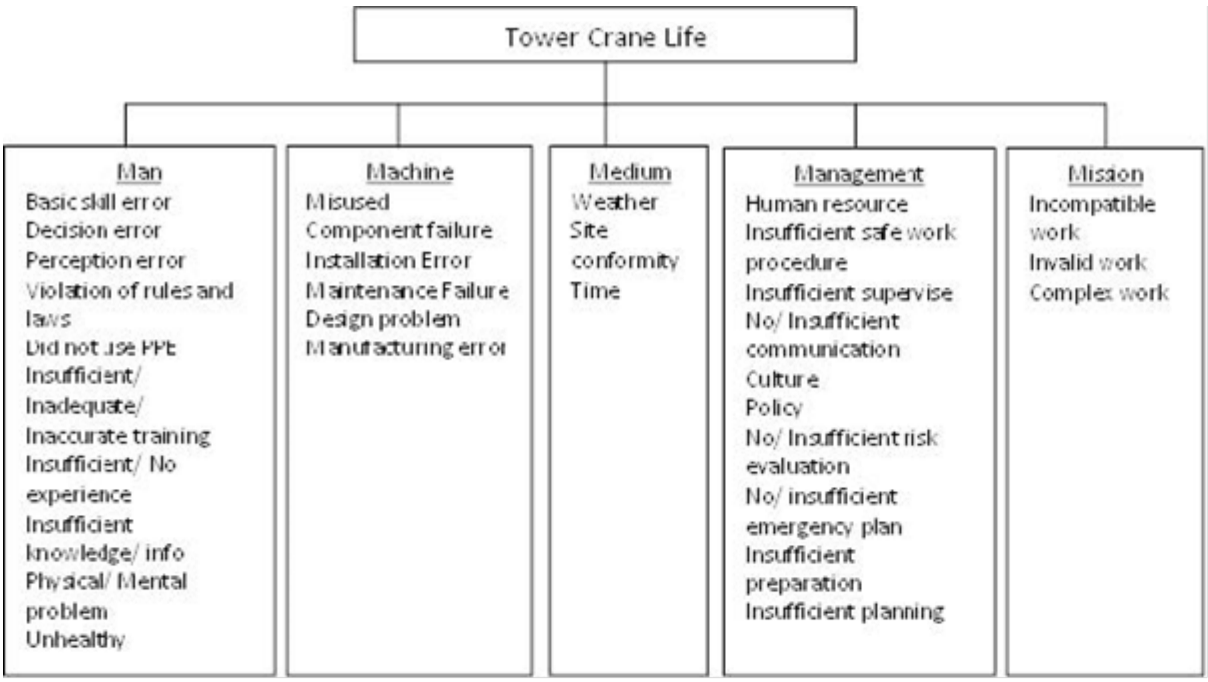


Figure 5.1 Fault tree analysis of the life of a tower crane

The human element and the management element are the largest contributors to tower crane failures and accidents. This can be seen from the number of sub-elements under the human element and management element. From here, it can be gathered that the machine, medium and mission elements do not have a great impact on crane failure, despite the fact that all failures can be physically observed on the structure and components of the crane itself.

5.2 Current Industrial Situation in Relation to the Overall Tower Crane Process/Chain

The case of an accident involving the lifting gear which fell onto a passing vehicle outside the construction area near Jalan Raja Chulan, Kuala Lumpur on 24 August and caused the death of the driver at the scene received wide coverage in the print and electronic media. Many parties, including members of the public, building contractors, NGOs as well as the authorities provided feedback and opinions regarding the cause of the accident. The police are investigating the incident under Section 304A of the Penal Code for causing death by negligence. Even though the case is still being investigated by the police, local authorities, and the Department of Occupational Safety and Health (DOSH) itself, this case presents several chronological chains of events, all of which reveal how each process in the tower crane chain had the potential to contribute to this tragic accident. The above case is one among several cases of tower crane accidents that have occurred in Malaysia over the last 6 months in 2016.

Among the factors that were observed to have contributed to the accident were:

(i) The crane operator was a foreigner
(ii) The crane operator did not have a valid licence to operate a tower crane
(iii) The crane operator was not competent and did not have the skill to handle a crane
(iv) The signalman was not competent and had no training
(v) The signalman who had been appointed was a foreigner
(vi) The management of the construction company employed foreigners illegally
(vii) The management of the company had broken the rules regarding the operation of tower cranes
(viii) The management of the construction company failed to trace the crane operator after the incident occurred

(ix) The management of the company had been negligent

(x) The limiting device was not functioning

(xi) The crane components were not according to specifications

Many weaknesses can be detected in the safety management system for cranes in the construction sector. It can be seen that this industry has no problems in obtaining tower cranes, especially from abroad. However, there are weaknesses in the procurement process when there are no legislations and/or regulations that can be used to prevent poor quality or used tower cranes from being brought into Malaysia. The issuing of the design approval and the Hoisting Machine Permit (*Perakuan Mesin Angkat*, PMA) should be tightened so as to improve the design, quality and safety of the tower cranes that are brought into Malaysia. It has also been seen that there are many shortcomings with regard to crane operations, especially in terms of the enforcement of the regulations concerning competent and valid crane operators and signalmen. The management of construction companies should play a big role in ensuring that procedures are complied with and that the workplace is safe and healthy for the workers.

It is believed that these weaknesses can be corrected if Malaysia has a code of practice and guidelines, especially for the safe use of cranes and matters related to the development, training and management of personnel involved in the tower crane chain as a whole, as is the practice in Australia, Singapore, Hong Kong, the United Kingdom, Germany and many other countries.

5.3 Summary

The life-chain of the tower crane study can be refined to produce a better management system, hence, to lead a vital step towards the reduction in tower crane accident in Malaysia.

Every process in the life cycle of the tower crane may contribute to failures and accidents, and the preventive measure is very important to be taken. Thus, a method of a fault tree analysis is important for identifying the life cycle of the tower crane, starting from the importation/purchase, design approval and licensing, installation/dismantling, operation, inspection, maintenance and storage. In order to improve the design, quality and safety of the tower cranes that are brought into Malaysia, the issuing of the design approval and the Hoisting Machine Permit (*Perakuan Mesin Angkat*, PMA) should be tightened.

ANNEX

Details of tower crane accidents in Malaysia

Tahun	Lokasi Kejadian	Jenis Kren	Butir kemalangan	Kecederaan/ Maut
7-Nov-02	Kuala Lumpur	Luffing	Bum kren *luffing* jatuh, bum dijangka alami kelesuan logam. Tiada kemalangan jiwa berlaku.	
20-Dis-03	Selangor		Tali dawai mengangkat kren menara putus.	Pekerja - 1 cedera, 1 maut
26-Nov-05	Kuala Lumpur	Luffing	Kren tumbang, akibat kegagalan *hoisting* semasa mengangkat beban, dan beban tersangkut. Operator cuba untuk naikkan beban tetapi gagal menyebabkan kren condong ke hadapan.	Pekerja - 3 maut, Operator - 1 maut
20-Dis-06	Pulau Pinang		Bahagian atas kren tecabut dan terjunam 40 meter ke tanah dari mast kren. Tiada kemalangan jiwa berlaku.	
30-Okt-08	Projek Pembinaan 1 Blok 18 tingkat Bangunan Persiaran Surian, Persiaran Surian, Sek 39, Mukim Petaling Jaya, Selangor	Luffing (MK140)	*Bucket* berisi konkrit dan bum jatuh ketika kren sedang dalam aktiviti penuangan tiang konkrit di tingkat 2 bangunan berkenaan. *Luffing rope* putus kerana telah mengalami lelasan akibat wujud pergerakan relatif di antara *strand* lapisan luar dan dalam. *Erection pendant* juga putus. Bum kren telah patah dan tersangkut pada bahagian *slew mount*.	Pekerja - 1 maut, Operator - 1 cedera
28-Jan-08	Projek pembinaan bangunan MRCB, Selangor	Luffing	Sebuah *luffing* kren telah tumbang ketika kerja mengangkat dilakukan. Kemalangan disebabkan kegagalan pada *luffing wire rope* kerana tersangkut *(jagged)* pada takal. Tiada kemalangan jiwa berlaku.	
3-Feb-09	Kuala Lumpur	Hammerhead model STL 200 (TC-3) Luffing model STL 230 (TC-4)	Melibatkan 2 buah kren menara iaitu *hammerhead* dan *luffing*. Kedua-dua kren beroperasi tidak jauh antara satu sama lain. *Counterjib* kren *hammerhead* telah melanggar dan menarik *tie rod* kren *luffing* sehingga	

			patah dan bengkok. Penyiasatan mendapati pelanggaran antara dua kren menara berlaku kerana kegagalan pihak majikan mengambilkira perancangan, pengurusan dan kawalan trafik operasi kren menara. Tiada kemalangan jiwa berlaku.	
8-Mar-09	Jalan Bangsar Utama, Kuala Lumpur		Dua pekerja binaan, kedua-dua warga asing, terbunuh selepas sebuah kren yang membawa bahan binaan di tingkat 22 bangunan (hampir 50% siap) jatuh ke atas mereka apabila tali dawai *hosting* yang tiba-tiba terputus.	Pekerja -2 maut
4-Sep-09	Selangor		Sebuah kren menara patah semasa beroperasi. JKKP selangor memerlukan bantuan BKF untuk tujuan ujian bahan ke atas struktur kren. Tiada kemalangan jiwa berlaku.	
17-Mac-09	Lot 20196, Mukim Sungai Buluh, Daerah Petaling, Tapak Pembinaaan SS2 Petaling Jaya, Selangor	Luffing	Kren *luffing* tumbang dan menghempap seorang pekerja.	Pekerja - 1 maut
2010	Selangor		Kejadian berbahaya. Tiada kemalangan jiwa berlaku.	
21-Nov-11	Taman Setia Tropika, Mukim Tebrau, Johor	Hammerhead (FO/23B)	Bum kren telah bengkok pada jarak lebih kurang 20 meter ketika sedang mengangkat beban besi rebar berkapisiti 2 tan. Setelah beban diangkat 3-5 meter dari aras tanah, troli ditarik 25-30 meter, bum kren telah bengkok ke bawah dan turun perlahan-lahan menuju ke kabin. Pemeriksaan tapak mendapati kegagalan berlaku pada salah satu bahagian bum. Dapatan ujian kegagalan disebabkan oleh bahan substandard pad jib no.3 Analisa komposisi kimia menjelaskan dapatan ini. Tiada kemalangan jiwa berlaku.	
29-Oct-11	Tangawaris Sdn Bhd Cadangan Pembinaan		Berlaku keretakan pada *mast* kren menara. *Mast*	

	Hostel Pelajar 12 Tingkat, Nusajaya, Johor		adalah *hollow section* dan *crack* pada *horizontal.*	
23-Mei-11	Tapak Pembinaan Bukit Tunku, Mukim Batu, Kuala Lumpur	Luffing (MK140)	Bum kren menara *luffing* jatuh secara mengejut. Ketika kejadian dua mangsa tersebut sedang berada di bawah kren tersebut. Akibat daripada kejadian itu, kedua-dua mangsa telah meninggal dunia ditempat kejadian kerana mengalami kecederaan parah di kepala. Kedudukan *luffing winch* beralih akibat daya sentapan *luffing rope*. Kecacatan pada system *luffing (winch, motor, gear, brake)* menyebabkan tekanan berlebihan pada *luffing wire rope* sehingga tali dawai (*wire rope)* putus menyebabkan bum jatuh.	Pekerja -2 maut
6-Feb-11	Kuala Lumpur	Luffing	Kemalangan maut	Pekerja -2 maut
27-Apr-11	Projek Pembinaan Komplek Perdagangan 2 Blok Menara Pejabat Petaling Jaya, Selangor	Luffing	Sebuah kren menara *luffing* telah terlibat dengan kejadian berbahaya dan bum patah. Tiada kemalangan jiwa berlaku.	
5-Jul-11	Armani Terrace 2, Damansara Perdana, Selangor	Hammerhead (Model FO/23B)	Ketika operator mengangkat cermin sehingga ketinggian 2 kaki dari atas lori, telah berlaku beban melampau *(overload).* Suis pengehad beban melampau telah diaktifkan dan operasi kren didapati tidak berfungsi *(functional trip)* dan kerja mengangkat cermin tidak dapat dilakukan dan cermin tergantung. Setelah *overload limit switch* teraktif, operator kren cuba melakukan *reset* ke atas sistem pengoperasian kren menara, dan pada ketika ini dengan tiba-tiba *slewing table* dan bum tercabut lalu jatuh dan tersangkut di tingkat 33 bangunan. *Counterweight* kren menara juga turut jatuh.	Operator - 1 cedera

4-Okt-11	Cadangan mendirikan 1 Blok 20 tingkat hotel (200 bilik) dengan 7 paras letak kereta di atas lot 837, 838, 839, 844 dan 845, Seksyen 14 DTL, Jalan Transfer Gerrgetown, Pulau Pinang	Hammerhead Potain (H-25/14)	Mangsa yang merupakan orang awam maut dihempap kren menara. Mangsa yang ketika itu sedang tidur, maut di tempat kejadian apabila kren menara yang dalam keadaan *free standing* tiba-tiba tumbang menghempap rumah kedai yang didiami mangsa.	Orang awam - 3 cedera, 1 maut
2012	Johor		Kabin kren terbakar semasa pemeriksaan. Tiada kemalangan jiwa berlaku.	
14-Apr-12	Cadangan Pembangunan 3 Blok Pangsapuri, Seksyen 89, Jalan Madge, Kuala Lumpur	Luffing (MK140)	Kren tumbang - *Pile Cap (foundation)* kren tercabut dari permukaan tanah. Kren tumbang ketika mengangkat beban dan menghempap struktur dalam bangunan.	Operator - 1 cedera
10-Feb-12	Kuala Lumpur		Kren tumbang – kegagalan pada asas tapak *(counterweight fell off).* Tiada kemalangan jiwa berlaku.	
Jan. 12	Projek Pembinaan Cadangan Kompleks Perniagaan Jalan Teknokrat Cyberjaya, Selangor	Luffing	*Luffing pulley* pecah menyebabkan *wire rope* putus. Kejadian berbahaya. Tiada kemalangan jiwa berlaku.	
2012	Selangor		Kejadian berbahaya. Tiada kemalangan jiwa berlaku.	
2013	Johor		Terkena kejutan selepas petir menyambar kren.	Operator - 1 cedera
Ogos.13	Lot 44, Sekyen 44, Jalan Sultan Ismail, Kuala Lumpur		Kemalangan berlaku semasa kerja-kerja *jacking* kren menara dari tingkat 4 ke tingkat 7 dengan menggunakan *internal climbing.*	
6-Jul-13	Prinsiptik Sdn Bgd, Taman Tasik Prima, Puchong, Selangor	Luffing (BN80.8)	Kren *luffing* tumbang ketika mengangkat besi BRC. Ketika beban diangkat naik bum kren jatuh secara perlahan-lahan. Beban yang diangkat dianggar 1 tan, dan kedudukan beban adalah melebihi jarak maksimum bum yang dibenarkan (50 m). Jarak beban pada bum antara 52 m ke 53 m. Semasa kejadian, bahagian *counterweight jib* terangkat	

			dan mengalami kegagalan. Bum telah patah pada bahagian hadapan akibat hentakan pada *slab*. Tiada kemalangan jiwa berlaku.	
23-Sep-13	BUCG (M) Sdn Bhd, Jalan SS 22/43 Mukim Sungai Buloh, Petaling, Selangor	Luffing (BN80.8)	Sebelum kejadian, kren menjalani pengubahsuain pengukuhan pada bahagian *counter jib*. Bum bengkok dan patah dua, *hoisting* dan *pendant rope* putus dan *counterweight* jatuh ke bawah. Berat beban semasa angkatan adalah 200 kg sebelum bum kren patah. Pin penyambung antara jib tidak dipasang dengan betul dengan *cotter pin*. Beban maksimum kren (bum) 1.2 tan pada jarak 50 m. Tiada kemalangan jiwa berlaku.	
1-Jun-13	Jasmurni Construction Sdn Bhd, Persiaran Pinggiran Putra, Bandar Putra Permai, Mukim Petaling, Selangor	Hammerhead	Kemalangan berlaku sewaktu hari cuti umum (sepatutnya tiada kerja pada hari tersebut). Sub-kontraktor pekerja besi menggunakan kren tanpa kebenaran pemilik untuk mengalihkan besi. Operator kren adalah tidak berdaftar/sah. Pekerja melarikan diri selepas kemalangan. Kren mengangkat beban melebihi had yang dibenarkan. Beban melampau berlaku pada bum. Bum patah, titik engsel dan tiang *mast* (pemberat *counter jib)* menghentam bahagian *mast*. Kemalangan diklasifikasikan sebagai *misuse*.	Operator - 1 cedera
15-Jul-13	Cadangan membina 1 Blok Pangsapuri Setinggi 24 tingkat Bandar Sunway, Daerah Petaling, Selangor	Hammerhead (H30/23C)	Kren menara mengalami kegagalan pada bahagian bum semasa mengangkat beban (tong sampah industri) dengan berat muatannya tidak diketahui. Bum bengkok dan patah menyebabkan *slab* pecah akibat hentakan dari bum dan *wire rope*. Pengaratan terdapat pada bahagian bum terutamanya pada	

			bahagian troli. Bum bengkok dan patah pada bahagian penghujung bum (jib no.2 dan no.3). Tiada kemalangan jiwa berlaku.	
2014	Johor		Retak tulang pinggang akibat jatuh tergelincir semasa turun tangga dari kren menara.	Operator - 1 cedera
5-Mei-14	Johor		Terjatuh dari ketinggian 6 meter akibat terlanggar oleh besi yang diangkat oleh kren menara.	Pekerja - 1 maut
15-Jun-14	AST Machinery (M) Sdn Bhd, No 2, Jalan Anggerik Mokara H, 31/H Kota Kemuning, Selangor (Eng Han Bina Sdn Bhd- Projek M- City, Ampang.	Hammerhead & Luffing (TC5 : SCD 5522 TC3: SCD 6024)	Kren berada dalam keadaan *out of service* yang menyebabkan wujudnya keadaan beban melampau dan kegagalan penyambungan di struktur tapak kren. Penyambungan sedia ada tidak mampu menahan beban melampau yang dikenakan ke atas kren sehingga menyebabkan satu daripada 8 bol tertanggal daripada nutnya dan menyumbang kepada kegagalan sambungan bol yang seterusnya. Berlaku kerana keadaan *overload* ke atas bol yang mengikat *beam* (struktur tapak kren). Kegagalan saluran komunikasi antara pemunya kren, pemasang kren serta jurutera profesional telah mengakibatkan kren tidak dipasang mengikut spesifikasi, dan kren juga tidak dipasangkan dengan *wall tie.*	Operator - 1 cedera
21-Mei-14	Toffco Sdn Bhd, Lot 46387, Mukiim Petaling Bukit Jalil, Kuala Lumpur (WP/13/03/9057)	Luffing	Ujian beban kren menara gagal. *Hoisting drum* gagal berfungsi dan bebanan jatuh. *Hoisting cable* terkeluar dari dram asal. Tiada kemalangan jiwa berlaku.	
16-Apr-14	Cadangan Pembangunan Komersil Pangsapuri Ara Damansara, Sime Darby, Selangor		Seorang operator kren menara maut selepas kren runtuh di tapak bangunan tinggi di Ara Damansara. Ia kelihatan seperti bahagian atas kren tersebut tercabut dari *mast* menara, di mana	Operator - 1 maut

			lingkaran bol *slew* atau komponen lain gagal.	
Dis 2014	Persiaran Sukan Seksyen 13 Shah Alam, Selangor	Luffing	Kemalangan berlaku semasa kren menara mengangkat tetulang besi dari lori ke tapak pembinaan. Beban yang diangkat jatuh ke bawah. Tiada kemalangan jiwa berlaku.	
13-Sep-14	Pulau Pinang		Mangsa ditimpa oleh batu-bata yang jatuh dari *lifting tray*. Ketika kejadian, *lifting tray* yang bermuatan batu-bata sedang diangkat dengan menggunakan kren menara.	Pekerja - 1 maut
8-Okt-14	Projek Pembinaan Paya Bunga Square, Kuala Terengganu	Luffing	Bahan pembinaan jatuh dari cangkuk kren ketika menurunkan bahan tersebut. Tiada kemalangan jiwa berlaku.	
1-Feb-14	KK Times Square, Sabah	Hammerhead (topless)	Kren tumbang dan bum patah. Tiada kemalangan jiwa berlaku.	
26-Jun-15	Johor		Mangsa terjatuh ke bawah setelah bekas konkrit yang diangkat oleh kren menara jatuh menimpa struktur perancah tempat mangsa bekerja.	Pekerja - 1 maut
Jun. 2015	San Sin Construction Sdn Bhd, Larkin Johor		Kren yang dioperasikan tiba-tiba melurut semasa mengangkat beban. Tiada kemalangan jiwa berlaku.	
Jun. 2015	Aturan Prosma Sdn Bhd, Cadangan pembangunan pangsapuri, Larkin Johor	Luffing	Seorang pekerja maut ditimpa limpahan konkrit yang diangkut menggunakan *luffing crane* (bum melurut ke bawah). Kren mengalami kegagalan pada mekanisma *luffing hoist* menyebabkan bum jatuh.	Pekerja - 1 maut
1-Sep-15	Projek Banyan Tree, Lot 383, Seksyen 57, Jalan Conlay, Wilayah Persekutuan, Kuala Lumpur (kontraktor: BUCG (M) Sdn Bhd)	Luffing	Kren sedang menjalankan kerja mengangkat beban (*bucket*) yang berisi besi *scrap* seberat 800 kg dan membuat sedikit pusingan dari zon 1 ke zon 2. Semasa di zon 2 operator menurunkan bum sehingga sudut 40^{o} dan terdengar bunyi (*luffing limit switch)*, seterusnya didapati berlaku bengkok pada sambungan jib 1 dan 2. Operator kren	

			berhentikan operasi dan membuat pemeriksaan mendapati satu besi penahan *safety wire rope* telah tercabut dan beralih kedudukan ke kiri operator. Dapati *safety wire rope* telah tersangkut pada pin sambungan pada jib no 1 dan 2. Tiada kemalangan jiwa berlaku.	
19-Mei-15	Projek Tamara Residence, (JKKP/WP/14/03/9327), Precint 8, Lot P8, 8R4, Taman Kejiranan Parcel 8, Putrajaya	Luffing	Kabin kren menara terbakar ditapak pembinaan. Tiada kemalangan jiwa berlaku.	
10-Okt-15	Sunway Construction, Velocity Phase 2, Seksyen 90A, Jalan Peel, Kuala Lumpur	Luffing (MCR225A)	Tong konkrit yang diangkat dari aras 5 jatuh ke bawah semasa melakukan kerja konkrit *wall* di aras 14. Kejadian tersebut berlaku disebabkan *hoisting rope* putus. Kerosakan pada bum dan puli. Tiada kemalangan jiwa berlaku.	
31-Jul-15	Crest Builder Sdn Bhd, Penthouse, The Crest No 2 Jalan 19/1, Petaling Jaya, Selangor (Kejadian: Jalan Damansara, Kuala Lumpur)	Luffing	Dua tong konkrit telah jatuh ke atas tempat mengumpul pasir semasa beroperasi, dikatakan mengalami masalah pada *hoisting motor gearbox*. Seorang pekerja maut akibat dihempap oleh *bucket* berisi pasir semasa kerja mengangkat menggunakan kren menara.	Pekerja - 1 maut
26-Okt-15	BUCG (M) Sdn Bhd, 75 Jalan Raja Chulan, Kuala Lumpur	Luffing	Kejadian berlaku ketika proses mengangkat *bucket* berisi pasir seberat 1.2 tan. Mangsa ketika kejadian berada di bawah jangkauan operasi mengangkat. Secara tiba-tiba *bucket* diangkat jatuh ke bawah menghempap mangsa.	Pekerja - 1 maut
Sept. 2015	Cadangan pembangunan 3 blok pangsapuri, OUG Bukit Jalil, Putrajaya	Luffing	*Luffing jib* terjatuh apabila *wire rope* yang memegang jib tersebut putus dan menghempap pekerja di bawah.	Pekerja - 1 maut
Ogos 2015	Persiaran Bandar Utama, Sri Pentas TV3. Geopancar Sdn Bhd. Kuala Lumpur		Bum termasuk *slewing table* dan kabin terjatuh dari ketinggian 28 m. Operator kren cedera.	Operator - 1 cedera

23-Ogo-15	Cadangan pembangunan Blok *Service Apartment* 37 tingkat, Tapak bina Lot 332, 333, 591, 592, 685, 844 dan 129 Seksyen 67, Jalan Imbi KL (kontraktor: Kerjaya Peospek (M) Sdn Bhd), Kuala Lumpur	Luffing	Bum kren menara telah patah semasa kren tersebut menjalankan kerja mengukur monorail. Bum yang patah telah menghempap bangunan sebelahannya. Kegagalan pada sistem *luffing (overluff).* Tiada kemalangan jiwa berlaku.	
14-Ogo-15	Selangor		Mangsa terjatuh semasa melakukan kerja-kerja merombak kren menara.	Pekerja - 1 maut
2015	Selangor		Kejadian berbahaya. Tiada kemalangan jiwa berlaku.	
2015	Selangor		Kejadian berbahaya. Tiada kemalangan jiwa berlaku.	
15-Dis-15	Tapak Pembinaan untuk Hotel Store Force Sdn Bhd, Ipoh, Perak	Luffing (SCD 5020)	Ketika mengangkat kepingan kayu ditingkat 12, bum dinaikkan pada kelajuan tahap 2, dan bum terus bergerak ke arah belakang. Bum tidak dapat diperlahankan oleh *luffing up deceleration switch* apabila mencapai sudut melebihi 72°. *Luffing limit switch* tidak diselaraskan dengan betul dan mengakibatkan bum tidak menyentuh *limit switch* walaupun bum telah melebihi sudut maksimum. Kemalangan ini disebabkan kecuaian operator kren kerana penyelarasan dan pemasangan peranti keselamatan yang tidak sempurna. Bum terkilas ke belakang dan mendapati bar *stopper/damp* terangkat ke belakang. Tiada kemalangan jiwa berlaku.	
8-Dec-15	Projek Pangsapuri Persiaran Perdana Kota Bharu, Kelantan	Luffing	Bum *luffing* kren mengalami kegagalan (patah dua ketika beroperasi). Tiada kemalangan jiwa berlaku.	
24-Feb-16	Taman Pembinaan Pangsapuri Taman Molek JB, Johor	Luffing	Kejadian merbahaya yang melibatkan sebuah kren menara jenis *luffing* telah berlaku. Hasil penyiasatan mendapati *luffing rope* kren tersebut telah putus dan menyebabkan bum kren jatuh menghempap jalan. Tiada kemalangan jiwa berlaku.	

21-Jul-16	Mukim Plentong, Taman Iskandar Marina Cove, Bakar Baru, JB, Johor	Hammerhead	Kren menara memunggah pasir dengan menggunakan bakul yang berkapsiti lebih kurang 1m^3 dari aras tanah ke tingkat 10. Ketika beban berada pada ketinggian setara dengan aras 5 dan troli berada pada kedudukan. Kegagalan pada bum dan patah ditengah-tengah jib. Kegagalan ini menyebabkan jib terpiuh ke arah belakang dan beban timbal *(counterweight)* jatuh ke atas tanah. Operator mengalami kecederaan ringan akibat terhantuk dinding kabin.	Operator - 1 cedera
25-Ogo-16	Jalan Raja Chuka Jalan Bukit Bintang, Royale Pavalian Hotel, Kuala Lumpur	Luffing	Besi penyangkut kren seberat lebih 300 kg terjatuh dari atas bumbung bangunan (ketinggian lebih 100 meter) dan menghempap sebuah kereta dan menyebabkan seorang wanita (24 tahun) maut. Orang ramai mendakwa melihat besi kren yang mengangkat muatan patah sebelum terjatuh dan menghempap kereta mangsa. Punca disebabkan kegagalan pada *hositing limit switch*.	Orang awam - 1 maut
8-Apr-16	Lot 422, Jalan Bangsar, Seksyen 96, Aneka Jaringan Sdn Bhd (Projek dimiliki oleh Etiqa Insurance Berhad), Kuala Lumpur	Luffing	Kren sedang mengangkat besi siku seberat 1.5 tan pada keadaan jib diangkat sehingga 82^{o} (berdasarkan bacaan meter) dan bum tersebut telah tumbang ke arah bertentangan dan hujung bum telah terkeluar ke jalan bersebelahan. Kerosakan struktur utama kren dan sebuah lori kecil. Tiada kemalangan jiwa berlaku.	
28-Jan-16	Weststar Consturction and Property, Kuala Lumpur	Luffing	Kren menara tumbang ketika menjalankan kerja-kerja memasang *jacking* terhadap kren. Kerosakan struktur utama kren. Tiada kemalangan jiwa berlaku.	
10-Ogo-16	Tapak Pembinaan Lew Tuck Chui & Sons Sdn	Hammerhead (H20/14C)	Kejadian berlaku semasa mengangkat beban besi 900 kg, pada sudut 40	

	Bhd, Taman Len Sen, Cheras, Kuala Lumpur		radius (kedudukan troli 30-40 meter), tiba-tiba bum patah dan beban jatuh di atas bangunan tingkat atas. Jarak beban dari lantai adalah 4 kaki. Beban maksimum 3000 kg. Kren juga tidak dipasangkan dengan *load indicator.*Tiada kemalangan jiwa berlaku.	
16-Apr-16	Binastara Construction Sdn Bhd, Kuala Lumpur	Luffing	Seorang pekerja jatuh dan meninggal dunia dari tingkat 23 ketika memasang *i-beam* ke *collar tower*.	Pekerja - 1 maut
15 Okt 16	Cadangan Pembangunan Perniagaan di atas Lot 41323, 41385, 51449, 55971, 5620, Jalan Cheras Eco West, Kuala Lumpur	Hammerhead (H20/14C)	*Hoisting rope* telah terputus semasa kerja-kerja mengangkat beban. *Hook block (blok hosting)* TC4 di blok J, dan beban yang di angkat telah menimpa seorang mangsa. Siasatan di tempat kejadian mendapati takal *(pulley)* dan troli telah mengalami kerosakan.	Pekerja - 1 maut
2016	Jalan 1/65A, Off Jalan Tun Razak, Kuala Lumpur	Hammerhead	Kejadian berlaku apabila paip logam sepanjang 2 m jatuh dari kren ke atas sebuah kenderaan di Wisma Bernama, Kuala Lumpur. Tiada kemalangan jiwa berlaku.	
29-Jun-16	Dataran Datum Jelatik Ulu Klang, Selangor	Luffing	Hipotesis awal JKKP mungkin tersangkut pada *stater bar* pada *coloumn pile cap* (besi sekitar bucket). Menurut saksi, bum kren jatuh *free fall*. Tiada kemalangan jiwa berlaku.	
2016	Selangor	Luffing	Kemalangan berlaku di sebuah tapak pembinaan. Dua batang pin penyambung *(connection pin)* di antara bahagian *platform counter jib* dan bahagian *slew table* patah. Ini menyebabkan *platform counter jib* tercabut atau tertanggal dari sambungan tersebut lalu terjatuh dari kedudukkan asalnya. Namun ia masih tersangkut pada bahagian sambungannya kerana	

			masih terdapat dua lagi pin penyambung yang memegang struktur *counter jib platform* tersebut. Tiada kemalangan jiwa berlaku.	
17-Jul-17	Tapak Pembinaan Forest City Tanjung Kupang, Johor		Tali dawai mengangkat *(hoisting rope)* putus dan *hook blok* menghempap pekerja tapak bina. Seorang pekerja maut.	Pekerja - 1 maut
1-Jun-17	Pembinaan Rah Properties Corporation Sdn Bhd, Cadangan Pembinaan Pangsapuri 39 Tingkat di Lot 3314, 3316 & PT39113, Jln Raja Ai, Kg Baru, Seksyen 41, Kuala Lumpur	Luffing	Sebuah kren jenis *luffing* telah mengalami kegagalan sistem brek dan mengakibatkan bum jatuh dan telah menimpa sebuah kereta di Kampung Baru. Tiada kemalangan jiwa berlaku.	
10-Jan-17	Prinsiptek Sdn Bhd Cadangan Pembinaan Kompleks Perniagaan di Plot J5, No. 2A, Jalan Tukul Besi, Jalan 13/41, Sekyen 13, 40100 Shah Alam, Selangor.	Hammerhead	Sebuah kren menara tumbang di tapak pembinaan di Seksyen 13 Shah Alam bersebelahan dengan pasaraya Giant. Siasatan awal mendapati kejadian berlaku semasa kerja merombak kren menara dan kegagalan berpunca dari bahagian tapak asas kren yang tidak stabil. Tiada kemalangan jiwa berlaku.	
16-Apr-17	Petaling Jaya, Selangor	Luffing	Bum *luffing* patah. Kejadian berlaku pada pada hari Ahad (tidak beroperasi) di mana bum *luffing* terpelanting ke belakang disebabkan oleh ribut. Tiada kemalangan jiwa berlaku.	
19-Apr-17	Lot PT 59579 Lembah Subang Mukim Damansara Daerah Petaling Selangor. Syarikat Prasarana, Jalan PJU 1A/46, Petaling Jaya, Selangor	Hammerhead	Strukur *mast* kren bengkok pada sambungan *mast* ke 13 dan 14. Kejadian berlaku semasa kren mengangkat *bucket* simen di tingkat 10. Sebelum kejadian operator ada memaklumkan terdengar bunyi *'ping'* seperti ada sesuatu yang patah. Punca awal yang dikenal pasti adalah disebabkan oleh pin penyambung pada bahagian *mast* kren patah. Ini menyebabkan *mast* tumbang dan bengkok (berlaku pada mast kedua	

			terakhir sebelum *slewing table*) dan menghempap lantai bangunan. Tiada kemalangan jiwa berlaku.	

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