Six Sigma approach to reducing fall hazards among cargo handlers working on top of cargo containers: a case study

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Abstract: In Hong Kong, more than 500,000 container units per year are handled by small midstream cargo operators located at the Public Cargo Working Areas (PCWAs). Unfortunately, over 600 fall accidents were reported at PCWAs over the past ten years resulting in more than 45 deaths. This paper reports the results of a Six Sigma study to reduce fall accidents at PCWAs. Work procedures leading to falls of cargo handlers from cargo containers are described and the sigma levels for the rates of such accidents are determined. With help from the Logistics Cargo Supervisors Association and the Hong Kong Occupational Safety and Health Council (OSHC), we conducted focus group interviews and questionnaire surveys at the PCWAs. Data indicated that jumping from one container to another and resting and standing on a lifted container are the most hazardous procedures. The three most critical factors are identified. They are:

1. not concentrating at work
2. disregarding safety regulations
3. using worn-out hooks and slings.

Detailed improvement actions to reduce the fall accident rates were identified. Control procedures were documented and passed to OSHC.
Six Sigma approach to reducing fall hazards

Keywords: Six Sigma technique; Define-Measure-Analyse-Improve-Control (DMAIC) approach; occupational safety; fall hazards.

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Fugee Tsung is an Associate Professor of Industrial Engineering and Engineering Management at HKUST. He received both his MS and PhD in Industrial and Operations Engineering from the University of Michigan, Ann Arbor, and his BSc in Mechanical Engineering from National Taiwan University. He worked for Ford Motor and Rockwell International and did his post-doctoral research with Chrysler. He is the Chair of the Quality, Statistics, and Reliability (QSR) Section of the Institute for Operations Research and the Management Sciences (INFORMS), and is currently on the editorial boards for the International Journal of Reliability, Quality and Safety Engineering (IJRQSE) and the International Journal of Six Sigma and Competitive Advantage (IJSSCA). He is the winner of the Best Paper Award for the IIE Transactions focus issues on Quality and Reliability in 2003, and is also an ASQ Certified Six Sigma Black Belt and ASQ Authorized Six Sigma Master Black Belt Trainer. His research interests include quality engineering and management, process control and monitoring, and Six Sigma implementation.

Richard So is an Associate Professor in Industrial Engineering at Hong Kong University of Science and Technology, has been teaching and conducting research in ergonomics and occupational safety for over ten years. He is a registered member of the UK Ergonomics Society and the founding Council Member of the Hong Kong Ergonomics Society.

T.S. Li, a Registered Safety officer in Hong Kong, has been working as a Professional Safety Engineering Manager for over 20 years. He has been the Chairman of the Hong Kong Industrial Safety Association from 1994 up to 1995 and the Safety Specialist Group of the Hong Kong Institute of Engineers from 1997 up to 1998.

K.Y. Lam, the Chairlady of the Logistics Cargo Supervisors Association (LCSA), has been working in the field of mid-stream logistics for over 20 years. She obtained her degree in Business Administration and has been working full-time for the LCSA since.
1 Introduction

1.1 Six Sigma technique

The Six Sigma technique was first introduced by Motorola in 1987 and its objective was to reduce process output variation so that six standard deviations lie between the mean and the nearest specification limit. This technique allows no more than 3.4 defect Parts Per Million (PPM) opportunities, also known as Defects Per Million Opportunities (DPMO), to be produced (Pyzdek, 2000), while currently most industries produce 2–3% errors or 20,000 to 30,000 defects per million operations (Arthur, 2002). Examples of large companies that are using Six Sigma technique include Samsung, Honeywell, and Sony (Breakthrough Management Group, 2001). This paper reports a study to enhance the level of occupational safety among midstream cargo operators located at the public cargo working areas in Hong Kong by controlling all appropriate factors and reducing operation errors according to the Six Sigma technique.

1.2 Background of the Hong Kong container handling industry

Hong Kong has been one of the world’s busiest container ports with an average annual throughput of 18 million TEUs (20-foot equivalent units). In 2002 alone, Hong Kong’s container throughput reached 19.1 million TEUs. There are three main modes of port operations in Hong Kong:

1. container terminals
2. midstream
3. river trade.

The container terminals mainly handle cargo containers transported by large ocean-going vessels, which account for about 62% of the total port throughput (Hong Kong Port and Maritime Board, 2002). The river trade terminal mainly handles the cargoes transported by river trade vessels traveling on the Pearl River to-and-from Guangdong, China, and it handles about 21% of the total port throughput (Hong Kong Port and Maritime Board, 2002). The rest of the sea freight is handled by various midstream operators whose average cargo throughput is about 17 million tonnes per annum and shares 17% of the total port throughput (HKSAR, 2003a). Within this 17%, about 3% of the cargos (i.e., about 540,000 TEUs) were handled at the Public Cargo Working Areas (PCWAs).

1.3 Problem statement

From 1992 to 2002, fall of person from height shared 50% of the fatal accidents in the cargo-handling industry (HKSAR, 2003b). This translates to an average death toll of four workers per year and all of these fatal accidents occurred in midstream port operations. Hence, reducing the number of fall accidents among the workers in midstream operations was the targeted problem in this study.
1.4 Details of cargo-handling activities in midstream operations

Since the midstream port operations are responsible for the fatal accident in the cargo-handling industry, its operation is analysed. Midstream operations involved loading and unloading of cargoes:

- between ocean-going container vessels moored at buoys and barges as well as
- loading and unloading of cargoes between the barges and the Public Cargo Working Areas (PCWAs).

The former involved Chinese seamen without Hong Kong citizenships and the latter involve workers with Hong Kong citizenships. This study focuses on the latter because there is no official record of accidents for the former.

A barge is a flat-bottomed vessel equipped with a derrick crane to transport containers through rivers (Figure 1a). At PCWAs, the loading and unloading of containers are carried out using the simple derrick cranes located in the barges. Figure 2 shows a typical workflow diagram for container loading activity in a PCWA. The use of the simple derrick cranes required the workers to work on top of containers to hook and unhook the slings of the derrick cranes to and from the containers (Figures 1b and 2).

Figure 1 Photos taken at a Public Cargo Working Area (PCWA): (a) barges berth at a PCWA; (b) a worker hook a cargo container

1.5 Objectives and overview

The objective of this study was to use Six Sigma technique to reduce the occurrence of fall accidents at the PCWAs in Hong Kong. The five tools of the Six Sigma technique were applied: Define, Measure, Analyse, Improve, and Control (DMAIC).

In the define phase, the significance of fall accidents at the PCWAs was identified through past statistics and interview survey. Factors affecting near misses and hazardous levels of different procedures were measured through questionnaire survey during the measure phase. In the analyse phase, the factors related to fall accidents were validated and critical factors were identified. Finally, during the improve phase and control phase,
recommendations were developed to reduce the critical factors, and plans to maintain the performance were established.

Figure 2  Process map of a typical container handling operation between a barge and a Public Cargo Working Area (PWCA)
Six Sigma approach to reducing fall hazards

2 Phase I: define

2.1 Past statistics on fall accidents in the cargo-handling industry in Hong Kong

From the past accident statistics obtained from Hong Kong SAR Marine Industrial Accident Statistical Reports between 1992 to 2002 (Figure 3), there were, on average, 63 accidents related to fall of a person per year in the cargo-handling industry resulting in about four deaths per year. On average, there were estimated 520,000 container loading operations in the PCWAs per year. Based on this estimation, the sigma level of the fall accidents was calculated to be ranging between 4.5 and 4.7. This implies that there were about 1350 fall accidents per million operations. Since Hong Kong is among the busiest logistics cargo ports in the world, maintaining a safe and efficient level of cargo-handling services is of utmost important. In 2002, the Occupation Safety and Health Council of Hong Kong had highlighted the reduction of fall accident with hooking and dehooking cargo containers as one of the priories concerns (HKSAR, 2002).

Figure 3 The statistics of the accidents related to the fall of a person happened in the cargo-handling industry in Hong Kong SAR (1992–2002), the accidents were categorised into Fatal, Serious, and Minor. The statistics were obtained from Hong Kong SAR Marine Department (HKSAR, 2003b)

2.2 Interview surveys to establish the working procedures

Interview surveys were conducted with eight experienced workers who had accumulated over 50 years of services. The purpose of the interview was to obtain accurate account of the working procedures at the PCWAs. In particular, details on all procedures that were considered to be hazardous were collected. Figure 2 shows a typical workflow of transporting a container from a barge to a PCWA. Inspections of Figure 2 indicate that the hooking and dehooking procedures expose the worker to fall hazard – a concern shared by the Hong Kong Occupation Safety and Health Council (HKSAR, 2002).
3 Phase II: measure

3.1 Preliminary interview

The eight experienced workers interviewed in the define phase were invited to list out all the factors that are associated with work safety in PCWAs. Results indicated that 38% of the responses have to do with long working hours due to:

- irregular arrival times of cargo vessels
- the reduction in number of coworkers because of the ongoing price wars within the container handling industry.

About 22% of the responses were related to the disregard of safety guidelines suggested by the Hong Kong Occupational Safety and Health Council. The given reasons for the workers to disregard the safety regulations were mainly because of inconvenience over the use of the safety appliances. For example, wearing safety shoes, as suggested by the guidelines, were disregarded because the safety shoes make it very difficult for workers to climb to the top of containers. Also, the use of safety harness, as suggested by the guideline was disregarded because workers believed that they could not find a suitable anchor point to apply the safety harness. In other words, workers considered the use of safety appliances as not practical. Another given reason was that the cargo services companies did not provide suitable safety appliances such as elevated fenced platforms for workers to get to the top of the containers. About 16% of the responses were associated with strong wind and wave during bad weather conditions. Strong wind could cause the slings of the crane to swing and knock a worker off a container. This information provided the basis for a larger scale questionnaire survey conducted to identify critical factors and procedures related to fall hazards in PCWAs.

3.2 Measurement tree

Based on the information collected from the eight experienced workers, a measurement tree was constructed according to the Six Sigma technique. Inspections of Figure 4 indicate three main types of measurements:

1. Hazardous procedures that can cause workers to fall from the top of containers.
2. Factors affecting the occurrence of fall accidents.
3. Near misses in PCWAs related to fall accidents.

This tree organised the expert information in a systematic way.
3.3 Questionnaire development

To further substantiate the expert opinion, two major questionnaire surveys were conducted. The questionnaire was developed based upon the information obtained from the interviews conducted in the define phase (see Section 3.1) and through thorough discussions with a practicing safety engineer (Mr. TS Li – a co-author) and Council Members from the Logistics Cargo Supervision Associations (one Council member’s family has been handling cargo at the PCWAs for three generations). A pilot survey was conducted on 42 midstream operation workers at one of the PCWAs. The initial findings were presented in the Safety and Health Expo 2003 (Ng et al., 2003) and to the members of the research committee of the Hong Kong SAR Occupational Safety and Health Council. Using the feedback and comments obtained from representatives of the Logistics Cargo Supervisors Association, Labour Department, Occupational Safety and Health Council, and attendees of the Safety and Health Expo, the initial questionnaire was revised. This revised set of questionnaire was then used in a larger scale survey covering six out of the eight PCWAs in Hong Kong. These PCWAs included New Yau
Ma Tei PCWA, Rambler Channel PCWA, Cha Kwo Ling PCWA, Wan Chai PCWA (later Chai Wan PCWA (HKSAR, 2003c)), Kwun Tong PCWA and Stonecutters Island PCWA. The other two PCWAs that were not included in this survey were Tuen Mun PCWA and Western PCWA. Workers in Tuen Mun PCWA had already participated in the preliminary questionnaire survey and they did not want to participate again in the main questionnaire survey. Furthermore, the goods handled at the Western PCWA were mostly not containerised; therefore, Western PCWA was not included in the main questionnaire survey. In other words, nearly 100% of the container handling workers in PCWAs took part in the questionnaire surveys.

3.4 The reliability of the questionnaire

The test-retest method was used in this study to examine the reliability of the questionnaire data (Litwin, 1995). Workers were requested to complete the same set of questionnaire twice within a few hours’ gap in between. A longer time gap was not used as it would greatly reduce the response rates in our study. The two completed questionnaires from the same worker were used to calculate the correlation r-coefficient indicating the reliability of the questionnaire. The order of the questions was rearranged to be different between the first and the second set to avoid copying using memory. This questionnaire survey did not record the names of the workers. One hundred and 31 workers participated in this questionnaire survey and 99 of these workers were willing to complete two sets of questionnaire. Answers to each questionnaire were coded into 236 items before conducting the correlation tests. Fifty-seven percent of the items reported in the first and second questionnaire were significantly correlated with correlation coefficients exceeded 0.7. These highly correlated items included:

- possible factors for fall accident
- hazardous operations
- examples of near misses in the PCWAs.

Examination of those items with correlation coefficients below 0.7 revealed two possible reasons for the differences:

1. the impatience of workers as well as
2. sudden physical presence of their employers while they were filling in their questionnaires.

The former was based on the larger portion of unanswered questions in the second attempts and the latter was based on matching between the circumstantial evidence observed by the research staff. Items with correlation coefficients below 0.7 were excluded in subsequent analyses.
3.5 Measurement I: the hazardous procedures related to working on top of the containers in the PCWAs

The three most hazardous work procedures related to fall accidents were identified to be:

1. Jumping from containers to the ground when the containers were being carried by the slings and situated in the mid-air.
2. Taking rest on top of containers.
3. Standing on top of containers which were being carried by the slings and situated in the mid-air (Table 1).

To our surprise, the hooking and dehooking procedures were not frequently reported as highly hazardous, although these two procedures were identified as the most hazardous procedures in the initial interview (see Section 2.2) and were the primary concerns of the Hong Kong Occupational Safety and Health Council (HKSAR, 2002). There were only nine out of 131 workers (i.e., 7%) who agreed that hooking was the most hazardous procedure; six out of 131 (i.e., 4.5%) workers agreed that dehooking was the most hazardous procedure.

<table>
<thead>
<tr>
<th>Hazardous procedures</th>
<th>Proportions of workers rated the procedure as most hazardous (each worker can vote for more than one procedure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumping from the containers which were still being carried in the mid-air</td>
<td>25/131 (19.1%)</td>
</tr>
<tr>
<td>Taking rest on top of containers</td>
<td>23/131 (17.6%)</td>
</tr>
<tr>
<td>Standing on the containers which were being carried in the mid-air</td>
<td>21/131 (16.0%)</td>
</tr>
</tbody>
</table>

3.6 Measurement II: the factors which are highly related to fall accidents from the top of containers in the PCWAs

Table 2 shows the nine most frequently reported factors for falls from the top of containers. These factors were grouped into three clusters:

1. personal factors
2. environment factors
3. disregard of safety regulations.

Personal factors include not concentrating at work (31.3%), failing to follow proper work procedures (22.1%), drinking alcohol (20.6%), and tiredness (18.3%). Environment factors include the use of worn-out hooks and slings (42.0%), oil on shoe soles (27.4%), and swinging slings (19.8%). Examples of disregard of safety regulations include the disregard of regulations (21.4%) and failure in using proper safety appliances (19.8%). The percentages indicate the proportions of 131 workers ranked that particular factor as the most important one. Since workers can select more than one most important factor, the percentages do not add up to 100%.
Table 2  List of factors reported to be mostly related to falls of workers from containers at the PCWAs

<table>
<thead>
<tr>
<th>Factors</th>
<th>Proportion of 131 workers ranked this factor as the most important one</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worn-out of the hooks and slings</td>
<td>55/131 (42.0%)</td>
</tr>
<tr>
<td>Not concentrated at work</td>
<td>41/131 (31.3%)</td>
</tr>
<tr>
<td>Oil on shoes’ soles</td>
<td>36/131 (27.4%)</td>
</tr>
<tr>
<td>Tiredness</td>
<td>32/131 (24.4%)</td>
</tr>
<tr>
<td>Not following correct work procedures</td>
<td>29/131 (22.1%)</td>
</tr>
<tr>
<td>Disregard safety regulations</td>
<td>28/131 (21.4%)</td>
</tr>
<tr>
<td>Drinking beer at work</td>
<td>27/131 (20.6%)</td>
</tr>
<tr>
<td>Disregard safety appliances</td>
<td>26/131 (19.8%)</td>
</tr>
<tr>
<td>Swing slings</td>
<td>26/131 (19.8%)</td>
</tr>
</tbody>
</table>

The disregards of safety appliances were further investigated. There were eight types of safety appliance mentioned in the safety guidebook to be used in cargo-handling industry (HKSAR, 1999). One of these safety appliances was the safety harness and its main purpose was to prevent fall and it was the only safety appliance mentioned to prevent fall accidents. Inspections of Table 3 indicate that safety harness was least used in the PCWAs followed by safety shoes, highly visible clothes, and safety helmets. Interestingly, this pattern was significantly correlated with that of safety appliance least provided by the employers (Table 4, $r > 0.3$, $p < 0.05$, Spearman’s rho correlation test).

Table 3  Types of safety appliance that were most frequently disregarded by the cargo-handling workers at the public cargo working areas in Hong Kong

<table>
<thead>
<tr>
<th>Safety appliances least worn by the workers</th>
<th>Proportion of 131 workers not using this safety appliance at work when needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety harness</td>
<td>74/131 (56.5%)</td>
</tr>
<tr>
<td>Safety shoes</td>
<td>67/131 (51.5%)</td>
</tr>
<tr>
<td>Highly visible clothes</td>
<td>56/131 (42.8%)</td>
</tr>
<tr>
<td>Safety helmet</td>
<td>41/131 (31.3%)</td>
</tr>
</tbody>
</table>

Table 4  Types of safety appliance that were least provided by their employers (i.e., unavailable) to the cargo-handling workers at the public cargo working areas in Hong Kong

<table>
<thead>
<tr>
<th>Safety appliances least provided by the employers</th>
<th>Proportion of safety appliance not provided by the employers (reported by 131 employees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety shoes</td>
<td>68/131 (51.9%)</td>
</tr>
<tr>
<td>Safety harness</td>
<td>57/131 (43.5%)</td>
</tr>
<tr>
<td>Highly visible clothes</td>
<td>38/131 (29.0%)</td>
</tr>
<tr>
<td>Safety helmet</td>
<td>8/131 (6.1%)</td>
</tr>
</tbody>
</table>
The most frequently reported personal reasons for not using the safety appliances are listed in Table 5. Workers did not use proper safety appliances at work because they were too much in a hurry to work (26/131 = 20%), safety appliances were not considered to be practical (22/131 = 17%), and work could be completed without using the safety appliances (13/131 = 10%). Interestingly, workers from the Stonecutters Island PCWA had a different view on this issue; they mostly considered that using safety appliances could delay their progress at work (6/30 = 20%) and also using the safety appliances at work increased the hazards of their work (5/30 = 17%). Further interviews with experts from the logistics cargo supervisors association suggest a possible reason on how and why a safety appliance can increase the hazards. PCWA at the Stonecutters Island has the roughest sea condition among all the PCWAs and containers are constantly moving so that workers have to be very alert of their surround in order to avoid being hit by containers or swinging objects (e.g., slings of the cranes). The use of a helmet to reduce the severity level of head injury can block part of their field-of-views and increase the fall hazard. Also, a rigid anti-slip shoe can slow down a worker and may increase the hazard of being hit by a moving object.

Table 5  Personal reasons of not using proper safety appliances when handling cargos at the public cargo working areas in Hong Kong

<table>
<thead>
<tr>
<th>Personal reasons on not using the safety appliances</th>
<th>Proportion of workers that agreed on this reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too hurry to go to work</td>
<td>26/131 (19.9%)</td>
</tr>
<tr>
<td>Not suitable in real situation</td>
<td>22/131 (16.8%)</td>
</tr>
<tr>
<td>Work could be completed without wearing the safety appliances</td>
<td>13/131 (9.2%)</td>
</tr>
</tbody>
</table>

Table 6 shows the overall results from the six PCWAs on disregarding of safety regulations. The three most frequently reported reasons why workers do not follow safety regulations at work were:

1. Part of the safety regulations were not practical (51/131).
2. Workers could complete their work without following the safety regulations (33/131).
3. Following the safety regulations at work could delay their progress (26/131).

Table 6  Personal reasons for disregarding proper safety regulations when handling cargos at the public cargo working areas in Hong Kong

<table>
<thead>
<tr>
<th>Personal reasons on disregarding the safety regulations</th>
<th>Proportion of workers that agreed on this reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part of the safety regulations were not practical</td>
<td>51/131 (38.9%)</td>
</tr>
<tr>
<td>Workers could completed their work without following the safety regulations</td>
<td>33/131 (25.2%)</td>
</tr>
<tr>
<td>Following the safety regulations at work could delay their progress</td>
<td>26/131 (19.8%)</td>
</tr>
</tbody>
</table>
3.7 Measurement III: near misses associated with the fall of workers from the top of containers in PCWAs

Questions related to the near misses associated with the fall accidents happened in the PCWAs were presented in two different ways. Workers were asked to report near misses faced by him or faced by his colleagues. By asking these two questions, a more complete view on the near misses related to the fall accidents could be obtained. As suggested by the council members of the Logistics Cargo Supervisors Association, most of the workers at PCWAs may be overconfident of their physical ability, and hence, not willing to reveal their own weakness (e.g., past records of near misses). As a consequence, the questionnaire also asked them to report near misses of their colleagues. The results of these two questions are listed in Tables 7 and 8, respectively. Combining the results from Tables 7 and 8, slip on the top of containers was the most frequently reported near misses (16/86).

Table 7 Proportions of near misses that happened to the workers themselves for the past year at the PCWAs

<table>
<thead>
<tr>
<th>Types of near-misses</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Being hit by the containers</td>
<td>11/38 (28.9%)</td>
</tr>
<tr>
<td>Slip on the top of the containers</td>
<td>4/38 (10.5%)</td>
</tr>
<tr>
<td>Being hit by the slings</td>
<td>4/38 (10.5%)</td>
</tr>
</tbody>
</table>

Note: There were totally 38 near misses reported by 131 workers

Table 8 Proportions of near misses that happened to their colleagues in the PCWAs for the past year

<table>
<thead>
<tr>
<th>Types of near-misses</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slip on top of containers</td>
<td>12/48 (25.0%)</td>
</tr>
<tr>
<td>Being hit by slings</td>
<td>9/48 (18.8%)</td>
</tr>
<tr>
<td>Fall from top of containers</td>
<td>7/48 (14.6%)</td>
</tr>
</tbody>
</table>

Note: There were totally 48 near misses reported by 131 workers

4 Phase III: analyse

Results collected during the measure phase were further analysed using the fishbone diagram and the relations diagram in accordance with the Six Sigma methodology. The fishbone diagram organises the factors that have been reported to have caused fall accidents from the top of containers (Figure 5). The clustering of various factors is based on expert opinion collected through focus group discussion with council members of the Logistics Cargo Supervisors Association. For examples, the use of worn-out hooks and slings can cause the imbalance of a container and destabilise any workers working on top of that container. When the soles of the shoes of the destabilised workers are oiled, they can fall.
After clustering using the fishbone diagram, a relationship diagram is used to identify the root factors of fall accidents (HKSAR, 2003b). Inspections of Figure 6 indicate that the following three factors have the highest number of arrows going ‘out’ from them:

1. not concentrating at work
2. disregarding safety regulations
3. using worn-out hooks and slings.

These three are labelled as the suspected root causes. Among the three most hazardous work procedures identified in the survey, standing on the top of a moving container that are lifted in mid-air has the highest number of outgoing arrows. Consequently, it is labelled as the most hazardous work procedure.

4.1 Critical factor I: not concentrating at work

Inspections of the fishbone diagram indicate that workers could have problems on concentrating at work after working for long hours and/or drinking beer at work (Figure 5). This is consistent with the questionnaire data indicating that 37% workers need to work for more than ten hours per day and 21% of the workers reported that drinking beer at work is the main cause of fall accidents.
4.2 Critical factor II: disregarding safety regulations

According to Hong Kong’s Shipping and Port Control (Cargo Handling) Regulations, Chapter 313 Section B, it is the responsibility of a worker “to wear a suitable safety helmet and use other appropriate protective clothing and equipment provided to him by an employer or person in charge of works” (HKSAR, 1999). If a worker disregards this regulation and falls from a container, he may suffer a much more serious injury. In addition, it is also illegal for an employer not to provide proper safety appliances to the workers (HKSAR, 1999). Results of the current survey indicate that 31% of workers do not wear safety helmet at work and 6% of their employers do not provide safety
4.3 Critical factor III: using worn-out hooks and slings

Through consultation with experts from the Logistics Cargo Supervisors Association, experienced workers at PCWAs and a safety engineer (co-author), it has been established that the use of worn-out hooks and slings is the result of not following proper procedures. According to the proper procedure, workers are required to check the usability of the slings and hooks, and to use the correct slings and hooks for lifting containers. If workers notice that a sling or a hook is worn-out, they should report this to their employers or the person in charge so that the worn-out equipment is replaced. This cause-and-effect relationship between the disregard of the correct work procedure and the use of worn-out hooks and slings is illustrated in the relationship diagram (Figure 6). The use of worn-out slings and hooks to lift a container can cause the container to tilt suddenly and greatly increase the chances for workers working on top of containers to fall. Again, this cause-and-effect relationship is illustrated in Figure 6.

4.4 The most critical procedure: standing on top of a moving container which was being lifted in the mid-air by a crane

Unfortunately, standing on top of a moving container is a very common practice. The research witnessed these common practices in all visits made to all the PCWAs. Worst of all, most workers were not wearing safety helmet nor safety harness. This practice raised great concerns in the HK Occupational and Safety Council (1999) (HKSAR, 1999) and it would be extremely hazardous if the workers involved were not wearing safety harness to prevent fall accident.

5 Phase IV: improvement

According to the Six Sigma methodology, after the critical factors and hazardous procedure are identified, solutions to reduce the risks brought by these factors and procedure should be determined. The suggested solutions and root causes of these critical factors documented in this section went through thorough discussions among the research group (composed of ergonomics, safety, and Six Sigma experts) and council members of the Logistics Cargo Supervisors Association (i.e., field experts). The suggested solutions were to be implemented to their validity. However, the employers of all the cargo services companies that we have contacted refused to work on the implementation phase because they worried about the risk of exposing their unsafe practices and this might disrupt their existing agreements with their insurance companies. As a result, the improvement scheme was passed to the HK occupational safety and health council in the hope that they, as a government agency, can persuade some companies to join the improvement phase.
5.1 Solution 1: risk reduction for workers standing on top of moving containers

The obvious solution is to eliminate the need for workers to stand on top of moving containers by replacing the existing simple derrick cranes with modern quayside gantry cranes so that manual hooking and dehooking procedures will not be needed any more. This suggestion was rejected by the field experts because midstream cargo service companies could not afford the expensive gantry cranes. Also, this would bring unemployment to the stevedores at the PCWAs because this suggestion will replace midstream operations with modern cargo container port operations. The latter exists and is already handling 63% of the annual container throughput of Hong Kong. According to the Logistics Cargo Supervisor Association, the midstream operation has its unique contributions:

- Midstream operations provide a very small-scale and effective cargo-handling service in the Pearl-river delta region through the use of barges and their derrick cranes.
- The midstream operations offer a cost-effective alternative for an ocean-going vessel to download or upload a few containers without the need to dock at a modern terminal.

Consequently, the following actions focus on measures to make midstream operation a safer task.

5.1.1 Action 1: communications with the monitoring authority

The authority should set up guidelines to help workers to decide when is the safe situation for a worker to stand on top of a moving container. Currently, the practice of standing on top of moving containers is very common even though it has caused great concern in the occupational safety and health council. It is hoped that, through this action, jobs requiring workers to be on top of moving containers can be further classified so that some tasks are banned completely and some tasks are allowed under strict safety procedures.

5.1.2 Action 2: improve the communications between the crane operator and the workers on top of moving containers

In order to make a worker working on top of a moving container to be better prepared for any sudden container movements, it is important to improve the verbal communications between that worker and the crane operator. Currently, hand signals are used as a means of communication (Figure 2). This action suggests workers on top of a moving container to use hand-free communication devices to communicate with the crane operator. With the availability of cheap and effective wireless hand-free phones, this action is not costly.
5.1.3 Action 3: easy-to-wear, lightweight safety harness with modified slings, and anti-slip shoes

An easy-to-use safety harness and safety belt was suggested to be worn by the workers who needed to stand on top of the moving containers. The existing method was to anchor a safety belt on a stable standalone platform, however such platforms are not always available at PCWAs. The suggested method was that a safety harness could anchor to one of the four slings which were hooked to four corners of a container. The sling can be redesigned so that it has a ring or loop at a position where workers could easily hook their safety harness to it via a retractable safety belt. The authors acknowledge that this suggested action requires further testing so that workers are not exposed to additional risks of being hit by a swinging sling.

5.1.4 Action 4: anti-slip shoes

Anti-slip shoes with toecap should also be worn by workers. Currently, workers are complaining that the existing anti-slip shoes are too heavy and prevent them from climbing a container. Action 4 suggests a better designed anti-slip shoe made of lighter and less rigid material should be made for this purpose.

5.2 Solution II: reduce the occurrences of workers disregarding safety regulations

The root causes of disregarding safety regulations have been identified: workers who consider that:

- The safety regulations are not practical.
- The work could be completed without following the related safety regulations.
- Following the safety regulations could delay the work progress.

In addition, the experienced workers reported during the preliminary interview that proper safety appliances were not supplied by their employers. The following actions are proposed to tackle these root causes.

5.2.1 Action 1: solving problems related to confusions over the safety regulations and lack of communications among the Labour Department, the Occupational Safety and Health Council, and the workers

We encourage the authority to arrange on-site training on the use of safety appliances for all workers. If possible, this training should be on a one-to-one basis. In addition, the authority should provide updated video tapes to demonstrate the correct uses of existing safety appliances at different PCWAs. The author, Ms. Edith Ng, attended the current safety training certification course and found that the existing course mainly focused on conceptual matters and did not provide one-to-one on-site training on the use of safety appliances.
5.2.2 Action 2: toolbox safety meeting

A toolbox safety meeting is a daily short meeting between the employer and his workers to discuss the safety issues of their works. For example, recent accidents or near misses happened in their PCWA. In the case of recent accidents, the authority should send the accident report to the employers (or persons-in-charge) with hints on how to prevent the same accidents from reoccurring. This report should be discussed in the daily toolbox safety meetings. The toolbox safety meeting should be an open discussion between the employer (or person in-charge) and the workers, and hence they could both express their opinions, concerns and suggestions on the safety issues.

5.2.3 Action 3: tackling inconvenience and delays caused by following safety regulations at work

The authors acknowledge that there is no quick fix for this problem. This action suggests the authority to set up incentive for employers and employees to get the correct balance between work efficiency and levels of safety.

5.2.4 Action 4: tackling problem related to employers did not provide safety appliances to their employees

The reason why some employers did not provide the safety appliances to their employees should be investigated. If the reason is due to financial problems, the authority can set up a loan scheme for them to apply. In any case, the authority should increase inspections to reinforce the regulations.

5.3 Solution III: improve the level of concentration at work

From the result of the questionnaire survey, the root causes of this problem were:

- drinking beer at work
- tiredness
- prolonged working hours.

Solutions for solving problems related to tiredness and prolonged working hours require another in-depth study. In the following paragraph, the improvement actions focus on the problem of beer drinking at PCWAs.

First, employers should ensure that no alcoholic drinks are stored or sold inside a PCWA. Second, the authority should organise a publicity campaign against alcohol consumption at PCWAs. The chair of the Logistics Cargo Supervisor Association (LCSA), Ms. Lam, mentioned that for the past few years the insurance fee for a normal worker working in the PCWA has already increased by 300% and now the insurance fee is around HK$ 3000 per worker per month. Ms. Lam hypothesises that insurance companies will welcome a campaign to reduce alcohol consumption at PCWAs and it may even lead to a reduction of insurance premium for those midstream operating companies who sign up for the campaign.
5.4 Solution IV: setup hooks and slings maintenance programmes

According to the council members of the Logistics Cargo Supervisors Association, there is currently no formal maintenance scheme on the lifting equipment used in midstream operations. In addition, there is no requirement of formal inspections of the hooks and slings used in PCWAs. Even if there is a designated examiner on hooks and slings in the PCWA, that examiner will have no formal training on how to assess a sling or hook. Consequently, the authors suggest that the authority should work with the employers to set up a maintenance system for slings and hooks. In addition, the authority should consider revising the Factories and industrial undertakings regulations on suspended working platforms to cover midstream container handling operations.

6 Phase V: control

To prevent a fall accident and its critical factors from reoccurring, control methods are needed. Suggested solutions are listed in Section 5 and they included engineering solutions on fall protection (e.g., new designs of safety harness and shoes), administrative solutions on training (e.g., toolbox safety meeting), and suggestions to improve cooperation among authorities, employers, and workers. As explained above, no company is willing to participate the improvement phase; as such, the following control methods are only suggested plans.

In Table 9, two control plans are suggested in order to sustain the improvements on hooks and slings maintenances and no alcohol consumption at work. For sustaining the improvements, both the authorities and employers are required to conduct inspections. Employers, or their designated persons, are suggested to conduct daily inspections. In addition, the results of inspections should be documented. Any problems found during inspections should be discussed during the daily toolbox safety meetings (see Section 5.2). The authority should inspect the progress of the improvement plans on a monthly basis. In addition, the authority could also discuss with the employers how to sustain the improvements which could also help to improve the connections between the authority and the industry.

<table>
<thead>
<tr>
<th>What is controlled?</th>
<th>Requirements</th>
<th>Control method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation of hooks and slings</td>
<td>Clear documentation of the routine maintenance scheme</td>
<td>Employers to ensure the scheme was implemented</td>
<td>Daily inspection by the employers is suggested</td>
</tr>
<tr>
<td>maintenance scheme</td>
<td>Designate trained persons in charge of the maintenance scheme</td>
<td>Inspection from the authority</td>
<td>Monthly inspection by the authority is suggested</td>
</tr>
<tr>
<td>No alcohol consumption at work</td>
<td>No alcohol are allowed to be stored inside PCWAs</td>
<td>Inspection by the employer and authority</td>
<td>Daily inspection by the employers is suggested</td>
</tr>
<tr>
<td></td>
<td>No alcohol should be sold in the canteens inside PCWAs</td>
<td></td>
<td>Monthly inspection by the authority is suggested</td>
</tr>
</tbody>
</table>

Table 9 The recommended control methods for the critical factors
Through these improvement schemes, chances of using worn-out hooks and slings are expected to reduce rapidly. In addition, occurrences of workers drinking alcoholic drinks should also be reduced. The expected consequence is a greatly reduced rate of fall accidents at PCWAs.

7 Conclusion

The critical factors and the most hazardous procedure related to fall accidents at the Public Cargo Working Areas (PCWAs) in Hong Kong have been identified. From the quantitative procedures outlined in the Six Sigma methodology, we identified the critical factors from the questionnaire survey as follows:
- lack of concentration at work
- disregard of safety regulations
- use of worn-out hooks and slings.

The most hazardous procedure that can lead to fall accidents from the top of containers is ‘workers standing on top of moving containers that are being lifted by cranes’. The survey has covered all the PCWAs in Hong Kong that handle containers. The root causes of these critical factors and hazardous procedures have also been determined through focus group discussion with the council members of the Logistics Cargo Supervisors Association and safety engineers. Solutions to reduce the causes are documented in the paper. Examples of engineering solutions include customised fall protection systems and lightweight anti-slip shoes. Examples of administrative solutions include daily toolbox safety meetings, measures to prevent alcohol consumption at work, and a formal equipment maintenance scheme. Measures to facilitate better cooperation among the authorities, employers, and workers have also been suggested to clarify safety regulations and the use of safety appliances. In addition, the authorities have been encouraged to reinforce the legal requirement of employers providing safety appliances to their employees. These solutions have been documented and passed to the Logistics Cargo Supervisor Association and the HK Occupational Safety and Health Council.

Currently, fall accident problems are handled through qualitative approaches that rely on experience and gut feelings without much quantitative measurement and analyses. The reported application of DMAIC provides a systematic and data-driven alternative approach to tackle these problems. The case study demonstrates the effectiveness of the Six Sigma DMAIC approach to reduce fall hazards and also indicates that such a rigorous approach can be a means to meet increasingly high safety standards and an eventual near-zero hazard rate.

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Six Sigma approach to reducing fall hazards

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