

To develop this program, the data layout between systems explained in Chapter 4.1 must be taken into account. The systems must be connected based on this data flow. The process of exchanging and connecting information between all the systems to create a whole system is seen in Fig. 11.

First, to connect the BIM Tool and the Monitoring System, the protocol between these two programs must be defined. As a result, the two programs will be able to exchange data freely. Next, the RTLS, the Alarm System's Engine, and the protocol between the Monitoring systems described above must be defined; then, all the programs can be integrated with each other.

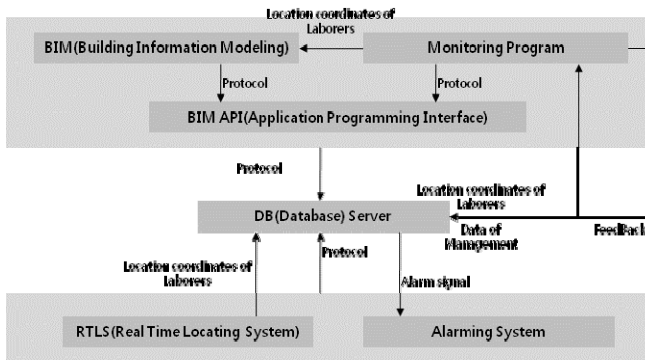


Figure 11. Proposal for the realization of the program

## 5. CONCLUSION

Currently, construction site safety management falls under the same standards, and it is not systematic but based on meeting the standard of tests. Therefore, ex-post treatment is more emphasized than prevention, which can result in considerable costs. Furthermore, safety management is often not as prioritized as other management activities (e.g., process, time, and cost management), and safety management may be extremely different from site to site, as it is highly dependant on the expertise of safety managers.

Therefore, this study proposed a program to improve current safety management practices. This program emphasizes prevention (e.g., workers are alerted with an alarm when they enter a danger zone) over ex-post treatment, and it is developed from the combination of a RTLS, BIM & real-time monitoring, an Alarm System, and a Data Mart.

### S17-5

## SUCCESS STORY OF THE SHIPBUILDING AND REPAIR INDUSTRY IN ACHIEVING EXCELLENT SAFETY PERFORMANCE: A LESSON FOR THE CONSTRUCTION INDUSTRY

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However, to develop this program for practical use, further study is required. First, data modeling of the proposed monitoring program must be performed. When complex, building, floor, process, and workers are input, the dangerous situation and preventative measures should be derived according to these factors.

Furthermore, the current locating systems still have a few limitations. For example, the signals between tags and readers can be weakened in the presence of concrete and/or steel obstacles. This must be addressed so that the proposed locating technique is more suitable to construction sites.

Finally, after the system is developed, the program should be verified through experiments in actual construction sites.

## ACKNOWLEDGEMENT

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**ABSTRACT:** In Singapore, the construction industry's performance in safety has often been the worst among the other industries. This paper seeks to compare the efforts of the shipbuilding and repair industry and the construction industry in improving the level of safety performance. One key factor identified in the paper will be the subcontractors' role in the safety aspect. Based on the analysis of statistic carried out by the Ministry of Manpower of Singapore and many others, this paper aims to identify the success of the shipbuilding and repair industry and gives thought as to how the construction industry can further improve its safety record.

*Keywords: Safety and Health; Selection of Subcontractors; Successful Construction Partnering*

## 1. INTRODUCTION

The shipbuilding and repair industry has been brought into the focus of this paper for two main reasons. One, it shares many similar characteristics as the construction industry. For instance, both were the building pillars of our economy during the early independence days of Singapore. Other than the role they play in the economy, the nature of the industries is largely similar. Both industries depend heavily on subcontractors and are involved in heavy works. Also in the past few decades, both industries have recorded the highest accidents numbers.

The other reason is that the shipbuilding and repair industry has a safety climate that is to the envy of those in the construction industry. After a series of serious explosions in the shipyards in the early 1990s, the shipbuilding and repair industry has stepped up its efforts on safety [4]. Their persistence and efforts are worth commending. The intent of this paper is to examine the key components which attributed to the success of the shipbuilding and repair industry in reducing their level of accident rates; and with a better understanding of the whole process, introduce changes to the current practices in the construction industry.

Both industries have their respective associations to represent the industries. The construction industry has setup the Singapore Contractors Association Limited (SCAL)<sup>i</sup> and

<sup>i</sup> SCAL was setup in 1977 due to the merging of two associations, namely the Singapore Chinese Contractors Association and the British Master Builders Association [18]. Today, the association

the shipbuilding and repair industry has the Association of Singapore Marine Industry (ASMI)<sup>ii</sup>. Both associations have common objectives such as promotion of good practices in the industry and meeting the requirements of the members in areas of legislation and industrial matters. However, this paper attempts to examine the role that each association plays in the area of safety.

## 2. AN ANALYSIS OF THE SHIPBUILDING AND REPAIR INDUSTRY

In the early years of independence, the shipbuilding and repair industry was flourishing [3, 4, and 5]. Then, rapid expansion of shipyards had led to an increase in the number of accidents in shipyards. From 1968 to 1972, it was estimated that accidents rose by 20 times. In 1991, the industry reached a record high of 1,277 numbers of accidents. But since then, the numbers have been declining steadily (Table 1).

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has more than 900 members and more than 75% of the projects in Singapore are carried out by its members. Therefore, it is recognized as the official representative of the construction industry in Singapore.

<sup>ii</sup> ASMI was setup in April 1968 [2]. Then it was known as Singapore Association of Shipbuilders and Repairers (SASAR). The association comprises of major players in the shipping industry which represented about a third of the shipyards in operation. Its name was changed to ASMI in 1988 but its main objectives were still the same; to represent the interests of its members, uniting the industry and promoting good and safe practices.

Table 1: Number of accidents in the construction and shipping industry

Sector	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07
Shipbuilding	1277	1140	954	829	803	754	681	666	518	311	454	429	394	393	456	638	490
Construction	802	802	764	856	887	1243	1538	1532	1504	1395	1455	1337	1193	1216	1300	2415	2460

Source: Ministry of Manpower of Singapore

In 2007, the number of accidents recorded was 490, and that is a 61.3% improvement as compared to the figures in 1991. The number of fatal accidents has also decreased from 17 in 1993 to 9 in 2007, which is a 47.1% improvement [25]. This remarkable reduction is an indication of a successful effort by the industry in promoting safety. Since 1994, the accident frequency rate of shipping and repair industry has dropped from 9.6 reported accidents per million man-hours hours worked to 1.3 in 2007, which is a 86.5% decline over the 13 years period. The accident severity rate has also declined by 91.7%, from 2174 man days lost per million on man-hours worked to 180 over the same period [25].

Similarly for the construction industry, in the early years of independence, the construction sector was the engine of our economy. There was a rapid expansion of the industry. As seen in Table 1, the number of accidents occurring in 2007 has risen by 206.7% as compared to 1991. The measures taken by SCAL are highly similar to ASMI but the construction industry had a record of 24 fatal cases of accidents in 2007 [25] which are about 38.1% of all fatal accidents and it was the industry with the highest fatal accidents records. Despite efforts from the Ministry of Manpower (MOM) to improve the safety record of the construction industry, statistics have shown that there are fundamental flaws in the measures implemented.

Comparing the two industries, it is evident that the shipbuilding and repair industry had a far more successful safety campaign to reduce the number of accidents at work sites. It is a remarkable improvement, considering that the shipbuilding and repair industry had a higher number of accidents recorded than the construction industry in the early 1990s. The key to the success of the shipbuilding and repair industry was the determination in

achieving the goal of safety excellence [5]. Constant emphasis on safety has resulted in the success today. Other key factors that attributed to the success include the implementation of comprehensive safety and health management systems and safe work practices as well as compliance with safety regulations; top management support; strong union cooperation and workers' involvement in safety programmes have also help to increase awareness and drive home the safety message to both the direct workers and the contract workforce in the shipyards. The attention paid to safety at the individual company level, and the strong cooperation and tremendous amount of mutual sharing of safety initiatives, innovations and experiences going on through ASMI at the industry level have helped to improve safety in the shipyards.

Another important aspect of the success of the shipbuilding and repair industry is in the selection and partnering of subcontractors with the shipyards [1]. Partnering brings together all parties involved in a construction project to eliminate conflicts through relationship building based on open communication and close cooperation for the purpose of establishing a mutually beneficial, proactive, cooperative environment [21]. The key to success of partnering is to have mutual objectives, trust and an understanding of each other's commitments. The results of partnering can be seen in the shipbuilding and repair industry. It has indeed instrumental in helping the industry to improve its safety performance greatly over the past decade.

ASMI President, Mr. Heng (2003–2005) stressed the importance of cultivating trust-based business relationships between shipyards, and supporting industries and sub-contractors. He attributed trust-building as an important component towards better collaboration among industry players. This could be achieved

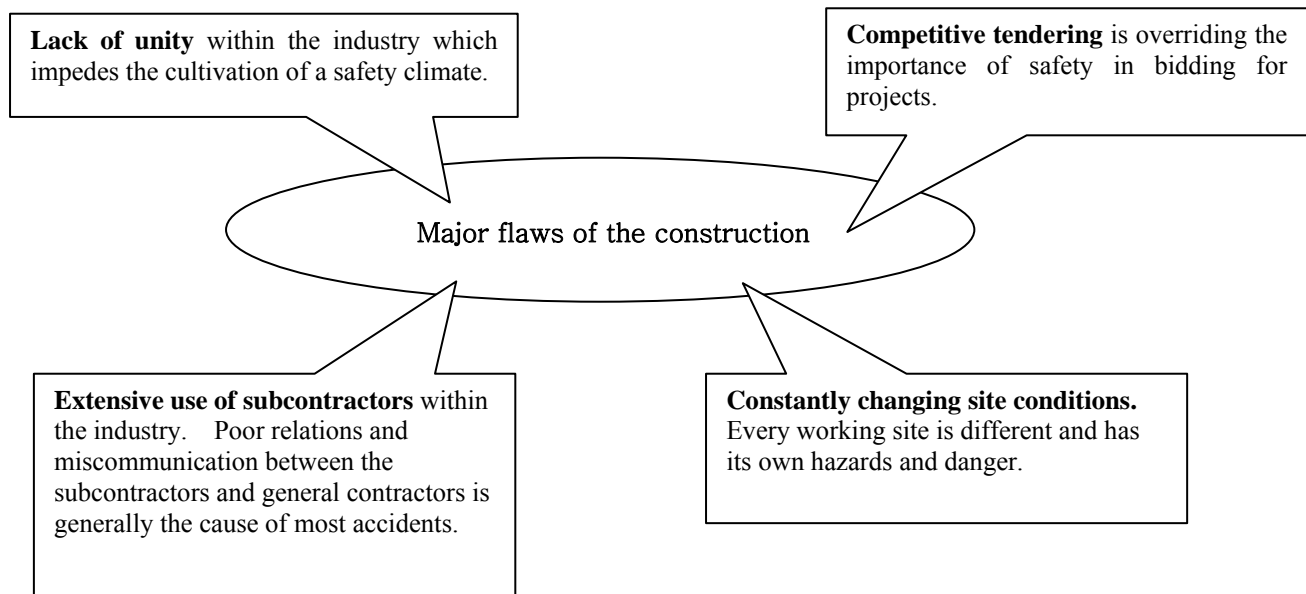
through better understanding of mutual systems, promotion of good business practices, and greater sharing of knowledge and improvements. Therefore, ASMI has organized dialogue sessions and activities that create greater unity among members and sub-contractors. These tend to foster greater communication between the sub-contractors and the shipyards and thus pave the way for greater co-operation and effectiveness in keeping the shipyards safe. One way which they have done so is in the way ASMI have categorized their members. There are basically three main groupings. They are Ordinary Member, Associate Member and Honorary Member [5]. Companies who are registered in Singapore and whose business activities are directly related to the shipbuilding and repair industry may apply to be an Ordinary or Associate member. Honorary membership is extended to relevant organisations by invitation only. Unlike the SCAL membership which categorizes members into their general trades, the ASMI's model attempts to merge all the members into two main groups, thereby creating opportunities for greater interaction

between main contractors and subcontractors. Another way to unite the industry is through social events. ASMI has organized annual soccer and bowling tournaments and even a CEO golf meet for managers and directors of members' companies. ASMI recognized the importance for industrial unity if it wants the industry to move forward. Hence, activities that are organized are focused on breaking barriers between firms in the industry as well as providing the top management of its member companies the chance to interaction.

### 3. KEY CAUSES OF ACCIDENTS IN THE CONSTRUCTION INDUSTRY

Although there are other causes of accidents within construction industry, this paper will only focus on the factors closely associated with the role of subcontractors and the effects of partnering (Figure 1). The causes of accidents shown in Figure 1 are found to be similar to those of the shipping and repair industry; except that the shipbuilding and repair industry do not experience changing site environments.

Figure 1: Key sources of accidents in the construction industry



As local construction industry relies heavily on the expertise of subcontractors, thus most of the works are done by them [14] and their involvement breaks up a fragmented industry into multiple layers and increases the problem of communication and co-ordination. Such problems resulted in most number of accidents involving them. Therefore, SCAL initiated the Singapore List of Trade Subcontractors (SLOTS<sup>iii</sup>) programme in 1992. The main objective is to identify and accredit a core of active subcontractors in the construction industry who are able to meet the quality and productivity standards of the industry [22]. However, this programme has not been able to succeed in bringing down the number of accidents as it lacks the critical element of success. The critical element to the success of the programme is that of the mindset of the clients. When safety is not emphasized by the clients, contractors and or subcontractors will definitely not be paying too much attention to safety because to achieve

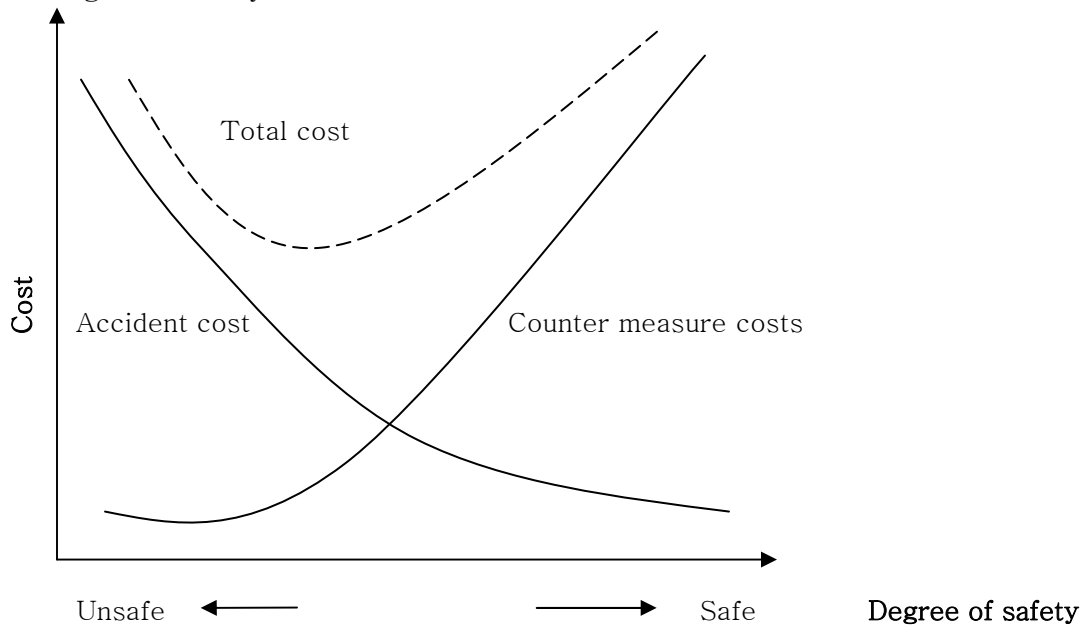
<sup>iii</sup> As of 23 April 1999, it is a requirement for subcontractors engaged in government related projects (for all trades except ceiling, glazing and metal work), to be registered SLOTS members. In addition, only SLOTS or BCA registered contractors will be granted work permits for their foreign workers.

high levels of safety requires extra cost. The contractors and subcontractors strongly believed that such costs will affect their profit margin.

Melchers [24] has proven that the above belief of achieving high levels of safety will require extra costs are incorrect as shown in Figure 2. Agreeing with Melchers, Stranks and Dewis [32] stressed that the greater the amount of safety measures put in place; the lower will be the overall expected costs, because of the smaller probability of accidents.

In a way SCAL has managed to bring together the players in the construction industry, from the leading companies to the subcontractors, by means of the registration system as shown in Table 2. However, registration is only a means of administrative formality, there seemed to be a distinct lack of interaction or co-operation at all fronts between members from different categories. If the construction industry is to be united, radical changes to the system must be introduced. Forums, dialogue sessions, seminars, co-operative programmes should be part of the initiation system for all the members. Ultimately, the main objective will be to bring the industry closer together to work towards a common goal.

Figure 2: Degree of safety vs. cost



Source: Melchers (1999)

Another fundamental flaw in the construction industry is that of competitive tender process and very often the lowest bid gets the job. Such selection methods has been criticized for not providing quality services and works [3], in addition, it has resulted in substandard workmanship and a 'quick-buck' attitude among contractors. Therefore, clients have a major part to play in this area. A study on specialty contractors by construction industry institute, found that the safety of subcontractors are largely influenced by the general contractors [17]. The selection of contractors must not be based on the lowest tender price but the best value for money. And that includes the cost of safety measures implemented. Studies have also shown that safety investment can increase profits, and reduce accidents rates [19].

#### 4. LESSONS TO BE LEARNT FROM THE SHIPBUILDING AND REPAIR INDUSTRY

There are three main lessons to be learnt by the construction industry. One, it is to unite the industry as a whole. ASMI recognize that in order for there to be any improvements in

safety, the whole industry must co-operate and work towards a common goal. They have adopted several measures that SCAL could take note. SCAL must look into the categorization of its members. The merger of subcontractors and contractors could facilitate greater interaction between both parties and may led to greater partnering opportunities. Following the example of ASMI, they have organized annual 'get-together' activities such as soccer and bowling competition for their members, and these activities provide another avenue for members to interact and bond together. Currently, SCAL do organized social events for its members however, greater effort is needed to bring together all its members [30]. SCAL should recognize the types of activities that will appeal to the masses of its members and direct their efforts towards that direction.

Two, the industry as a whole has to have a change in its mindset. According to Tan [34], the poor performance in safety in the construction industry in Singapore is because of the negative attitudes of supervisors, and the lack of safety supervision on site. Also, the current practice of awarding tender to the lowest bid has not been beneficial in terms of

safety, as the safety aspect has often been compromised. Clients have to balance the importance of safety and cost [27]. The Construction 21 report also indicated that clients are the ones that provide the impetus for change and ensure those construction projects are completed timely and safely using efficient means. According to ASMI Safety Chairman from 1997 to 1999, Mr. Wong, safety measures are not enough as ‘regulations are regulations’ and the most reliable results are those obtained by improving the mindset of the players in the industry. Therefore ASMI has

come up with safety themes, seminars and campaigns that are focused on specific themes to educate the workforce. Professor Lim, Chairman of the Advisory Committee on Occupational Safety and Health for the shipbuilding and repairing industry, believes that further improvements in safety would have to come from changing attitude and behaviour. This would mean moving towards Behavioural-based Safety (BbS) and a shift in focus from system management to behavioural management of safety outcomes.

Table 2: SCAL Members Classification. Source from <http://www.scal.com.sg>).

Category	Description
HONOURY MEMBERS	Individuals who have contributed to the advancement of the objectives of the Association and upon whom the Council may, in recognition of such services, confer honorary membership.
ORDINARY MEMBERS	Any person, corporate firm or partnership actively participating as general main contractors in the building and engineering construction industry.
<a href="#">ASSOCIATE MEMBERS</a>	Any person, corporate body or partnership engaging in allied services of the building and engineering industry, suppliers, product subcontractors and also firms with majority foreign equity or management.
<a href="#">TRADE MEMBERS</a>	Corporate bodies, firms, partnerships or sole proprietors engaging in the building and engineering construction industry as labor only subcontractors and/or other trade services suppliers.

Lastly, partnering creates a win-win situation for all. Partnering not only improves business relations it can also alleviate the problems of competitive tendering and hence bring about greater safety awareness. However, for the concept to flourish in the construction industry, it has to be accepted by all parties especially the upper management. The critical element of partnering is trust and it has to be slowly developed over time. The selection of subcontractors for shipyards is not solely based on the lowest priced tender but also on the subcontractors’ past safety performance and t

he safety programme. If clients are to emphasis their concern for safety, contractors will be compelled to adhere to their demands.

### 5. IDEAL CONSTRUCTION MODEL FOR SAFETY

Using this ideal construction model (Figure 3), the intention of this paper will concentrate on the partnering aspect and how SLOTS can play a role in it. Further research may be carried out on the Safety Management System (SMS) aspects of this model.

Currently, Ministry of Manpower (MOM),

Real Estate Developers' Association of Singapore (REDAS), SCAL and other agencies are looking into the development of the concept framework of the Construction Design and Management Regulations (CDM) [12]. The CDM will require every stakeholder, from developer to designer and from main contractor to subcontractor to play an active role in achieving safety excellence [33]. It attempts to bring together all the parties involved in construction in order to account for health and safety issues from before the design stage to the demolishing stage. Goh [16] states that the introduction of CDM Regulations to the Singapore construction industry will ensure that health and safety issues will be addressed early in a project so that there will be fewer ill health problems in the future and the design of buildings will be safe to construct.

Partnering can become an integral aspect of CDM. As mentioned earlier, partnering can improve the working relationship among the client, designers and contractors in a construction project. In a way, partnering helps to fine tune the mindset of the players so that the whole project group works well as a team [15].

Figure 3 shows a simplified working model for partnering. There are three main levels, each at different stages of construction. At the Project Initiation Level, before the commencement of the project, a design team has to be set up [29]. At the Selection of Subcontractors Level, before construction, the design team<sup>iv</sup> can make use of SLOTS to come up with an initial list of suitable subcontractors. The team will evaluate these subcontractors based on the selection criteria provided in Table 3 [6, 21].

Short-listed subcontractors will then go through an interview (Figure 3). The main objective of the interview is to let the project team have a better understanding of the subcontractors' background, and also for the subcontractor to have a deeper understanding

of the role that they might play in the team. It is also through this interview that partnering concepts are introduced and they are gauged by their response to the concept. The subcontractors will also be given the general specifications and estimated quantities and are asked to submit their tenders which will be analyzed by the project team. The main contractor holds the ultimate decision in deciding which subcontractor to be selected. Once the subcontractors are selected, they will be invited to a committee meeting with the rest of the team. The main objective of this meeting is to sign a partnering agreement which is to be developed by all members of the committee. Within the agreement, there can be pacts on safety and management issues and also expected targets to meet. The other focus of the meeting is will be for the safety officers to conduct a thorough safety review with all those involved in the project. Hence, in tandem with the objective of CDM, the emphasis on safety starts right from the beginning.

Figure 3 illustrates the elements to a successful partnering experience during the construction stage [10]. Basically, without **mutual trust**, the partnering model will never succeed. Trust has to be developed over time and not gained instantly. Measures have to be taken to build the climate for partnering. Social gatherings, partnering review meetings, project specific partnering workshop are some of the partnering tools that are widely used today. Firstly, a set of common project **goals** has to be established. Each party must make clear its stand on the issues on hand. With a common understanding of each other aims and goals, it will reduce problems due to miscommunication. Strategies have to be developed to achieve the goals stated. CDM and SMS are the essential management systems that can enable the project team to attain their goals through the strategic **process**. Throughout the duration of the project, the progress and **performance** of the contractors has to be monitored. When the required level of performance is not attained, the source of the problem must be identified by both parties so that counter measures could be taken via a **feedback** forum.

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<sup>iv</sup> Design team comprises of (a) Client and his Cost Consultants, (b) Project Design Manager, (c) Civil and Mechanical Design Engineers, (d) Architects, (e) Main Contractor, (f) Contractor's Safety Officers and (g) Project and Contract Manager.



## 6. RECOMMENDATIONS

The programme of the Singapore List of Trade Subcontractors (SLOTS) has to be revamped in order for it to be incorporated into the partnering model.

The proposed revamped programme must be able to achieve these objectives: (a) being a representative of the industry, (b) assisting in the training and upgrading of skills of workers and (c) to provide a list of recommended and accredited subcontractors with good safety records. However, the focus of SLOTS should be shifted towards partnering excellence. In order to boost the effectiveness of the programme, here are some suggested recommendations.

### *Reclassification of membership categories*

The main contractors and subcontractors should be merged as a group. This merging could facilitate easier interactions between both groups of contractors. It will also enable joint seminars and workshops to be conducted. Such activities will help both parties to have a better understanding of the roles they play in the industry. Social activities such as organizing annual games that appeal to the mass would encourage greater participation among the members and in turn build up the level of bonding within the industry itself.

### *Push for partnering concept in the industry*

The concept of partnering should be introduced to the contractors. Contractors under the SLOTS scheme can be made to attend workshops and seminars for partnering. A better knowledge of the partnering concept is essential to building better partnering relations. The SLOTS scheme can then be used as a stepping stone for the main contractors to source out their prospective partners. Several studies [7, 20] have shown that partnering projects on the average are more successful than traditional ones. However, Bresnen and Marshall [8, 9] have stressed that not all partnering projects do well and that there are no 'quick fixes' or methods that guarantee success. Thus, an integral part of such a scheme (SLOTS) is to establish a long term

collaborative working relationship for encouraging trust and communication. The roadmap for success for partnership process is to set up the partnership charter to spell out the safety objectives agreed upon basing on the teambuilding method in promoting good and safe practices with united efforts.

### *Restriction of access into the market*

The relative ease of entry into the industry has created problems of a congested market. Competition in the market is necessary to force companies to be more innovative and productive. However, the current trend of contractors undercutting one another is certainly unhealthy. Although the problems of competitive tendering can be due to the mindset of clients, one way in which the problem can be solved is to have Building and Construction Authority (BCA) to place more stringent requirements for potential entrants into the industry. This is to ensure that the new contractors are of a certain standard. In fact, C21 has also suggested that contractors be assessed on their safety management systems for the purpose of registration. Currently, the registry of contractors in BCA serves the procurement needs of the public sector only; hence business entities that are not registered with BCA are not precluded from conducting business as contractors or suppliers outside the public sector. Therefore it is highly recommended that regulations may then be passed such that only registered contractors in the SLOTS programme or the BCA registry of contractors are allowed to carry out any operations in the industry. In this way, there can be greater control on the number and quality of contractors in the industry [12].

### *The Construction Industry together as one*

The industry needs to be united as one in order to overcome the problems of safety. The task of bringing together an industry as fragmented as the construction industry is no mean feat; however things have to start somewhere. SCAL has to put in greater efforts to try and bring the industry together. The SLOTS scheme could be used as a stepping stone. By improving relations between the

contractors through bonding and interactive sessions, they can further network outwards to others in the industry. It is a long and time consuming process, but the benefits it will reap for the industry is insurmountable.

## 7. CONCLUSION AND FURTHER RECOMMENDATIONS

The safety of subcontractors on site can be enhanced by partnering and proper selection. The main emphasis is on the selection of subcontractors and building good relations with them. The partnering model could be used as a guide to incorporate the concept of partnering into the construction industry. However, SCAL and the major general contractor companies should also put in more effort to promote greater safety awareness among the subcontractors such as creating quarterly dialogue sessions for the industry players to address safety issues. The partnering model serves only as a general guide but it could be further developed to become a partnering tool for companies. However, it must be kept in mind that partnering is a concept that involves both parties; hence mutual trust and common goals are the key elements.

The shipbuilding and repair industry is an excellent case study for the construction industry. The industry had united and succeeded in the area where the construction industry failed badly. Hence, there are important lessons for the construction industry to extract from the experience of the shipbuilding and repair industry. The most important element in keeping accident and fatality rates to a minimum is to have the correct working habits and attitudes towards safety. Safety must be incorporated into the industry's culture and it must never be compromised for convenience or cost.

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