THE CONSTRUCTION SECTOR CHAIN DISASTER THEORY AND A CASE STUDY

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Abstract:
Management approaches are of paramount importance in the built environment. Efficient management approaches ensure timely project completions and consequently lead to economic growth. However, there are also challenges within the construction industry that could lead to disastrous effects and to significant death tolls. In this article, the Construction Sector Chain Disaster Theory (CSCDT) is presented. This theory mirrors the construction sector as an ongoing disaster zone. In light of CSCDT, a limited number of past accidents within the global construction industry will be investigated with respect to the building blocks of the theory and in view of inadequate management practices that have made positive contributions to triggering disasters. The identified shortcomings will enable a more comprehensive approach to management in favor of disaster minimization in the construction sector.

Keywords: Construction sector chain disaster theory, health and safety hazards, construction workers, management in the construction sector.

1. Introduction

The role of the construction industry has been notable throughout history. Whether representing a building of magnificent wonder or a large residential complex, the construction sector has consistently remained as one of the building blocks of civilization. Although new branches of construction constantly highlight the need to address new challenges in the built environment (Lin, 2012; Gohardani and Björk, 2012), the dangerous working conditions of the construction workers remain as a convoluted challenge (Grondstrom et al, 1980; Adsul et al, 2011; Sancini et al, 2012).

In this journal article, the Construction Sector Chain Disaster Theory (CSCDT) is developed from a hypothesis that in part reflects an established view point about the interaction between vulnerability, disaster and hazard. The purpose of proposing this theory is mainly to provide the larger scientific community with an approach to more efficiently address the health and safety issues of construction workers. The partial aim of this article is thus to elucidate the interaction between various elements of the theory and to highlight their individual and collective impact in this regard. Capitalizing on the application of CSCDT, the elucidated roadmap in this article provides an unprecedented option to address a potential disaster. Even though a great number of preventive actions are taken to avoid disasters, CSCDT typically targets the potential elements of a disaster before the actual event and hence provides an additional advantage over available procedures to target disasters.

2. Theory background

Perhaps the most important question that arises in the pretext of establishing a need for further insight regarding the health and safety hazards of the construction workers is the sheer reason why such a theory is needed. In light of an increasing level of building construction activities and the fact that construction accidents/hazards/fatalities are rather common (Lin et al, 2011; Pines et al, 1987; Ahlgren et al, 1983), the global research arena has to be revisited with objectives to identify a more efficient approach to manage health and safety aspects of construction workers in the built environment. Findings from a comprehensive literature review (Gohardani and Björk; 2013) have mirrored the following conclusions that equally serve as the basic motivation for the introduction of CSCDT:

- Over the last century, an increasing number of technological disasters have been reported. Until the turn of the century, the general trend has equally pointed to an increasing death toll due to the technological disasters which also include the activities of the construction sector.
- Building structures with unknown characteristics may endanger the lives of construction workers worldwide and result in ill-health and death.
- With an increasing level of understanding the health and safety hazards in the construction industry, more efficient prevention measures can be taken in order to enable a disaster management cycle which is able to respond to the rigorous demands of the construction industry.
- From a theoretical point of view, disaster can be perceived as a collective combination of hazard and vulnerability with subcategories such as: underlying causes, dynamic pressure, unsafe conditions and trigger events.

In consideration of the aforementioned findings, the quest for the CSCDT was initiated.

3. The Construction Sector Chain Disaster Theory

CSCDT is an alternative viewpoint that portrays the construction sector as an ongoing disaster zone. This perception establishes that disaster within the construction sector corresponds to the temporary or permanent ill-health or death of a construction worker. The fundamental brick stones of CSCDT are related to elements such as vulnerability, disaster and hazard. Khan et al. (2008) identified a connection between these elements and in wake of the drawn conclusions by Gohardani and Björk (2013), the relation between the aforementioned elements were expanded to the construction industry.

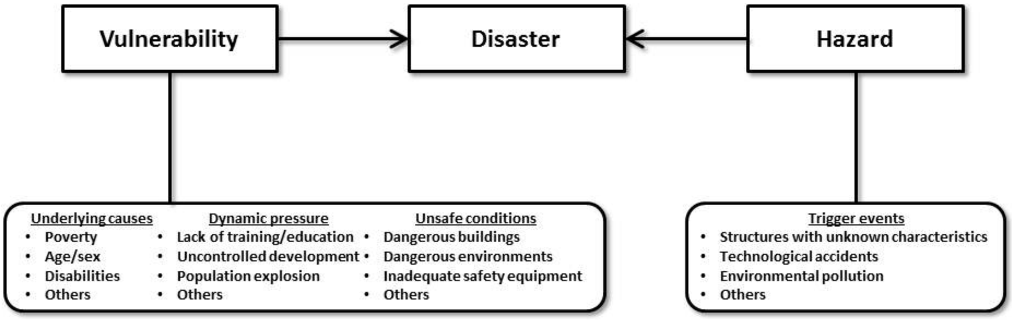

Figure 1. Vulnerability, disaster and hazard for a selected case in the construction industry (Gohardani and Björk, 2013).

If the highlighted elements in Figure 1 are adopted as the needed components for the occurrence of a disaster (temporary or permanent ill-health or death of a construction worker) in the construction sector, it can equally be determined that there is a resemblance between the occurrence of a single disaster and the secondary effects of that particular disaster. Since natural disasters represent one of the frequent types of disasters, it would be appropriate to address the chain effect in these events through an analogy to secondary effects in a particular natural disaster such as an earthquake.

Following an earthquake, flood and landslide could potentially occur. Hence, flood and landslide can be regarded as chain effects of the earthquake which initially triggered them. A similar vision can also be emerging for the CSCDT. Figure 2 represents a viewpoint that breaks down the collective chain effects into different action phases. These action phases depict various stages throughout the evolution of a triggering event over time. The triggering event in the case of the CSCDT is denoted by the occurrence of a disaster. In consideration of Figure 1, it would be interesting to connect the CSCDT with a number of elements in Figure 1. In all the events, a disaster takes place with the adopted definition of the CSCDT an interaction has already taken between vulnerability and hazard. Undoubtedly, the CSCDT is chiefly confined to the construction sector and the nature of the accidents would mostly be technological accidents that lead to the temporary or permanent ill-health or death of construction workers. The underlying causes, the highlighted dynamic pressure items or unsafe conditions should also be investigated on case by case basis to track their respective impact on vulnerability.

Figure 2 indicates that following a triggering event, the immediate action phase domain is followed by secondary action phases which in their own turn converge to consequential action phases and ultimately impact the triggering event in one or a number of ways. In order to investigate these events in further detail the following section provides an example of how a hypothetical scenario of a construction disaster can be traced through the CSCDT.

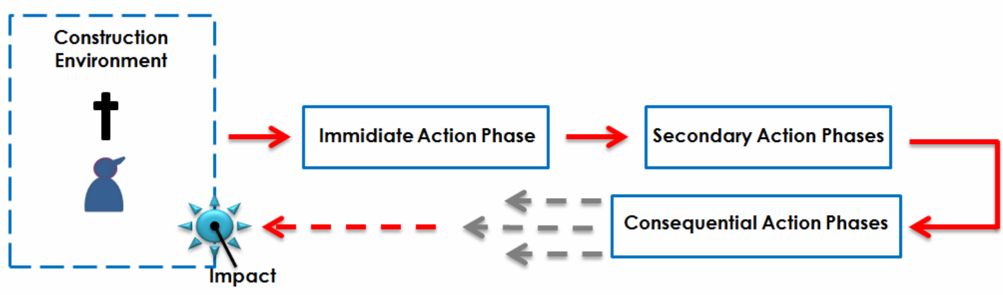

Figure 2. The various elements of the Construction Sector Chain Disaster Theory.

4. CSCDT and a hypothetical case

Hitherto, the fundamentals of the CSCDT have been highlighted and discussed. However, the application of this theory to the practical facets of the construction industry still remains ambiguous. For this specific purpose the illustrated blocks in Figure 2 can be revisited with a hypothetical series of events that are plausible for the construction industry. In addition to this initial approach of linking the various blocks of CSCDT to actual settings, the aim of management practices in conjunction with the findings of the CSCDT is to improve the health and safety conditions of construction workers.

The chain of events in the wake of a triggering event is a concise representation of the CSCDT. Under the assumption that the triggering event would refer to the death of a construction worker, it would be interesting to analyze CSCDT in further detail. Many glimpses from the sad chapters of renovation and building construction activities are related to the loss of life amongst construction workers while working on site a bridge or a building. For simplicity, one can make the assumption that a construction worker is working on a floor as the entire floor suddenly collapses. This results in the fact the construction worker is fatally wounded or instantly killed. The triggering event in this scenario would be the death of a construction worker as the initial action domain led to an immediate red light for ongoing construction activities regarding the site in mind. Hence, the loss of human life leads to a construction halt. Apart from the human aspects of losing an employee, co-worker, friend on acquaintance, this triggering event undoubtedly leads to a psychological impact among the construction workers. This is an exemplary event of a second action wave, which is found within the sequential action phase domain. Furthermore, the death of a construction worker also comes with the expense of the capital invested in that particular human being. This invested capital would be related to the training a construction worker has received over the years and the skills he or she has developed throughout his or her career. Some of the amoral perspectives of not adopting the laws that would regulate and protect the rights of construction workers are to ignore the loss of each worker as a human being and rather treat these as an economic asset. Hence, in many developing countries of the world, the social conditions imply that the loss of a construction worker should simply be addressed by replacement of that particular person with another person. This viewpoint does not bear a human or economic dimension. A more efficient approach to address the difficulties in the aftermath of a construction disaster is to take measures with respect to the management inadequacies. Despite the fact that the secondary action phases seem to be diverse in some ways not directly involved with the triggering event, the consequential actions they introduce have significant impact on the triggering event itself.

Tracing the path back to the construction worker who lost his or her life due to the collapsing construction floor, it would be a primary concern for the management team to track the problem back to its original source. This process involves identification of all the parties involved in designing that specific floor. Following an investigation regarding the cause of a disaster of this nature which also contributes to an economic burden and loss of production hours, the cause of the collapse will be identified. Furthermore, it can readily be established that dependent on the severity of a disaster, the overall impact and management aspects of dealing with that particular disaster could jeopardize the continuation of the entire project. The severity of a triggering event is perceived on the level of personal injury or damage. Thus, the immediate death of a construction worker does have a different impact than a direct personal injury such as blindness during the line of duty or a gradual impact such as eczema which might develop over many years. In order to link CSCDT with real life events, the following sections illustrate a real life scenario which will be analyzed for illustration purposes and for implementation of the theory.

5. One Case Study and the CSCDT – Collapse of the I-35W Mississippi River Bridge

Bridge 9340, also known as the I-35W Mississippi River Bridge, was Minnesota's fifth busiest bridge, carrying 140,000 vehicles daily. Opened in 1967, this eight-lane, steel struss arch bridge, carried Interstate 35W across the Mississippi River in Minneapolis, Minnesota, United States. Figure 3 details the location of the bridge in relation to the Mississippi River. On August 1, 2007, the bridge suddenly collapsed, killing 13 people and injuring 145 (Levy, 2007). Analysis of the events that followed this bridge collapse is the center of axis for implementation of the CSCDT.

The purpose of highlighting this specific event is to provide the reader with one possible application of the CSCDT and to identify a number of key points that should have had been considered to prevent this horrific event. In order to track the evolution of the events that were generated in the wake of the collapse, supplementary pieces of information have been added to the various phases illustrated in Figure 2.

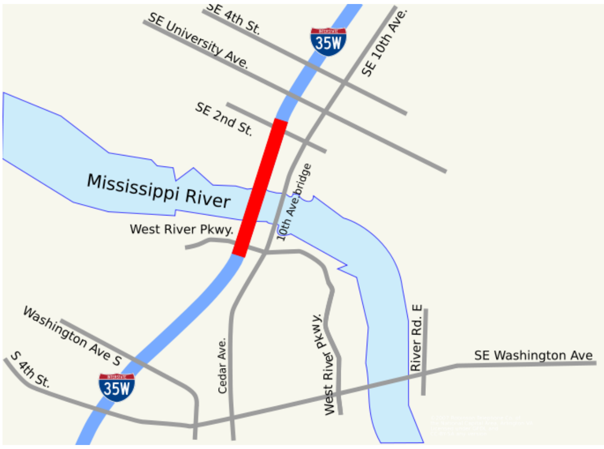

Figure 3. The geographical location of bridge 9430 in Minnesota, United States.

The breaking down procedure of each individual phase further provides the CSCDT user with a preliminary assessment regarding the flow of information to subsequent phases. Hence, the immediate action phase, the secondary action phases and other consequential action phases will individually be discussed.

The triggering event:

On Wednesday, August 1, 2007 in the midst of the afternoon rush hour traffic through the limited number of bridge lanes, the central span of bridge 9430 gave away – followed by the adjoining spans – consequently collapsing into the river and the riverbanks below. In this process, the south part moved 25 meters in the eastward direction. With approximately 100 vehicles involved, it was reported that the vehicle occupants and 18 construction workers fell 35 meters down to the river (Eye Witness News, 2007; Chicago Tribune, 2007). The main reason construction workers were present on the bridge was due to the fact that bridge was being repaired at the time of the collapse (Minnesota Department of Transportation, 2007). The construction work consisted of replacing concrete, lightning and guard rails. At the time of the collapse 4 out of 8 lanes were closed and there was 261,000 kg of construction supplies and equipment on the bridge (Hoppin, 2007).

Immediate action phase:

In the wake of the collapsing bridge, the immediate action phase was rapidly initiated. The rescue work began almost immediately and lasted for about three hours. The immediate action phase further culminated in subsequent action phases according to Figure 4.

Secondary action phases:

In the secondary action phases, the recovery of victims took over three weeks. Per request of the United States Department of Transportation (USDOT), the Navy sent 17 divers and a five-person command and control element from their Mobile Diving and Salvage Unit (MDSU) 2 (BBC News, 2007). Seventy-five local, state and federal agencies were involved in the rescue and recovery (Lee and Lewis, 2007). These included volunteers and emergency personnel from the St. Croix County in Wisconsin, and the following Minnesota counties: Anoka, Carver, Dakota, Hennepin, Olmsted, Ramsey, Scott, Washington, Winona and Wright, and others (Kyle, 2007). Once the last person's remains were removed from the wreckage, initial efforts were instigated of dismantling the bridge's remnants (Associated Press, 2007).

Hence, the demolition operation was substantially completed by the end of October 2007, enabling construction to begin on the new I-35W bridge on November 1, 2007 (City of Minneapolis, 2007).

Consequential action phases:

In the aftermath of the secondary action phases, federal officials brought some of the bridge steel and concrete to the National Transportation Safety Board (NTSB) Material Laboratory in Washington, D.C. for analysis into determining the cause of the collapse. The NTSB also interviewed eyewitnesses. Officials from the Department of Homeland Security (DHS) ruled out terrorism with regards to the collapse (Diaz, 2007). The United States House of Representatives and the United States Senate each voted unanimously for US$250 million in emergency funding for Minnesota. This funding was signed into law by President Bush on August 6 (Howarth, 2007; Qualters, 2010). In August 2010, the last of the lawsuits were settled for $52.4 Million to prevent prolonged litigation. The cases were handled via a novel consortium of legal entities that worked on a pro-bono basis (Frank, 2010; The Washington Post, 2012). Additional lawsuits were also brought to the company that designed the bridge (Dulek, 2007) and throughout these consequential action phases, traffic detour, job losses and a decline in small businesses were observed (Wyant, 2007; Cormany, 2008; Lohn, 2007). Furthermore, following the announcement of the replacement bridge – for $ 234 Million – the bridge was opened to the public on September 18, 2008 (Mn/DOT, 2007; Gohardani and Björk, 2013).

CSCDT analysis

The triggering event: One of the most striking facts that almost immediately raise concerns about the bridge collapse is the presence of construction supplies at the time of the collapse. Although, it can be argued that the total mass of the vehicles - that during typical circumstances - occupy the four closed lanes of the bridge are equivalent or less than the mass of the construction supplies, the best approach of the maintenance can still be questioned. The issue of redundancy is perhaps one of the most crucial aspects of the bridge design that has been overlooked. Throughout the history of the bridge, part of these issues where mentioned. However, a macroscopic view about the design equally reveals that the bridge design was partially made with a rather optimistic view that none of the supporting elements (such as gusset plates etc.) would malfunction. In the aftermath of this disaster, it is essential that structural designs and efforts of construction renovations and refurbishments are accompanied by a number of what-if questions. Even though this incident resulted in fatalities, the rescue and recovery efforts have to be praised. Through the declaration of emergency for the state of Minnesota, local officials were able to attract federal help which proved to have a tremendous impact on all the involved.

Secondary action phase: The secondary action wave was prominently fuelled by the declared state of emergency for the state of Minnesota. Hence, the recovery process started and assistance of in total 75 local, state and federal agencies were provided. Interestingly enough, the rebuilding efforts were also instigated at this point and hence, this procedure provides a viewpoint to question why traffic detour measures were not initiated in a earlier instant. This scenario provides a rather stellar example of vulnerability. The location of the bridge over the Mississippi River and the heavy traffic highlight the vulnerability level of transportation. In this regard vulnerability (the sensitive geographical location of the bridge) was combined with hazard (risk for collapse) and a disaster could be expected.

Consequential action phases: In continuation with efforts to minimize the risk for disaster, the combination of vulnerability and hazard should be carefully examined. Following the secondary action phase, the provided funding by the government provided one new measure to resolve the issue. Although an investigation of this incident was estimated to become rather lengthy, it also provided the government with important lessons. Much of the discussion regarding this particular topic seems logical after the occurrence of this disaster and hence the appropriate time frame for application of the CSCDT can be questioned. CSCDT simply encourage that what-if questions and scenarios are part of each and every construction project. Despite the fact that not all possible scenarios can be predicted beforehand, posing questions such as follows may impact the decisions to be made. For this specific case, the following questions could have made a change:

1. Is there any design risks associated with this bridge?
2. How does the bridge material degrade over the years?
3. Were any alternative traffic detour plans considered?
4. Would it be possible to utilize a combination of “gusset plates” and other supporting mechanisms to maintain the structural form of the bridge?
5. How was the timeframe for renovation of the bridge assessed? Was anything overlooked? Could the measure of assessments been more accurate?

In this specific case, the lawsuit settlements clearly illustrated that the initial construction phase can be highly contingent to the level of construction work. In other words, the entire domain will be directly impacted by the events that led to the triggering event. Conceivably, one of the most striking lessons learned by the implementation of CSCDT is to recognize that the structural failure of the bridge was not an isolated event. The CSCDT assists the user to track the evolution of this failure and further paves the path for in-depth analysis.

This specific case study has elucidated that additional measures could have been taken to prevent this disaster to occur. Due to the unknown characteristics of the gusset plates at the point of the accident, it would not be a valid point to criticize their usage in the construction of the bridge. However, there have been many additional points that could have raised red flags for the authorities regarding bridge 9340. In an ideal world one can envision a large number of these scenarios, but the reality does not allow such practical fluctuations. One of the principal aims of implementing the CSCDT in future construction and renovation projects is to learn from the past mistakes of the construction industry. If recognition of the dangerous occupational environment of construction workers is made, this will indeed facilitate the measures for a safer occupational environment.

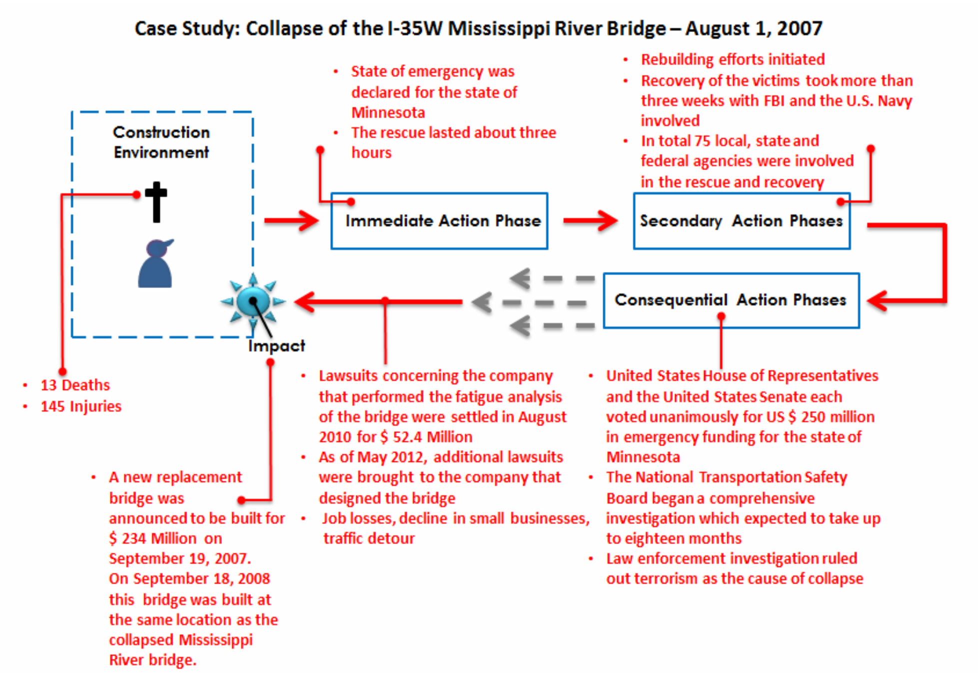

Figure 4. The various elements of the Construction Sector Chain Disaster Theory with an exemplary case study.

Even though, one can argue that the health and safety aspects of construction workers only concern themselves, an excursion through various phases of the CSCDT has clearly indicated that this is not the case. The risk of fatalities, casualties, lawsuits, and a questionable reputation are weighty factors for ensuring successful business development and a safe occupational health environment for construction workers .In view of the available instruments and methods used in the construction industry to diminish the impact of crisis situations, the CSCDT has emerged. In this study, only one facet regarding the application of CSCDT was considered. In an ongoing study however, the application of CSCDT for addressing the working environment of Swedish construction workers will be evaluated.

Conclusions

In the interest of reducing the health and safety hazard issues for construction workers, the CSCDT has been presented through two different approaches in this journal article. In the first approach, a hypothetical scenario has been unveiled for elucidating the step-by-step approach of the theory. In the second approach the focus shifted considerably to illustrate a real-life example where the theory can be implemented. Following the application of the CSCDT to the collapsing I-35W Mississippi bridge, it was readily revealed that the impact of this structural failure stretched beyond construction worker fatalities and casualties. The collapse of the bridge resulted in a significant socio-economic impact. In summary, the findings of this study suggest that the CSCDT should preferably be implemented throughout the initial construction and renovation phase to ensure that adequate measures are taken in favor of the health and safety aspects of construction workers.

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