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## Identification of the “Pathogenic” Effects of Disruptions to Supply Chain Resilience in Construction

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### Abstract

In today's interconnected world, disruptions arising from one party in a supply chain network could cause disruptions to other parties in the chain. Indeed, recent evidence suggests that supply chain disruptions had caused a wide-scale impact to the construction industry in various developing countries including the Malaysian construction industry, with increasing report on project performance deficiencies such as cost and time overruns of severe magnitudes. Although risk management is widely practiced in construction, the challenge now is to make systems and construction supply chains sufficiently resilient so that the project organisations can bounce back and thrive from catastrophes and disruptive events. Past studies of supply chain resilience however tend to overlook the underlying latent conditions that reside in the system that made an organisation vulnerable to such disruptions in the first place. The “pathogen” metaphor is used in this study to reflect these inherent hidden vulnerabilities that remain dormant in a system until a critical failure occurs. Although these pathogens are hidden and may not be causing any problem at the moment, they might trigger a later onset problem causing cascading impacts to the supply chain and its operations. While disruptions in construction are often difficult to foresee and is hard to eliminate entirely, these pathogens, however, can be identified and mitigated before a disruptive event occurs, which this paper aims to discuss. This paper therefore presents the identification of key pathogenic effects in the Malaysian construction industry through preliminary interviews with four experts in the field. Overall, the identification of the pathogens in the study will help the researcher to assess how vulnerable the project organisations are to making significant errors in a systematic way, thus providing the foundation to build appropriate strategies for their prevention and build the resilience of the construction supply chain to disruptions.

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## 1. Introduction

The modern supply chains in today's global economy are becoming highly complex and interdependent through globally dispersed assets and international trade of products and services. The interdependency among supply chains in the uncertain environment has brought an increasing number of interconnected risks that transcend beyond the organisation boundaries. This includes risks such as supply chain disruptions, natural disasters, geopolitical risks and unforeseen events that caused disruptions to business operations and great losses to organisations. It is indeed challenging to identify and anticipate such risks as they could emerge from any direction of the linked parties in the supply chain and its operating environment. The impact of such risks could also spread across related and unrelated parties, causing significant disruptions to their operations. This is prevalent especially in the construction industry. The main difference between the construction industry from other industries is that it deals with temporary supply chains that work on different start and end dates in several phases of one-off construction projects. This makes it difficult for construction parties to gain full visibility of their supply chain operations and its associating risks, making them highly vulnerable to any disruptive events [1]. Understandably, managing these risks and parties from different tiers of the supply chain in construction is indeed challenging especially when disrupted with disruptions that cause large swings in capacities and resources in project delivery. This is evident not just in the developed countries, but also in various developing countries, whereby increasing report on project performance deficiencies were reported due to supply chain disruptions [2,3].

One of the developing countries that have been hit hard by supply chain disruptions is the Malaysian construction industry. Similar to other developing countries, the local projects in Malaysia have frequently end up being delivered late, causing cost overruns and poor project delivery [4,5,6]. The recent report on local public sector projects [7] also identified several supply chain disruptions in project delivery such as non-conformance of work to specifications, low quality, unreasonable price, wastage and transportation disruptions that caused poor project performance. For instance, the second Penang Bridge, which has recently been completed, faced delay for more than 12 months due to additional technical aspects that were not considered in the early stages [4]. This shows that despite the formal risk management plans imposed by the public organisations, managing supply chain disruptions had constantly become an issue to the public organisations in meeting their project objectives.

Indeed, it is difficult for the public organisations to have full visibility of their supply chain operation due to the large scale of public projects and the extent of their supply chain network. This could be problematic as it makes it harder for the public organisations to detect any hidden problems or latent conditions that lie within their supply chain network. These latent conditions, also known as “pathogens”, tend to be overlooked by the public organisations in its current risk management practice. Although these pathogens are hidden and may not be causing any problem at the moment, the pathogens might trigger later on and manifest into catastrophic disruptions [8] if they are not identified and mitigated much earlier in the project. While disruptions in construction are often difficult to foresee and is hard to be eliminated entirely, these pathogens, however, can be identified and mitigated before a disruptive event occurs, which this paper aims to achieve. The aim of the paper is to therefore identify the critical inherent pathogenic influence within the public organisations and its supply chain network that make them vulnerable to such disruptive events in the first place. The identification of these pathogens will help the researcher to assess how vulnerable the project organisations are to making significant errors in a systematic way, thus providing the foundation to build appropriate strategies for their prevention and build the supply chain's resilience to disruptions in public projects.

## 2. Literature Review

### 2.1. Supply chain disruptions and resilience in construction

Supply chain disruptions can be defined as an event that can affect the performance of the supply chain causing deviation of their operation from meeting the project objectives [9,10]. Previous literature exists on managing supply chain disruptions from the manufacturing, retail [11,12], automotive and oil and gas sector [13], but little attention has been paid to the disruptions faced by the supply chain in construction industry, especially in the developing countries, such as in the context of this study. The Malaysian construction industry has faced several supply chain disruptions [4,5,6] that deter the government's goals to become a developed country by the year 2020.

Delays due to supply chain disruptions in local public projects are prevalent, for instance, the construction of a large dam in Terengganu faced significant delay due to the lack of expertise of the contractors hired to helm the construction of the dam [7]. Disruptions by client are also quite common in public projects, whereby the frequent changes in scope of the public projects had resulted in cost overruns and delay [14]. These disruptive events had caused the public organisations' to not get the best value for money for their expenditure, which consequently hampered their reputation in the public eyes. Many initiatives have been put forward by the Malaysian government and previous researchers in light of this supply chain issue such as partnering and outsourcing [4,15], but there is still a lack of understanding on the current resiliency of the public organisations and its supply chain and how they currently respond and recover from actual disruptions.

In order to deal with the supply chain resilience, Pettit et al. [16] assessed the linkages between the organisation's vulnerability and a set of successfully employed capabilities to overcome that vulnerability. However, the study tends to look at vulnerability in a static condition without considering the latent conditions, thus missing some of the key driving forces that influence the supply chain vulnerability, which this study aims to address. Within the supply chain resilience literature, to date, resilience in the construction industry also remains under-researched due to the lack of participation from construction supply chains in previous studies. Most studies looked at a single organisation across different industries [16,17,18], overlooking the effects of connectivity between organisations across the supply chain. The lack of empirical study across the supply chain limits the current understanding of the hidden problems and interdependent risk of disruptions between organisations in the system, which is what the Malaysian construction industry is currently suffering from. Without understanding the underlying problems and the current state of the system, the resilience strategies imposed in previous studies [16,19,20] might not be effective to build their resiliency to disruptions. Overall, there is definitely some prospect that this situation can be improved both in theory and in practice, hence the value of this research.

## 2.2. Pathogenic influences in construction projects

As previously discussed, it is important to consider the underlying reasons as to why a supply chain member might be more vulnerable in certain areas than the other. These latent conditions have been referred to as "pathogens" in previous studies [8,21,22] where they were identified as the key factors that set the conditions for disruptions such as errors, failure and disputes to occur in construction projects. In studying the latent conditions in projects, Busby & Hughes [8] suggested a distinctly systemic way of thinking about error and failure, and introduced the term "pathogens", whose greatest conceptual value is that they remain dormant in the system until an actual failure occurs. This term was originated in the field of biology as an analogy for the development of disease in natural organism. The pathogens were defined in the study by the following qualities [8]:

- "They are a relatively stable phenomena that have been in existence for a substantial time before the problem occurs"
- "Before the problem occurs, they would not have been seen as obvious stages in an identifiable sequence failure"
- "They are strongly connected to the problem, and are identifiable as principal causes of the problem once it occurs"

Subsequently, Busby and Hughes [8] revealed 8 main categories of pathogens identified in their study that had caused significant problems in large scale engineering projects, as listed in Table 1.

Table 1. The main categories of pathogen [8]

Category	Description
Practice	Pathogens arising from people's deliberate practices
Task	Pathogens arising from the nature of the task being performed
Circumstance	Pathogens arising from the situation or environment the project was operating in
Convention	Pathogens arising from conventions, standards, routines and codes of practice
Organisation	Pathogens arising from organizational structure or operation
System	Pathogens arising from an organizational system
Industry	Pathogens arising from the structural property of the industry
Tool	Pathogens arising from the technical characteristic of the tool

The same “pathogen” metaphor was also used in the following study by Busby and Zhang [21] to identify the causes of organisational breakdown that are built into projects at their inception. The study found that project participants sometimes have different interpretations of what actions or decisions are pathogenic and what decisions are taken as adaptive or protective measures. In a different context, Love et al. [22] adopted the pathogens metaphor to assess project disputes. Despite identifying the pathogens and its effect on project performance, both the previous and latter studies however did not address the pathogens in relation to the resiliency of the supply chain in dealing with disruptions, which this study aim to assess.

### 2.3. Synthesis of literature: Adopting the concept of pathogen to resilience studies

Past studies have adopted the concept of “pathogens” in various context; in relation to pathogens in the medical sector [23], error in construction projects [8], organisational breakdown [21] and project disputes [22,24,25]. While research relating to pathogens in this study’s context of supply chain resilience does not exist, the use of “pathogens” by previous researchers suggest that the term can be applied and tailored to different area of research, especially research relating to failure. Failure in the sense of this study generally mean the failure to achieve project objectives due to a foreseeable or unforeseeable disruptive event that affects the usual operation and stability of an organisation or a supply chain [26]. Identifying the pathogens in the resilience context will help address the research gap identified previously in resilience studies. Although researchers have focused on the capability of organisations to survive, adapt and grow in the face of disruptions [16,19], without addressing the root cause or inherent pathogens that reside in the system, the effort to implement resilience strategies would be problematic as organisations will be used to making the same mistakes repeatedly, making them more vulnerable to disruptive events. Figure 1 depicts the relocation of the concept of pathogens within the resilience context.

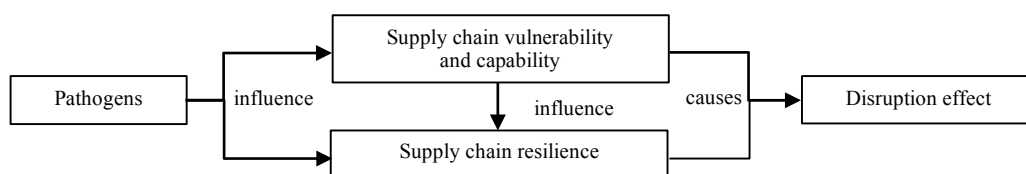


Fig. 1. Adopting the concept of pathogen to supply chain resilience

Certainly, disruptions in construction are often difficult to predict and is hard to be eradicated entirely, but these pathogens in Figure 1 can be identified and mitigated before a disruptive event occurs. By tackling these pathogens or root causes, the supply chain vulnerabilities can be reduced and the risk of disruptions to occur can be avoided in the first place. This study therefore aims to identify these pathogenic influences that caused the public organisations and its supply chain to be vulnerable to such disruptions. It also allows the researcher to obtain a holistic view in assessing and building resilience of the construction supply chain.

### 3. Research Method

In fulfilling the research aim, the study adopts the qualitative research method as it is an ideal way to explore the views and experiences of the professionals [27] in dealing with disruptions in public projects. Semi-structured interviews were conducted in this study to identify the underlying pathogens within the public organisations and its supply chain as detailed insights on the participants’ attitudes, thoughts, and actions are required. Purposive sampling was used to ensure particular professionals from both the public organisations and its supply chain (i.e. private organisations engaged) are selected in this study. In this paper, preliminary interviews were conducted with four construction professionals working in Malaysian public projects. The interview data were analysed through the computer software package Nvivo to identify the common themes. Similar to previous studies [24,25], content analysis was used to analyse the qualitative data, whereby the pathogens identified through the analysis of the interview data were compared against the pathogens laid out from the literature (see earlier Table 1). As different respondents may discuss different pathogenic influences based on their particular situation, emergent pathogenic themes were also considered. Interviews were recorded and transcribed in Malay, and relevant parts were translated into English before the analysis.

Overall, the respondents include one project manager (who also acts as an engineer) and one superintending

officer (SO) representing the public organisations, one engineering consultant from the external organisation engaged to deliver the public projects, and one contractor. The interviews were conducted face-to-face through the agreed appointments set by the researchers with the respondents. All respondents had over 20 years of experience working in public projects, hence were able to provide meaningful perspective on their experiences in dealing with disruptions in public projects. The respondents were also mainly involved in large scale engineering projects (i.e. roadworks, bridges, dam), which are the main projects that the public organisations are involved in. Despite only having four respondents, the researchers believe that it is sufficient to provide an overview of the current real world scenario in the public sector projects towards identifying the potential critical pathogenic influences. The preliminary outcome will also become a good platform for the researchers to further explore about the subject matter in future study.

#### **4. Findings and discussion**

The most common pathogens that resulted in disruptions identified from the interview data are practice, circumstance, and the emergent pathogen of behaviour. These pathogenic influences are further discussed below.

##### *4.1. Practice pathogen*

The practice of poor assumptions in decision-making had caused significant disruptions to the public organisations' engineering projects. This is evident based on the consultant's experience in dealing with a bridge project. In this case, the public organisations wanted to utilise an existing bridge and upgrade it into a main road instead of building a new road in order to reduce costs. Although this practice was seen as a way to save money, the initial estimates of the existing bridge failed to consider the high traffic load that will come when the bridge turns into a main road. The consultant highlighted that,

“The existing bridge is used mainly by the local people to commute to their plantation farm. If we were to modify this existing bridge to become the main road, there will be a significantly higher traffic. These costs unfortunately were not captured during the award stage”.

The consultant stated that the estimates were based on basic upgrading works which were not sufficient to the project. Further inspection, simulation and projection of the traffic loading in 10 to 20 years had to be conducted by additional specialists to ensure the bridge can carry the expected high loading, which subsequently adds to the budget. It can be seen here that poor assumption by the public organisations on the costs of reusing the bridge had increased their vulnerability to budget overruns. In making such decision to save costs, additions to the design and resource when reusing the bridge went unnoticed throughout the planning stage causing significant raise of the project budget. This shows that the practice of satisfying goals of saving costs could also end up being pathogenic to the public organisations. The consultant's practice of outsourcing their work to assess the bridge could also be pathogenic to the project budget as additional external parties need to be engaged to execute the design work.

The SO also addressed similar pathogenic practice of poor assumption. During the construction of a roadwork project, a utility was discovered on site that could not be replaced due to the high costs of replacement. The SO believes that this was caused by the carelessness in terms of the planning and design work, whereby the parties involved did not actually go to the site during the planning and design phase. The practice of poor assumption by looking at design drawings at the initial phase without the actual verification on site had caused pathogenic effect to the subsequent construction phase of the project. However, the consultant argued that this pathogen can not be predicted earlier before actual disruption occur. It was noted that while some risks can be identified earlier, underground utilities such as pipewater and piling can only be identified later during excavation on site. Furthermore, the consultant added that in dealing with a very long road of highway, they could only map 7 to 8 points in their utility survey due to the limited budget and time imposed by the public organisations. Thus, it might be the case that the precedent act by the public organisations that do not want to spend so much money and time on the planning phase contributed to their vulnerability to the utility disruption at the first place. This led to the consultant to proceed with tentative assumptions based on the limited time and resource that they have in producing

the final design. Examples of these disruptions and the pathogens that contributed to their occurrence are represented in Figure 2.

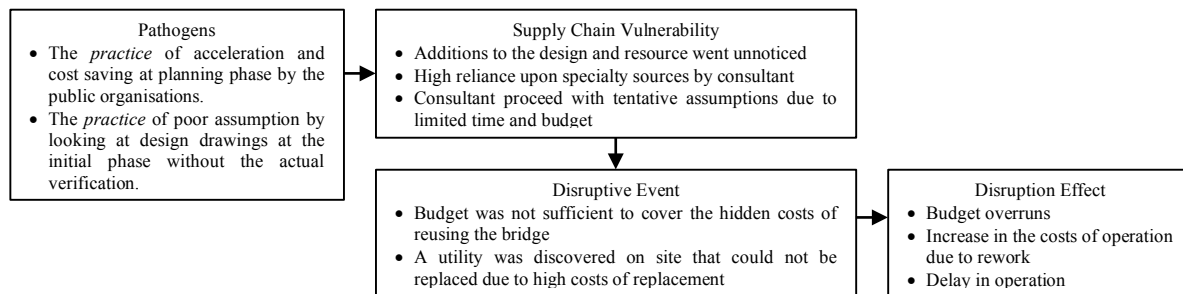


Fig. 2. Underlying practice pathogen that caused disruptions

#### 4.2. Circumstance pathogen

The circumstance arising from the political environment that the projects are operating in was identified as one of the main underlying latent conditions for disruptions in public projects. The project manager acknowledged that the first factor in the list of public project risk priorities had always been political. The contractor also expressed his concerns on political influence during tendering, particularly in the direct negotiation of nominated subcontractors by the public organisations. He finds that such project team arrangement feels like a force marriage, as the contractors have to sign the subcontractors under them even though the public organisations tendered it. This shows that the circumstance of unfavorable project team selection, that could be linked with the political environment, is perceived as pathogenic to the contractor. Changes in political power was also identified as pathogenic to the contractor's operation. Based on the contractor's experience, due to the change in government power to the opposing party on the state that their site was located in, the government authority protested and closed their services in that state. This had subsequently caused significant delay in the approval of land acquisition of up to two years. Hence, even though it only involves external political parties that is not directly related to the project, such political circumstances could still disrupt the public organisations and contractor's operation.

Financial circumstances of the public organisations was also deemed as pathogenic to the engineer as it limited his design standards. The engineer stated that they mostly have to optimised the design based on the available budget instead of maximising the design standards. Ultimately, even if they produce the best design, the public organisations do not have sufficient budget to implement the design. The lack of financial resources by the public organisations could therefore reduce the standard of design of the roadworks, which could subsequently lead to quality problems. On the other hand, the contractor had also faced significant financial disruptions due to economic circumstances. The rise of oil price had affected the contractor's operation significantly, whereby the contractor could face an immediate loss of 28 billion Ringgit Malaysia. This is because when the price of oil increased, the price of bitumen increase, and when the bitumen price increased, the cost of material and transport will also significantly increase. In this case, the contractor had to absorb all the losses due to the current procurement arrangement with the public organisations, whereby in the turnkey contract, there is no Variation of Price. This shows how the pathogenic effect of the current circumstance of economic pressure and procurement arrangement were indeed critical to the contractor, causing substantial loss of profit to the contractor. The low risk sharing arrangement between the contractor and the public organisations also made it harder for the contractor to recover from such disruptions. Ultimately, the contractor had to mobilised their resources by cutting down subcontractors to reduce their losses.

#### 4.3. Behaviour pathogen

Opportunistic behaviour by contractors is also seen as pathogenic to the consultant and the public organisations. For instance, according to the consultant's experience, the contractors tend to use unsettled land matters as an excuse to claim for extension of time (EOT) for roadwork projects because they could not start work on site. However, the consultant claimed that the contractor did not necessarily had to wait until all the existing utilities are

relocated before he can start work on site. There were certainly some areas on site where the contractor can begin their work, it is only the 'red areas' that are still unsettled and could not be touched yet. Subsequently, the contractor was able to justify and use this land matters as an excuse to get the EOT up until three times. Ultimately, the contractor's act of taking advantage of the unsettled land matters had caused the contractor to be penalised by the public organisations for liquidated damages due to the late completion of the overall project. This had also caused the contractor to face the significant loss of profit. The contractor interviewed acknowledged that for contractors, every disruption comes opportunity because problem to the contractors means money. The contractor explained that he managed to recover from financial losses in a recent project by modifying the work sequence, technical and the specifications of the project. However, the contractor justified that,

"I took advantage of alternative specifications and work sequence to cut cost but I never break the law, I only bend the law. It is like if we take a ruler and bend it as much as we can but never break it."

Nevertheless, the project manager from the public organisation identified this act as pathogenic, as the contractor usually finds the area that they can cut their costs to gain profit. This subsequently affects the quality of the work. This opportunistic behaviour can therefore be seen as pathogenic in some cases by other parties, but in the case of the contractor, this behaviour of taking opportunities was seen as a reactive action for them to recover from disruptive events.

There is also a common "us versus them" attitude among project team members identified by the respondents. All respondents seem to have a common view that conflicting behaviours among parties is one of the main pathogens that contributed to the vulnerability of the project team to disruptions in public projects. The contractor pointed out that,

"It is usually the case where the client goes, "oh, I am the client, listen to me", the contractor says, "oh, I am the contractor, I have got to make profit, I do not want any losses", and for the consultants, "oh, I am the policeman here!" and they only observe our mistakes. Sometimes the public organisations also have this attitude, "I am from the public organisation, I have authority". That is problematic as well."

This divergence usually leads to problems as each party has their own priorities. There is no doubt that each party has their own interests, but it is important for the contracting parties to arrive to a certain agreement so that the project can be delivered effectively. The SO finds that behaviour is the most problematic risk as it is hard to mitigate someone's behaviour. This is also known as 'active failure' by Love *et al.* [25], whereby it involves the inappropriate acts by people who are in direct contact with the system or operation. These 'active failures', when combined with the pathogens could cause significant problems and adverse impact on project performance. This shows that the problem is existing and already lies within the behaviour of the contracting parties itself.

Overall, the findings of this study were consistent with previous similar studies [8, 25], whereby 'practice' and 'circumstance' were identified to be the critical pathogens that caused significant disruptions in construction projects. However, unlike Busby and Hughes' [8] and Love *et al.*'s [25] studies, the nature of the 'task' performed was not identified as pathogenic to the respondents; an emergent theme of 'behaviour' was identified as pathogenic instead. Behaviour was not seen as a pathogen by these past studies but rather was considered as one of the triggers that could cause the pathogens to arise. However, in treating the pathogens as subjective interpretations (i.e. what the respondents considered as being pathogenic) in this study, the researchers find that behaviour was one of the main pathogen that was constantly raised by the respondents as the underlying conditions that make them susceptible to disruptions. It is also worth noting here that the pathogens identified could be interrelated, for instance, the contractor's poor financial circumstances could lead to their opportunistic behaviour of cutting costs. Indeed, Reason [23] recognised that behaviour is difficult to change, but believes that the conditions under which people work can be improved and remedied before disruption occurs. Understanding the behaviour of the project team could therefore help in developing the countermeasures to other pathogens identified in previous literature.

## 5. Conclusion

This paper has discussed the relevant pathogens and vulnerability of the public organisations and its supply chain to disruptions in public projects. Pathogens identified from the preliminary interviews include people's deliberate practice and pathogens arising from the circumstance that the project was operating in. The practice of poor

assumptions at the planning and design phase had disrupted the subsequent construction phase of the project. The failure of these assumptions was not realised until an actual failure occurred on site. Furthermore, the current circumstances of political interferences and poor financial and economic conditions had also resulted in unfavourable project team selection, limited quality standards and the significant loss of profit faced by the contractor. Additionally, behaviour was also identified as pathogenic by the respondents, whereby opportunistic behaviour by contractor and conflicting behaviours among parties had affected the project performance. Overall, the identification of the pathogenic influences through these preliminary interviews had allowed the researchers to have a good understanding on the area that the parties are vulnerable at. It also becomes a good foundation for the researchers to conduct further interviews and analysis in future work. The public organisations will also have a better understanding on what is pathogenic to their project team, which might not be clearly visible before. Furthermore, considering that there are a lot of studies conducted on cost and time overruns in construction projects, the distinct approach of this study that looks at these problems from the pathogenic point of view could address the gap identified in the literature. The relocation of the literature on pathogens and its applicability within the resilience context also adds value to the overall resilience agenda and conference theme, particularly in understanding risk in a pathogenic context.

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