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SUSTAINABLE SUPPLY CHAIN MANAGEMENT IN WATER RETICULATION WORKS

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Abstract — Since the emergence of sustainability, people have generally focused on issues related to the triple bottom line: social, economic, and environmental. This paper focuses on the integration of sustainability and supply chain management in the construction industry, particularly in water reticulation works. The peculiarities in documentation and technical issues encountered during the water reticulation works had prompted the need for this research. The challenges associated with the implementation of sustainable supply chain management in water reticulation works in Malaysia were identified, and improvements were suggested to overcome these challenges. A qualitative study was conducted by having a case study on six different packages of pipe replacement projects. An in-depth interview was carried out with semi-structured questions based on predetermined themes identified in the literature review. Based on the findings from four participants who were interviewed, they corroborated the costs, management, technical capabilities, complexities, mindset, and cultural changes. In conclusion, industry professionals can expand on numerous management facets to enhance future improvements.

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***Keywords*:** Malaysian construction industry, supply chain, sustainable supply chain management, water reticulation

1.0 INTRODUCTION

People have mostly concentrated on issues connected to the triple bottom lines, which are social, economic, and environmental, since sustainability first appeared. There has been a growing awareness recently about integrating sustainability into construction issues [1]. Therefore, scholars are reorienting their research on supply chain management to incorporate sustainability considerations. Construction supply chain management initiates with the initial design and plan and persists until the project's completion. Therefore, sustainability in supply chain management needs to be diversified across all stages, considering the three significant aspects of social, economic, and environmental [1, 2].

Furthermore, the United Nations (UN) declared the Sustainable Development Goals, also known as SDGs, in 2015 with 193 member states on 17 SDGs and targets [3]. SDG 6, which aims to provide clean water and sanitation for all, is a significant goal to achieve by 2030. Thus, it is essential to have proper management of water and sanitation to achieve the goal [4].

Water reticulation works, comprising complicated and expanding water pipe networks, play a crucial role in providing clean water, which is necessary to our everyday lives. Over the years, there have been major advances in pipeline technology. However, pipes can be deteriorated by an increase in age, which has led to failures such as pipe leakage that have increased unaccounted and non-revenue water losses [5]. A point worth mentioning is that the ageing of pipes leads to high failure rates in water supply networks, resulting in high maintenance costs [6].

Air Selangor, one of Malaysia's largest water utility providers, has introduced a pipe replacement programme to address the problem. In 2022, Air Selangor will have completed 77.2 kilometres of replacing dilapidated pipe and old pipe networks to ensure water sustainability in the future [7]. Thus, it is very intriguing to do research on what the challenges are in the supply chain management for water reticulation works to be integrated with sustainability, especially in supporting SDG 6.

This paper discusses seminal approaches to sustainability and supply chain management for water reticulation works. This paper aims to comprehend the qualitative concept of sustainability as it relates to supply chain

management in water reticulation works, using a case study of a pipe replacement project by Air Selangor as an example. Over the years, Air Selangor has integrated sustainability with supply chain management to achieve the triple bottom line of social, economic, and environmental benefits. However, a thorough examination of its implementation remains necessary. Therefore, this paper intends to identify the challenges associated with implementing Sustainable Supply Chain Management (SSCM) for water reticulation works in the Malaysian construction industry and provides recommendations to overcome these challenges.

2.0 SUSTAINABLE SUPPLY CHAIN MANAGEMENT

Originally, there were three widely explained pillars of sustainability: social, economic, and environmental aspects [8]. It is also suggested that sustainability includes resource depletion, nature and other ecological aspects of conservation, as well as quality of life for human well-being [9].

Generally, Supply Chain Management (SCM) is defined as "the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer" [10]. It first originated in the manufacturing industry and has since expanded, but it is still largely dominated by logistics [11].

Moreover, the introduction of SCM is underscored as a suitable methodology for addressing fundamental issues in the construction supply chain [12]. This is achieved through the understanding of existing problems, redesigning, control, and continuous improvement. It has an integrated framework made up of five aspects: flow of material and supply management, live information and communication exchange, technology support, supply chain coordination and integration, and safety management issues [1].

According to a study by [11], as cited in [1], there are four roles in construction SCM. These roles include focusing on the interface between the supply chain and construction, managing the entire process of transferring activities from the construction site to the supply chain, managing the supply chain itself, and integrating the SCM with the construction site.

Moreover, to achieve the goal of sustainable development for water quality and resource management requires a very particular and detailed approach [13]. Furthermore, the same study has identified several challenges facing the water industry, including inadequate coordination among stakeholders, unstructured regulations and enforcement, insufficient budget allocations, and privatisation involvement. The entire process of supplying safe water while preserving its resources can be a difficult task due to leakage and theft [14].

2.1. Challenges in Implementing Supply Chain Management

Various studies have previously identified challenges in implementing supply chains, as detailed in Table 1 below. The literature review identifies five major themes that pose challenges in SCM implementation: costs, management, technical capabilities, complexities, and mindset and cultural changes.

Sustainability and SCM have evolved over time. Companies aim to achieve the triple bottom line of sustainability—economic, environmental, and social—by integrating sustainable business processes with supply chains [17]. In addition, the definition of SSCM is coined as “the management of material and information flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental, and social, and stakeholder requirements into account” [1].

Furthermore, the combination of three sustainability dimensions with supply chain management can lead to a sustainable supply chain [1]. A sustainable supply chain requires meticulous observation from the initial stages of raw material procurement and production until the final handover to the client. The industry should adopt and implement practices such as green purchasing, government policies promoting sustainability, cleaner production, and all aspects of the green supply chain [18]. Thus, SSCM expands upon the extensively discussed topic of supply chain management, integrating sustainability and the triple bottom lines of social, economic, and environmental considerations. Therefore, the authors have conducted this research to incorporate sustainability and supply chain management into the water reticulation works.

Table 1: Challenges in Implementing SCM.

Themes	Authors	Challenges in implementing SCM
Costs	[15]	The huge cost of adoption.
	[16]	In developing countries, significant dilemmas include a lack of efficiency in logistics systems, insufficient funds, and difficulties reconciling the need for accelerated economic growth with sustainability.
Managements	[15]	Nonseriousness of senior management, poor communication, poor organisational capabilities, poor performance measurement systems, reproducing another organisation's SSCM strategy, deficiency in the application of statistical theory, weak linking to suppliers.
	[16]	Driven by increasing stakeholder and societal pressures, construction companies and construction supply chains are faced with multi-dimensional challenges, inefficient warehousing strategies, and construction company restraints.
Technical Capabilities	[15]	Lack of knowledge, technological compatibility, poor infrastructure, lack of technical skills, lack of IT system standards, lack of modern technologies.
	[16]	Lack of information and lack of appropriate indicators, increasing carbon footprint, environmental problems in demolition processes, warehouses being a main subject of greenhouse gas emission contributors, and steelmaking industries depleting energy and natural resources.
Complexities	[15]	The third party's findings are complex.
	[16]	Social pressure of high pollution and high energy consumption, complications to supply sustainability approaches for reasons such as high amounts of skill, data, and time requirements.
Mindset and Cultural Changes	[15]	Resistance to change, lack of clear vision and skills, the difference between the firm goal and customers' demand, and absence of team or employee interest.
	[16]	Sustainability is based solely on public communication.

2.2. Methods for Overcoming the Challenges

Several strategies were proposed by [19] to enhance water distribution and actively control leakage. These strategies include pressure management, which involves maintaining the system's pressure close to the minimum required level; boosting productivity in repair work, particularly in time to ensure leakage stops sooner; and replacing risky pipelines. These efforts are believed to aid in longer pipe service lives, reduce the risk of water losses, and lower failure rates.

There is a necessity of updating the current water governance frameworks and policies, along with implementing management strategies to provide incentives and generate opportunities for sustainable use of water resources [20]. Moreover, effective restoration and a proper water management plan ultimately contribute to the triple bottom line of sustainability, economy, society, and environment. Furthermore, the fact that *"urban water supply requires improved administration and operation of the domestic water distribution networks"* is emphasised [20]. There is also the need to establish an integrated approach plan that involves all stakeholders as well as community participation, which would cultivate a sense of ownership [21].

Therefore, in alignment with SDG 6, which aims to procure clean water for consumers, Air Selangor has invested a significant amount of capital to ensure they eventually achieve their target. Air Selangor initiated a pipe replacement programme over the last five years with the objectives of improving customer experience by reducing pipe burst incidences and water interruptions, improving non-revenue water by reducing water losses, and improving water quality. The programme started in 2016 and involved awarding numerous packages to its panel contractors.

3.0 METHODOLOGY

Essentially, this research employed a qualitative design, utilising case studies, document analyses, and in-depth interviews as key research tools. A systematic sampling method was used to select several case studies on water reticulation and pipe replacement work. Besides, document analysis was done on the work programme to study the flow of water reticulation work.

A case study was conducted on Air Selangor's water reticulation works and pipe replacement project. Information was gathered from key players, specifically the main contractor, who consists of G3-G7 contractors or specialists in water reticulation works with more than one year of experience in that field. Currently, there are a total of 90 packages for the pipe replacement project proposed by Air Selangor since its early year of implementation in 2016. The authors achieved these results by gathering information from the selected work programme and conducting in-depth interviews with project representatives. Table 2 indicates the 6 packages from the overall project list.

Table 2: Details of the Scheduled Interviews and the Collected Work Programme.

Item	Projects	Reference	Approaches	Work programme
1	Proposed Pipe Replacement Programme in Selangor, Wilayah Persekutuan Kuala Lumpur & Putrajaya 2017/2018. (Package P7 – Sepang)	Participant A	Face-to-face (2:00-3:30 P.M.)	
2	Proposed Pipe Replacement Programme in Selangor, Wilayah Persekutuan Kuala Lumpur & Putrajaya, Year 2020. (Package 42 – Kuala Lumpur)			
3	Proposed Pipe Replacement Programme in Selangor, Wilayah Persekutuan Kuala Lumpur & Putrajaya, Year 2021. (Package 45A – Hulu Langat)			
4	Proposed Pipe Replacement Programme in Selangor, Wilayah Persekutuan Kuala Lumpur & Putrajaya, Year 2021. (Package 56 – Klang)	Participant F	Zoom platform (8:30-9:00 P.M.)	
5	Proposed Pipe Replacement Programme in Selangor, Wilayah Persekutuan Kuala Lumpur & Putrajaya, Year 2021. (Package 63 – Kuala Langat & Sepang)	Participant G	Email	
6	Proposed Pipe Replacement Programme in Selangor, Wilayah Persekutuan Kuala Lumpur & Putrajaya, Year 2022. (Package 77 – Gombak)	Participant I	Phone call (8:00-8:30 P.M.)	

The authors used NVivo 12 to collect, organise, analyse, and visualise semi-structured data from an in-depth interview. Researchers have widely used this qualitative data analysis computer software in a wide range of academic studies. It replicates qualitative data by highlighting, writing notes, and connecting ideas. Furthermore, NVivo 12, according to a past study by [22], could generate data analysis accurately and transparently.

4.0 RESULTS AND DISCUSSION

The thematic analysis of the in-depth interview divides the results and discussion into three sub-sections: the demographics of the interviewed participants, the challenges faced by SSCM in water reticulation works, and suggestions for overcoming these challenges.

4.1. Demographics of Participants Interviewed

The following Table 3 displays the demographic details of the participants interviewed, based on the thematic analysis of the in-depth interview. According to the authors' observation, the maturity of the answer depends on the participant's designation as well as years of industry experience.

Table 3: Demographics of Participants Interviewed.

Item	Contractor	Designation	Experience
1	Participant A	Senior Quantity Surveyor	4 Years
2	Participant F	Project Engineer	2 Years
3	Participant G	Project Manager	10 Years
4	Participant I	Quantity Surveyor	7 Years

4.2. Challenges in Implementing Sustainable Supply Chain Management in the Water Reticulation Works

The thematic analysis of the in-depth interview data was conducted using predetermined themes extracted from the initial literature review. The themes included cost, management, technical capability, complexity, mindset, and cultural change, among others.

4.2.1. Challenges in cost

In terms of cost, most of the participants assumed that sustainability aimed to optimise with less waste and higher profit margins. The pipe replacement project was a balloting project that established the schedule of rates based on the rates quoted by the panel contractor before the project was awarded to them as a package. However, according to Participant A, the rates for most of the items specified in the schedule were below market rates, resulting in significant challenges for contractors, particularly those with poor project management. Figure 1, which compares cost and schedule of rates, clearly illustrates this. This statement contradicted the assertion brought forward by [1] that the implementation of sustainability in the economic dimension should not conflict with the company's interests.

	Cost						Schedule of Rate (SOR)					
No	ITEM	Unit	Qty	Rate	Amount	Item	ITEM	Unit	Qty	Rate	Amount	Margin
1	BENDS & TEES 200mm											
	Bend 45 deg 200mm	no	1	600.00	600.00	B196	Bends 45 Deg 200mm	No	1	414.00	414.00	
	- Bolt nut	no	24	1.50	36.00	B3	Trench Excavate	m	1	29.00	29.00	
	- Rubber gasket	no	2	13.20	26.40							
					662.40						443.00	(219.40)

Figure 1: Cost and schedule of rates comparison extracted from package 42.

Furthermore, Participant G agreed with Participant A's challenge in cost, which was that the supplier's rates had immense variations and inconsistencies, especially for mild steel pipes and fittings. Figure 2 presents a comparison of quotations from three suppliers over two distinct dates.

Furthermore, sustainability in terms of cost should consider smooth project cash flow from project initiation until completion. Economic stability was identified in [23] as one of the practices of SSCM. However, both Participants F and I noted that the contractor was delayed in preparing progress claims. Typically, the primary cause of the delay in claim preparation was the inability to receive site data, such as a pipe log, from the site agent. Despite Air Selangor's guidelines requiring claims to be prepared by the 25th of each month, quantity surveyor typically only managed to prepare and submit drafts by the 5th of the following month, at the latest. Consequently, the delays had impacted the smoothness of the cash flow, given that Air Selangor's payment term was 60 days from the date of the contract administrator's signature on the certificate.

			CONTRACT			COMPARISM					
						Supplier X		Supplier Y		Supplier Z	
Item	Description	Unit	RATE	QTY TO ORDER	AMOUNT	RATE	AMOUNT	RATE	AMOUNT	RATE	AMOUNT
	Package 63 - Kuala Langat & Sepang										
	(Price Validity till 15.8.2022)										
B 84	150mm Flanged and Socket Ended Straight Pipes	Nos	372.00	10	3,480.00	681.00	6,810.00	570.00	388,170.00	348.00	3,480.00
B 118	150mm Flanged and Spigot Ended Straight Pipes	Nos	334.00	20	6,000.00	270.00	5,400.00	585.00	157,950.00	300.00	6,000.00
B 264	150mm junction tee double flanged ended barrel	Nos	483.00	10	3,600.00	487.00	4,870.00	375.00	182,625.00	360.00	3,600.00

			CONTRACT			COMPARISM					
						Supplier X		Supplier Y		Supplier Z	
Item	Description	Unit	RATE	QTY TO ORDER	AMOUNT	RATE	AMOUNT	RATE	AMOUNT	RATE	AMOUNT
	Package 63 - Kuala Langat & Sepang										
	(Price Validity till 3.2.2022)										
B 84	150mm Flanged and Socket Ended Straight Pipes	Nos	372.00	10	3,350.00	603.00	6,030.00	550.00	331,650.00	335.00	3,350.00
B 118	150mm Flanged and Spigot Ended Straight Pipes	Nos	334.00	20	4,140.00	239.00	4,780.00	215.00	51,385.00	207.00	4,140.00
B 264	150mm junction tee double flanged ended barrel	Nos	483.00	10	3,490.00	413.00	4,130.00	370.00	152,810.00	349.00	3,490.00

Figure 2: Supplier's comparison extracted from package 63.

Additionally, implementing SSCM for water reticulation works had been challenging due to a lack of cost data. Participant G asserted that the quantity surveyor and management relied on previous cost data to forecast budgeting for the upcoming project, a crucial step in preventing overspending and unnecessary expenditures, particularly in preliminary and other unforeseen overhead costs. It was important to use best practices for SSCM, as mentioned by [24].

4.2.2. Challenges in management

The management aspect focused on two major challenges: purchasing and documentation. Purchasing involved communication lines between site and office staff, especially the site agent and purchaser. The quantity surveyor acted as the middleman in delivering information between those two, as well as ensuring orders had been made according to the budget allocated in bills of quantities and aligned with Air Selangor's specifications. The stated challenge of deficiency in the application of statistical theory and weak linking to suppliers was highlighted by [15]. According to Participant A, the site team frequently expressed dissatisfaction with the purchasing arrangement between suppliers. During the construction phase, constant issues had arisen, including wrong material order delivery, sudden unavailability of material stock, uncertain delivery time, and low quality of supplied material.

Most pipe replacement projects frequently experienced delays in the preparation of site documents, including the pipe log and site diary. This delay occurred because the same site agent responsible for supervising work at the site was also tasked with handling all documentation work simultaneously, as explained by Participant F, a project engineer. Additionally, Participant I noted that the lack of expertise within the contractor's company, particularly among site engineers, resulted in a situation where the same staff had to work at multiple sites simultaneously. As a result, the preparation of site documentation had experienced significant delays. The overloaded work of the site agent also led to resignation as well as frequent changes in the staff, as justified by Participant G. During project progress, regular staff changes created chaos in managing project information.

In addition to the challenges previously mentioned, Participant G also emphasised the importance of task delegation within the project team, particularly between the site agent, quantity surveyor, and safety supervisor. Participant G stated that "everyone is unaware of their job scope and acts bluntly when a delay in document preparation happens". Situations such as assuming other people will do the job, even though it was within their job scopes, had created misunderstandings within the team. Ambiguously, the site safety supervisor refused to fill out the permit to work and assumed the site agent would complete the task. Thus, it was essential to know the job scopes and delegate the tasks clearly to the team before the project was commissioned.

4.2.3. Challenges in technical capability

Next, the technical capability aspect encompassed equipment, plants, and machinery, as well as labour. Highly skilled labour was required for certain technical tasks, including the laying of ductile iron pipes and the installation of high-density polythene fittings. Participant A had recounted multiple instances where a non-specialist was tasked with laying ductile iron pipes, resulting in the team spending days searching for leaks, as the pipeline failed the

pressure test conducted by an Air Selangor representative. Participant G reiterated that certain tasks required a worker who was extra cautious and well-trained and narrated a tale of material waste stemming from an insufficient understanding of how to join HDPE fittings.

Evidently, the poor availability of machinery and a shortage of skilled workers also contributed to this situation. Such a lack of technical skills among operators posed challenges in water reticulation works, as noted in the study of [25]. Both Participant G and I emphasised that the contractor cannot guarantee the availability and sufficiency of plants and machinery during the construction period, given that most of their projects were executed concurrently and each site was typically located at a considerable distance from the others. Contractors faced challenges in achieving sustainability due to the slow progress of non-skilled workers. Daily productivity was low, which eventually led to delays and poor work performance. Participant I also emphasised that the lack of confirmed material availability during construction was one of the challenges related to technical capability. Thus, it also validated a study conducted by [13], which stated that a water reticulation work necessitates a precise and detailed approach.

Furthermore, Participant G asserted that numerous documentation tasks, including a site diary, site inspection report, biweekly report, daily pipe log, and others, necessitated preparation concurrently with site progress. However, most contractors relied solely on a single appointed site agent to handle both site monitoring and documentation tasks, resulting in a daily work schedule that often concluded late. Therefore, the site agent was often required to multitask, which led to mistakes and late submissions. Unfortunately, most contractors also lacked fully supported software to prepare drawings, such as shop and as-built drawings, which was an inconvenience for the technical team to prepare drawings as soon as possible. This conclusion was in line with the finding of [16] that developing countries faced significant challenges in implementing supply chain management, particularly in balancing the need for rapid economic growth with sustainability.

Lastly, Participant G mentioned that a challenge in the technical aspect was the lack of precedent site information, which was a result of an improper site survey and dilapidation report that was completed prior to project commencement. This further corroborated the challenge in water reticulation identified by [26], which involved unexpected subsurface conditions. Consequently, unexpected site obstructions often led to contractors damaging other utility cables at the site and halting their work.

4.2.4. Challenges in complexity

During the conducted interview, challenges in achieving sustainability for SSCM in water reticulation works were identified. The primary concerns regarding this aspect were the intricacy of site work and the documentation involved. All four participants expressed the need for intricate documentation throughout the project's duration. Generally, Participant A and I discussed documentation without focusing on any specific document that needed preparation. Participant A asserted that the quantity surveyor must consistently lead the WhatsApp group in ensuring timely submission of all necessary documents, as late receipt of site documents delayed claim preparation. Furthermore, Participant I, who had a longer tenure as a quantity surveyor, had noted that each project team, particularly consultants, had a unique approach to document format, milestones, and on-site work execution. Therefore, contractors must adapt to each consultant's style before they proceed with the documentation work, a challenge previously identified by [26] in the complex commissioning process of water reticulation works.

Furthermore, Participant G stated that contractors must also address Air Selangor's complex documentation procedure, particularly for variation orders. A longer time was required to get approval, especially in terms of budget approval whenever variations of work occurred, even though work on-site proceeded with the contract administrator’s instruction. Participant I had also mentioned the absence of guidelines for Air Selangor documentation and procedures, which the contractor and consultant were expected to follow. They relied on their prior experience from previous projects for guidance and practice. Participant G's statement, which highlighted the frequent turnover of management staff, underscored this challenge, as it posed a hindrance to the company's efforts to retain experienced personnel.

Pipe replacement projects also tended to face delays and obtain extensions of time due to late receipt of local authority approval. Participant F emphasised the complexity of getting local authority approval, which involved two concerns: idling time and documentation. This finding was similar to the one from [21], which indicated that the complexity of locating a third party posed challenges in supply chain management. Contractors and consultants

were required to fill out many forms that were different for each local authority, such as *Dewan Bandaraya Kuala Lumpur* (DBKL), *Majlis Perbandaran Ampang Jaya* (MPAJ), *Jabatan Kerja Raya* (JKR), and others. The work programme analysis revealed the need to allocate ample time early in the project schedule, as it typically required at least one month for document preparation, submission, and approval (Figures 3 and 4). In fact, the local authority had granted an extension of time to all selected pipe replacement projects, citing delays in obtaining permit authority.

ID	Task Name	Duration	Start	Finish
0	**PROPOSED PIPE REPLACEMENT PROGRAM IN WILAYAH PERSEKUTUAN KUALA LUMPUR AND PUTRAJAYA YEAR 2021 : PACKAGE 45A (HULU LANGAT)**	**708 days**	**Thu 7/15/21**	**Thu 6/22/23**
1	**1 GENERAL AND PRELIMINARIES**	**707 days**	**Thu 7/15/21**	**Wed 6/21/23**
2	**1.1 Local Authorities**	**260 days**	**Thu 7/15/21**	**Thu 3/31/22**
3	1.1.1 Document Preparation	118 days	Thu 7/15/21	Tue 11/9/21
4	1.1.2 Document Submission and Permit Approval	142 days	Wed 11/10/21	Thu 3/31/22
5	1.2 Material Order and Delivery	567 days	Wed 11/10/21	Wed 5/31/23
6	1.3 Mobilisation & Demobilisation of Plant & Machinery	447 days	Fri 4/1/22	Wed 6/21/23
7	1.4 Site Safety and Traffic Management Plan	447 days	Fri 4/1/22	Wed 6/21/23
8	1.5 Provide & Maintain Preliminary Item (Site Office, etc)	707 days	Thu 7/15/21	Wed 6/21/23
9	**2 PIPE LAYING WORK AT JALAN SEMENYIH**	**402 days**	**Sun 5/15/22**	**Tue 6/20/23**

Figure 3: Excerpted work programme of P45A

Task Name	Duration	Start	Finish
PROPOSED PIPE REPLACEMENT PROGRAM IN SELANGOR, WILAYAH PERSEKUTUAN KUALA LUMPUR AND PUTRAJAYA 2022: PACKAGE 77 - GOMBAK.	**458 days**	**Mon 28/8/23**	**Wed 27/11/24**
1 General & Preliminary	**457 days**	**Mon 28/8/23**	**Tue 26/11/24**
1.1 Acquisition of Permit from MPAJ	**120 days**	**Mon 28/8/23**	**Mon 25/12/23**
1.1.1 Preparation of Document	40 days	Mon 28/8/23	Fri 6/10/23
1.1.2 Document Submission	40 days	Sat 7/10/23	Wed 15/11/23
1.1.3 Approval	40 days	Thu 16/11/23	Mon 25/12/23
1.2 Performance Bond / Performance Guarantee Sum	0 days	Mon 28/8/23	Mon 28/8/23
1.3 Insurance	0 days	Mon 28/8/23	Mon 28/8/23
1.4 CIDB Registration and Contract Document	0 days	Mon 28/8/23	Mon 28/8/23
1.5 Material Delivery by Air Selangor (Batch 1)	7 days	Tue 26/12/23	Mon 1/1/24
1.6 Mobilization and demobilization of plants and machineries	330 days	Tue 2/1/24	Tue 26/11/24
1.7 Contractor's Site Office and Maintenance	337 days	Tue 26/12/23	Tue 26/11/24

Figure 4: Excerpted work programme of P77

Participant F also added that contractors must consistently incur higher overhead costs when procuring permits from the local authority, including the preparation of multiple physical copies of required document submissions. He sighed, saying that sometimes the several difficult copies submitted required amendments and resubmissions. The worst situation was when the submitted documents went missing. Likewise, the report of [26] also highlighted permitting delays as one of the challenges in water reticulation works.

Subsequently, Participant A asserted that on-site obstructions, including cables from other utility providers and confined working space, contributed to the complexity challenge. Furthermore, Participant G mentioned difficulty working in congested or hotspot areas such as school and the main road, where they must work at night. However, in contrast to Participant A's experience, he worked for P42 at *Jalan Mahkota*, where most restaurants operated for

22 hours a day and were bustling with customers dining outside during the night. The contractor must negotiate with the restaurant owners to allocate time and space to do their work. Although the owners agreed, the time given was very short, and the contractor must complete the work as soon as possible.

4.2.5. Challenges in mindset and cultural changes

The implementation of sustainable practices in SCM for water reticulation works was also challenged by mindset and cultural changes. Participant A brought to light the differences in opinion between the contractor and the consultant. Air Selangor typically followed consultant recommendations. Everyone was inclined to maintain their position based on their experience and the information they had gathered. Its strength lay in the findings from [26], which highlighted the challenges of coordination and communication issues in the water reticulation works. Meanwhile, Participant G underscored the importance of sustainability in supply chain management, stating with a hint of laughter that "of course everyone has their own method of handling projects and wants to stick with it; rigid people dislike change and difference". Similarly, a report by [15] also identified that people resisted changes.

As previously mentioned, the site agent was responsible for preparing a significant amount of site documentation while construction work was ongoing at the location. Participant F asserted that despite the contractor's recognition of a delay in documentation during a previous project, the culture persisted in subsequent projects, with minimal steps being taken to enhance work performance. The issue was highlighted by [26] as well. Participant G stated that another challenge for the site agent was the difficulty in diligently preparing the site documents, as workers at the site required his presence at the site during work being executed on site. Communication with the site workers had been challenging due to language barriers.

In addition, Participant F expressed dissatisfaction regarding the consultant's tendency to make decisions too late. The consultant typically issued memos and site instructions late, which occasionally resulted in extended idle time at the site. However, participant I mentioned that the contractor sometimes gave late notice about the site's obstruction, which also led to the consultant's late decision-making. As a result, it was not a surprise that it was important to practice information sharing in sustainable supply chain management, as was identified by [27].

4.2.6. Challenges in other aspects

The participants had also mentioned integrity, corruption, waste management issues, and insurance claims. Integrity in the construction industry has been a widely discussed issue since its emergence. Participant A, with support from Participant G, asserted that other challenges to achieving sustainability in SCM for water reticulation works included integrity and corruption. Integrity encompassed honesty in delivering the project on-site, particularly in terms of material quality and work specifications such as backfilling thickness and premix reinstatement, as well as the method of construction execution. Participant G added, "We could create a separate research topic to expand on the topic of interacting with local authorities."

In addition, the participant mentioned waste management but did not elaborate further on it. However, he highlighted that insurance claims due to damage to third-party property, such as cables provided by other utilities, i.e., *Tenaga Nasional Berhad* and *Telekom Malaysia*, had usually been rejected by the insurer due to insufficient documents given. Whenever the contractor applied for an insurance claim, the insurer typically requested several documents to support the claim, particularly those detailing safety precautions taken prior to project commencement. However, some of the required documents, such as a letter to the relevant authority inquiring about the location of the existing underground cable prior to the commencement of excavation work, were not available, as the contractor was unaware of their requirement. Moreover, the insurer dismissed the claim due to insufficient data from the initial on-site survey. It was related to Participant G's statement previously about challenges in the cost aspect: "improper site survey/dilapidation report done prior to project commencement." Participant I sighed that an insurance claim for cable damage or any other reason was not easy, and contractors mostly spent overhead costs to pay premiums but found it difficult to get a claim.

4.3. Improvement Recommendation for Overcoming the Challenges for SSCM in the Water Reticulation Works

The authors gathered and obtained recommendations from the participants, taking into account the challenges they had expressed. The predetermined themes—cost, management, technical capability, complexity, mindset and cultural change, and other aspects—had also guided the recommendations.

4.3.1. Recommendations in cost

Firstly, in addressing the challenges related to the cost aspect, the participants provided several recommendations. For instance, Participant A suggested that contractors should maintain records of costs and expenditures from previous projects. It was important to keep data to refer to when planning for the next project, as the contractors can also study the data to optimise bigger profit margin items and pay more attention to smaller profit margin items. Participant G had reiterated that a quantity surveyor was required to document all cost data, particularly for any unforeseen expenses incurred during the project that the contract did not cover.

Next, in terms of plants and machinery, the participant complained earlier about the higher cost spent on dumping trucks. Therefore, Participant F recommended that the contractors should purchase their own dumping truck instead of renting one, as the long-term costs of renting were higher than those of owning their equipment. Furthermore, Participant I recommended that the contractor secure a price agreement with suppliers for the materials they needed to purchase before the project commenced on site to mitigate the risk of market price fluctuations. However, this measure requires a significant capital allocation, and not all contractors possess this capability.

In the meantime, the participants had also stressed the importance of preparing for interim progress claims. For these challenges, Participant G recommended that the project manager ensure his project's team followed Air Selangor's standard procedure for submitting claim milestones, as illustrated in Figure 5. Furthermore, the quantity surveyor claimed that the delay in claim preparation was due to the late receipt of site documents, such as pipe logs. Therefore, Participant I suggested that the site agent should update daily records in a designated WhatsApp group to streamline the document preparation process.

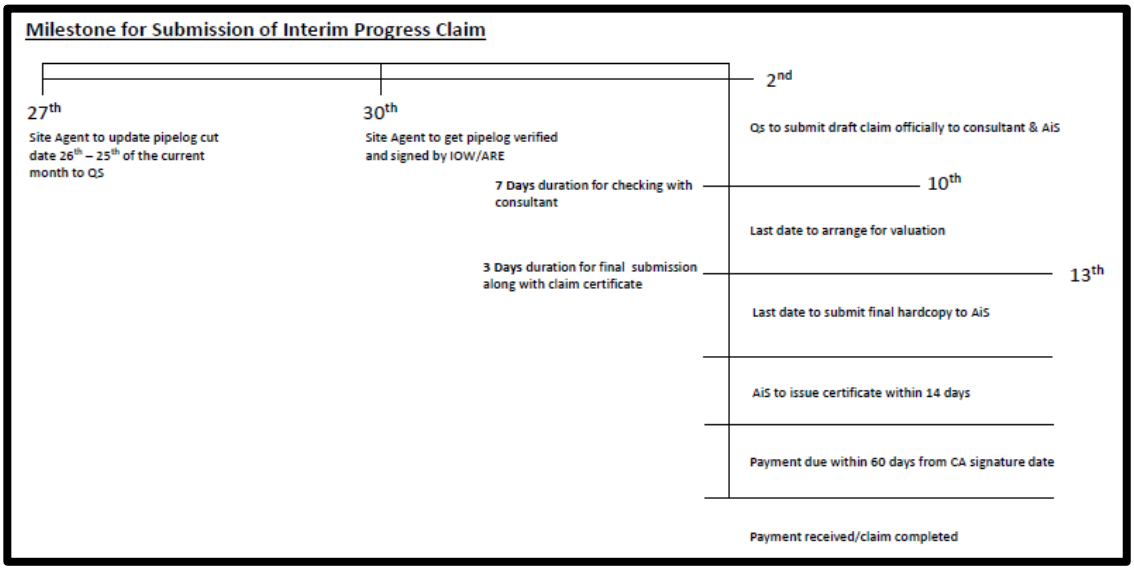


Figure 5: Milestone for claim submission

4.3.2. Recommendations in management

All parties involved in the water reticulation works had identified communication as a crucial skill to improve in the management aspect, but the real challenge lay in figuring out how to achieve this. As deduced from Participant F, who had sparked the situation, "Do we really have to be like school orientation in order to enhance communication between all parties involved in each project?". The challenge of poor coordination among stakeholders was identified by [13] a long time ago. However, Participant G persisted in suggesting that the project's team should enhance their communication skills to promote more productive discussions and speed up the decision-making process.

Additionally, to address challenges in purchasing management, both Participant A and Participant G suggested developing a system or software that served as a central hub for suppliers and the contractor's purchaser. It was important to ensure that all parties can adapt the system to ease the purchasing process. According to [15], one of the challenges in implementing supply chain management was the high cost of adoption. Thus, software can only be functional if people are willing to accept the technology and changes.

Furthermore, Participant I suggested that exposing engineers to water reticulation works early in their university careers can overcome their lack of interest in this field. The goal was to raise awareness about the job opportunity and encourage further exploration of water reticulation works. This supported the claim made by [9] that the economic dimension of sustainability must include consideration of how businesses impact society.

4.3.3. Recommendations in technical capability

In the aspects of technical capability, the participants' recommendations mostly mentioned enhancing workers' skills and the availability of machinery. Both Participant A and Participant I made these suggestions. These days, training centres held numerous classes and provided certificates to anyone who wished to enhance their skills. Furthermore, Participant F proposed an increase in compensation for local workers, with the aim of attracting more skilled workers from areas with simpler documentation requirements.

Additionally, the contractors had the option to invest more in purchasing their own plants and machinery, eliminating the need to rely solely on the availability of rental machinery, as suggested by Participant F. Participant I believed that this measure, despite requiring more capital, was a solution to the problem of frequent unavailability of plants and machinery, which had also caused delays.

Furthermore, Participant G had recommended that the contractors assign a site supervisor specifically for each project, ensuring that no more than three (3) projects were located in an area that was significantly distant from each other. This was to avoid unnecessary time and cost spent travelling and created a more optimum working environment. He also added that separating the tasks of preparing site documentation and site monitoring for two different staff can overcome the challenge in technical capability to implement sustainability in SSCM for water reticulation works. The contractor shall not depend on a quantity surveyor or a site agent only to prepare site documentation, as they have their own job scopes as well.

4.3.4. Recommendations in complexity

Managing documentation issues first, particularly in the acquisition of local authority permits, can help overcome complex challenges. Participant A, along with Participant G, suggested that the project team ensure all documentation actions were properly written and recorded. Keeping track of document submissions during project execution was very useful, as it eased project management and served as a reference for future projects. Participant A highlighted the complexity of the document flow involved in acquiring a local authority permit.

Moreover, as suggested by Participant I, the local authority should provide contractors with step-by-step instructions on how to apply for permits. Participant F also mentioned the need for local authorities to publish clearly explained guidelines and flowcharts on how to obtain local authority approval. Additionally, all participants had emphasised the importance of overcoming challenges related to local authorities, as the majority of pipe replacement projects were experiencing delays due to the late receipt of permit approval.

However, Participant G had proposed strategies to address the complexity of site conditions. The contractors needed to pinpoint areas that required additional safety precautions and identify any site obstructions, such as disorganised cables from other utility providers. Participant G stated that the contractor should assign multiple teams to carry out work in the identified hotspot area. Air Selangor also needed to carefully select the contractor early in the project award process, taking into account their past performance in hotspot areas such as the central city of Kuala Lumpur. Furthermore, risk management had been listed by [28] as a practice of sustainable supply chain management. Therefore, assessing the site's condition prior to work execution was crucial for risk mitigation.

4.3.5. Recommendations in mindset and cultural changes

All participants, with the exception of Participant F, had suggested overcoming the challenges in mindset and cultural exchange by strengthening their thinking skills and work methods. Participant A also recommended that the project team enhance their communication skills, particularly in exchanging ideas and opinions. The consultant also had to be open-minded in receiving feedback from the contractor, and the contractor had to follow the specifications given by Air Selangor unless there was a discrepancy in site conditions. Participant I concurred with the suggestion that the contractor should adhere to the work specifications published by Air Selangor.

Furthermore, Participant G recommended that all parties should not be overly strict with the formatting of the documentation, provided it was accurate and aligned with the intended message. The challenge of unclear vision and skills in supply chain management implementation was highlighted by [15], which this measure can address.

4.3.6. Recommendations in other aspects

As previously stated, none of the participants offered any recommendations for overcoming challenges in other aspects. According to Participant F, resolving corruption in the construction industry required all parties, including contractors, consultants, clients, and even local authorities themselves, to uphold the integrity pledge they had signed.

Although every participant offered suggestions to address the issues raised in the interview, the results differed from those derived from a previous literature review. The participants mostly suggested the management aspect, while the literature review mentioned the technical aspect.

5.0 CONCLUSION

This study explored SSCM in water reticulation works, highlighting challenges and improvements in overcoming them. This study contributed to existing knowledge by addressing SSCM specifically within the less-studied sector of public infrastructure in developing regions. While offering valuable insights, the study's qualitative design and context-specific scope limited generalisability. The study connected sustainability ideas with supply chain practices and provided help to project managers and policymakers to improve SSCM by involving stakeholders and getting regulatory support. Future research should employ broader, mixed-methods approaches and examine digital integration and stakeholder dynamics to build more resilient SSCM models.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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