



Enhancing Resilience in Construction Procurement: Strategies and Technologies for Mitigating Risks and Improving Performance

Master Thesis

Construction management and Real-estate Development

Joint Study Programme of Metropolia Helsinki & HTW Berlin

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.....

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Conceptual Formulation

**International Master of Science in Construction and Real Estate Management Joint Study Programme of
Metropolia Helsinki and HTW Berlin**

Master Thesis for Mr. Muhammad Ragab

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Signature of the first Supervisor



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Background

The procurement process in construction is multifaceted, involving the acquisition of materials, services, and labour. Decisions made during procurement significantly impact project timelines, costs, and overall success. The concept of resilience in construction procurement and supply chain management refers to their capacity to withstand and recover from disruptions and uncertainties while maintaining essential functions. In procurement, this means effectively managing material sourcing and labour risks, ensuring continuity amidst potential risks. Overall, resilience emphasizes adaptability and proactive risk management to enhance project outcomes in the face of challenges.

Traditional construction procurement practices often focus on cost optimization through competitive bidding. While this approach can yield initial savings, it can leave projects vulnerable to disruptions in the supply chain. Moreover, limited communication and collaboration between project stakeholders can exacerbate challenges. These factors contribute to project delays, cost overruns, and decreased performance.

The research aims to identify critical challenges and vulnerabilities in construction procurement and supply chain, assess current practices and approaches for managing risks, and propose innovative solutions to improve the resilience of procurement operations. In addition, it investigates the impact of technological advancements in procurement tools and supplier relation management systems and how it can leverage engagement among diverse stakeholders, including contractors, suppliers, and regulatory bodies. Furthermore, the study aims to provide practical insights and guidelines for industry practitioners, policymakers, and researchers.

In particular, the study aims to answer the following questions.

- 1- What are the key considerations and strategies for effectively managing risks associated with supplier procurement in the construction industry?
- 2- What factors contribute to successful supplier relationship management in construction procurement, and how can these factors be optimized to enhance overall project performance?
- 3- How can supplier diversification and inventory management techniques contribute to a more resilient supply chain?
- 4- In what ways can stakeholder engagement be strategically managed and leveraged to optimize procurement along project lifetime?

5- How do digital technologies, such as Building Information Modelling (BIM) and e-procurement platforms, impact the efficiency and effectiveness of procurement decision-making and monitoring?

Methodology:

The research methodology for a study on this topic will depend on mixed types of research methodologies.

- Literature review concerning innovative procurement strategies and approaches. This examination aims to uncover existing knowledge, pinpoint research, and establish a fundamental basis for structuring the research design.
- Questionnaire and survey: based on the literature review, specifically tailored to address the gaps in knowledge and key challenges identified during the review process.
- Interviews with Construction professionals, sales engineers, and procurement managers.
- Analysing collected data to derive conclusions and formulate recommendations.

Time scale:

	Start	End
Literature Review	March 2024	Mid – April 2024
Survey	Mid -April 2024	May 2024
Interviews	Mid- April 2024	May 2024
Comparison and analyzing	May 2024	June 2024
Draft	June 2024	June 2024
Final submission	July 2024	Jul 2024

Abstract

The construction industry is fraught with risks and uncertainties that can significantly impact project outcomes. Recognizing procurement as a core process influencing project success, this thesis explores strategies and technologies to enhance resilience in construction procurement. The research focuses on three main perspectives: procurement strategies, procurement-related risks, and the adoption of new technologies.

The study begins by providing an overview of construction supply chains, procurement processes, and best practices from international literature. Moreover the research investigates the advanced technological tools adopted in the construction procurement . To contextualize these practices within the Egyptian construction industry, a detailed survey was conducted with procurement professionals to compare theoretical insights with actual practices.

The analysis of the questionnaire highlights specific challenges faced by Egyptian construction firms and the global market as well, such as delivery delays, market volatility, and supply chain disruptions. Furthermore, it shows how procurement management practices can minimise this risk.

A key outcome of the research is the development of an initial procurement planning framework aimed at addressing some of the highlighted procurement- risks in the literature. This framework integrates supply risk assessment, JIT approach, and e-procurement in procurement process workflow.

In conclusion, the thesis provides practical recommendations for industry practitioners on implementing these strategies and technologies to build more resilient procurement systems.

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List of Abbreviations

Fig.	Figure
ISO	International Organization for Standardization
PMI	Project management institute
CAD	Computer-aided design
CRM	Customer relationship management
ERP	Enterprise resource planning
SRM	Supplier relationship management
SCM	Supply chain management
B2b	business to business
JIT	Just in time
EOQ	Economic order quantity
MRP	material requirements planning

1. Introduction

Background

Approximately \$10 trillion is spent annually on goods and services related to construction, which accounts for 13% of global GDP and employs 7% of the working population. That being said, one of the main areas of the global economy is construction.

In the dynamic landscape of the construction industry, the management of supply chains and procurement processes plays a pivotal role in project success. The industry faces a wide range of challenges, from inefficient procurement practices to supply chain disruptions, which can have a significant impact on project budgets, schedules, and quality. The need to strengthen supply chains and procurement procedures for construction to better withstand these challenges is becoming increasingly apparent.

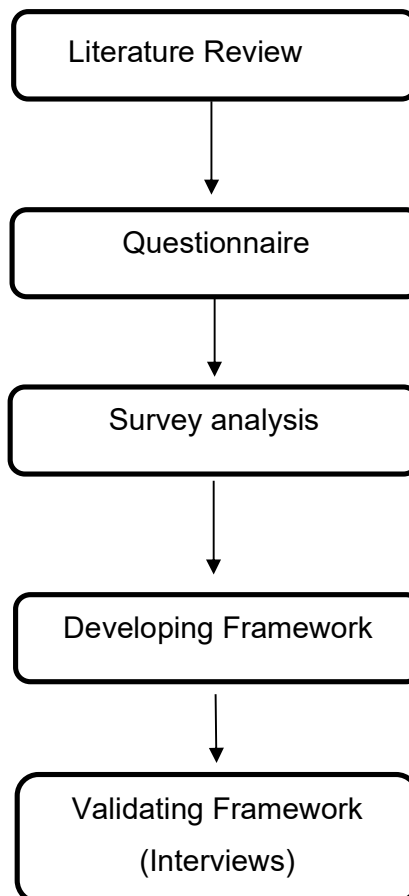
Optimizing procurement processes can be achieved through strategic planning, advanced technologies, and effective engagement with diverse stakeholders, including contractors, suppliers, and regulatory bodies.

Looking ahead, the future of construction hinges on embracing innovative solutions to these longstanding challenges. By leveraging technology to streamline procurement processes, fostering collaboration throughout the supply chain, and adopting a more data-driven approach to decision-making, construction companies can build resilience and achieve greater project certainty. This change requires a paradigm shift to a more integrated and coordinated construction ecosystem where all stakeholders are working together more effectively to optimise resources and information flows from project inception to completion. This collaborative approach, supported by technological advancements, will unleash the true potential of construction, its unprecedented growth and continuous development.

Research Methodology

The research methodology will consist of

- Conduct extensive literature review on the current and innovative industry practices in the construction procurement field this will include scientific papers, periodical magazines, and international conferences.
- Pre-structured Interviews with industry professionals such as procurement managers, construction managers, Sales engineers, and executives.
- Questionnaires aimed to explore the effectiveness of current practices and future trends in the procurement management.
- Develop a supplier procurement planning framework
- Analysing collected data to derive conclusions and formulate recommendations.



Research Objectives

- The research aims to study the challenges and risks facing the construction companies in procurement during various project stages. And define the potential risks and their appropriate response. In addition to evaluate the existing strategies adopted by construction companies to form a resilient procurement system.
- Examine the current stakeholder's collaboration techniques and the effective ways of information flow among.
- Investigate the impact of Modern practices and technology tools in facilitating and optimizing the procurement process.
- provide practical insights and guidelines for industry practitioners, policymakers, and researchers.

Research Questions

The research addresses the following questions.

- 1- What are the main approaches and strategies for efficiently managing risks associated with supplier procurement in the construction industry?
- 2- What considerations attribute to successful supplier relationship management in construction procurement, and how can these factors be optimized to enhance overall project performance?
- 3- How can supplier diversification and inventory management techniques contribute to a more resilient supply chain?
- 4- how can stakeholder integration be strategically managed and leveraged to optimize procurement over project lifetime?

5- To what extent can digital technologies, such as Building Information Model procurement and e-procurement platforms, impact the efficiency and effectiveness of procurement decision-making and controlling?

2. Construction supply chain

Construction supply chain consists of all processes, activities, factors, and interdisciplinary interactions of the project from its inception, designing, to the acquisition of siting, fittings and all the components of a building project during construction, to the process of maintenance and repair during utilisation, to eventual replacement and final demolition. moreover, CSC encompasses the various organisational stakeholders involved in the process of construction – including the client/owner, designer, general contractor, subcontractors, and suppliers (Vrijhoef, Koskela, & Voordijk, 2003). It includes all the lifecycles stages of the materials or services from extracting, manufacturing until delivery and operation. it can be considered as higher system in which construction procurement operates.

Meanwhile Procurement is the process of obtaining services or material, hiring labours to provide the required resources according to the project plan. Procurement processes have a significant impact on the project delivery cost and timeline. The procurement strategies can directly influence the supply chain resilience. hence understanding the potential risks and manage them effectively will result in more. However, Integration in construction supply chain is still less developed than this in the manufacturing due to uniqueness and of each project and the characteristics of the construction industry(Briscoe & Dainty, 2005). Thorpe et al., (2003) argue that the construction industry has a long way to go in fostering that trust within its supply chain.

Furthermore, the Supply chain network is complex and includes manufacturers, suppliers, subcontractors who some of may not be locally presented. Construction companies work at the end of this complex network. therefore, the project manager role is to develop the efficient procurement strategy which should withstand deficiency that may occur somewhere else in this complicated network.

According to Muya et al(1999)., CSC can be categorized into three types:

- The primary supply chain, which supplies materials used in the final construction products.
- The support chain, which supplies the equipment and materials that aid the construction process.

- The human resource supply chain, which concerns with the provision of workers.

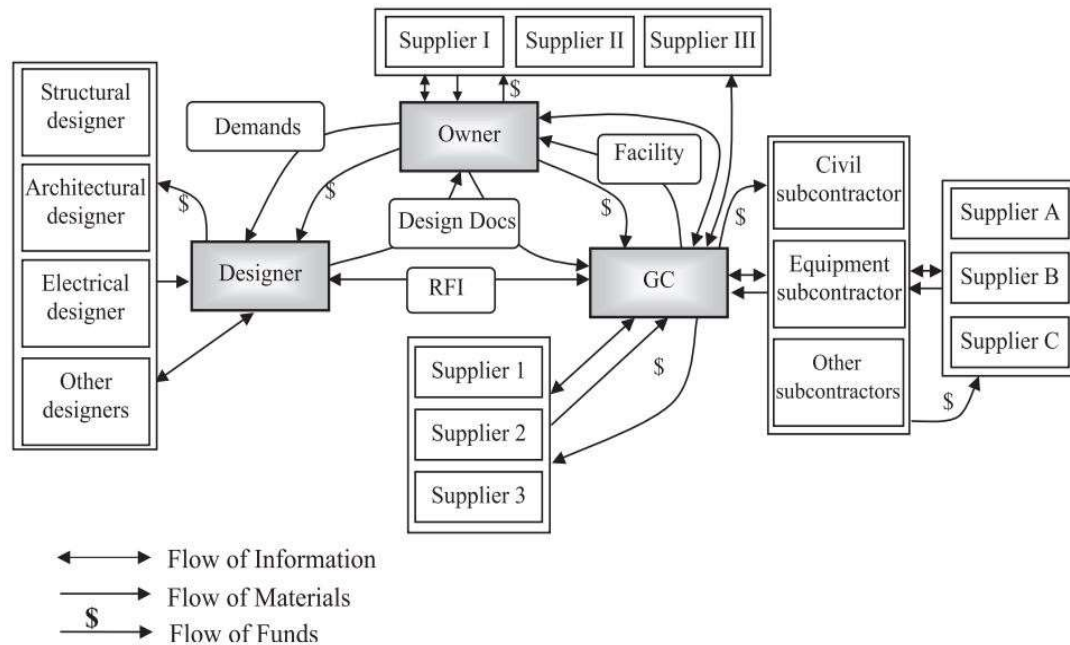


Figure 1 Construction supply Chain model (Xue et al., 2005b)

Figure 1 provides a model of typical parties of a CSC. The general contractor (GC) is the centre of the CSC, the other two main partners are the owner and the designer, in addition to direct suppliers of the GC, the subcontractors are also seen as a supplier of the GC, the subcontractors have suppliers of their own.

Palaneeswaran et al. (2003) . sorted the common challenges in CSC

- Conflicts of interest between contractors and clients.
- Lack of recognition for sharing risks and benefits. Fragmented methodologies.
- Short-sighted win/lose attitudes and short-term focus.
- Asymmetries of power and recurring contractual breaches that result in default, poor execution, low quality, conflicts, disputes and claims.
- Overemphasis on bid prices, neglecting life-cycle costs and overall value.
- Poor transparency, limited information exchange, and insufficient communication.
- Minimal or no direct interactions fostering sustainable long-term relationship

2.1 Supply Chain Management (SCM)

Supply chain management is a complex and ever-changing field, as seen in the wide range of definitions proposed by specialists. It draws from various areas of research and has evolved from its roots in logistics to include ideas from social and organizational sciences. Over time, concepts like collaboration between partners have become integral to our understanding of how to manage supply chains effectively. (Croom et al., 2000).

Supply chain management encompasses handling everything from getting the raw materials to making the final product, and even dealing with recycling and reusing materials when possible. It's how companies work with their supply chain partners to extract the best from their assets, technology, and skills to win in the marketplace. It can be realized as a way of managing the business ecosystem beyond the organisation's boundaries, bringing different companies together for the benefit of customers and everyone else. (Tan et al. 1998). Another definition is A comprehensive method for managing how materials move from suppliers to end-users, covering both planning and control aspects. (Jones and Riley (1985). Furthermore, takes a systemic or integrated approach, which aims at achieving long-term, win-win and cooperative relationships between suppliers and other parties to optimise the performance of the construction process for increasing client value at a lower cost (Xue et al., 2005b).

One major issue of Supply Chain Management (SCM) is that maximising the efficiency of single stages of the chain is not always equivalent to optimising the performance of the whole network (Gunasekaran et al 2004). Vrijhoef and Koskela (2000) identifies four major roles of SCM in construction, contingent on whether the concern is on the supply chain, on the construction site, or both.

- 1- the effects of supply chain management from site activities perspective intent to lower the cost and duration of such activities; the central aim here is to ensure the reliable flows of materials and labour to the site and avoid its potential disruptions; this can be achieved by focusing on the links between the site and its suppliers. As the contractor is the most concerned with the site activities, it is the contractor who is best positioned to perform this.

- 2- The focus could also be on the supply chain itself, with the aim of reducing costs, particularly those associated with logistics, lead times, and inventory. Material and component suppliers might also adopt this perspective.
- 3- The Focus might be on moving activities out of the site to an earlier stage in the supply chain. This can assist in avoid suboptimal on-site conditions and allow hence open the possibility of greater concurrency between activities, which is typically not possible on-site where there are extensive technical dependences. The main objective is to minimise total cost and time. This can be done either by the supplier or the contractor.
- 4- The focus would then be on integrated supply chain and site production management and improvement, with site production simply being part of a broader supply chain management – starting by a client, a supplier or a contractor.

2.2 Resilience in construction supply chain

Resilience is a wide concept, and has multiple definitions according the targeted disciplinary and industry. in the supply chain context, Peck (2005) defines resilience as the capability to recover from or adapt smoothly to adversity or change. Limnios and Mazzarol (2011) distinguish two distinctive concepts of resilience: offence (adaptation) and defence (resistance) to internal or external disruptions. Adoption can refer to a system or supply chain changing its structure, processes, and functions in response to surviving disruptions. On the other hand, resilience can refer to a supply chain resisting change or absorbing shocks while maintaining the structure and processes that existed before the disruption.

Pettit et al. (2010) proposed that supply chain resilience can be evaluated based on two key dimensions: vulnerabilities and capabilities. As shown in Figure 2, a supply chain can enhance its resilience against unexpected events. by minimizing vulnerabilities

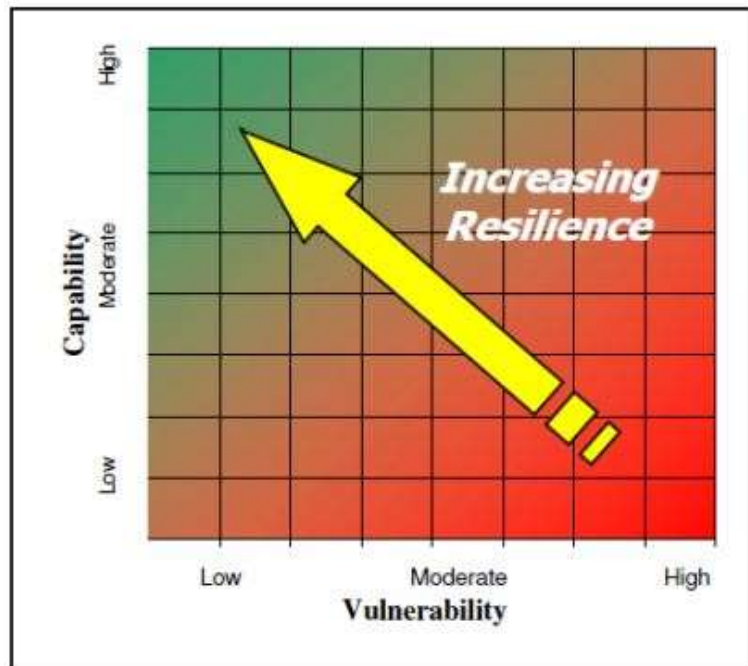


Figure 2 Resilience assessment (Pettit et al, 2010)

Wagner and Neshat (2010) categorized vulnerability drivers into three main groups as follows:

Demand side or (Downstream) : Demand here represent the client which is in the construction case is the contractor . Vulnerability drivers on the demand side can result from the uncertainties surrounding demand. For instance, continuous changes in customer requirements can result in significant time and cost overruns (Wagner and Neshat 2010).

supply side vulnerabilities (upstream): Vulnerabilities here are found within the supply base, or supplier network. This is especially important in construction, where weak financial performance or insolvency of contractors and suppliers can hinder the progress of the works, making the entire supply chain more vulnerable to any disruptive events that might happen during project delivery (Wagner and Neshat 2010).

supply chain structure: stems largely from the fragmentation of supply chains and the globalization of value-adding processes (Wagner and Neshat 2010).

2.3 Supply Chain Disruptions.

Zsidisin et al. (2000) described as a significant event that seriously endanger the regular operations of the involved supply chain members. However, disruptions impacting a supply chain are unavoidable, indicating that all supply chains inherently face risks (Craighead et al. 2007).

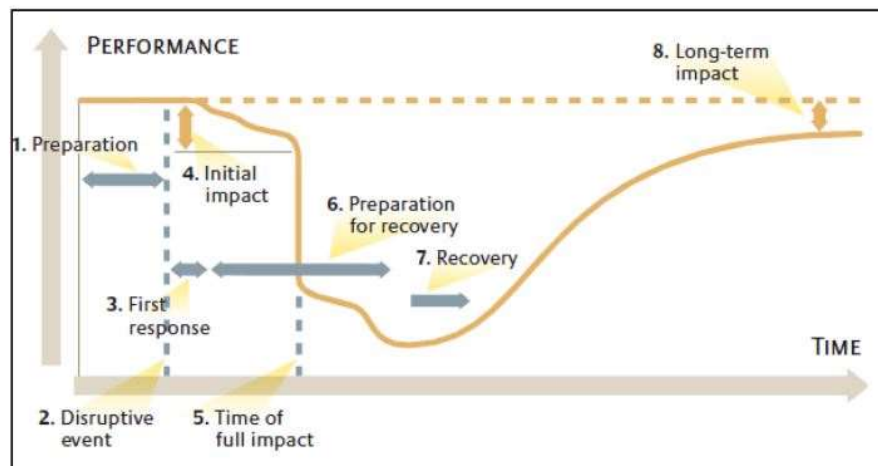


Figure 3 Disruptions stages (Sheffi and Rice, 2005)

Cockram and Van Den Heuvel (2012) stress, the implementation of a diverse range of forward-looking, resilience-based management strategies in the pre-crisis phase is important for crisis prevention as well as mitigating the effects or duration of crises if they do happen.

Abidin and Afroze (2018) divide the disruption event into 3 main stages pre-disruption, during disruption, and post disruption to determine the effective response in each stage.

Pre disruption: This is similar to the risk management process conducted before starting construction. This proactive approach consist of Identifying, evaluating, managing and monitoring risk .

During disruption: An effective reactive response can limit the spread of a crisis's impact. This response involves putting into action the contingency plans that were created during the pre-disruption phase. Sheffi (2005) argues that there are

circumstances where pre-planned contingencies are not sufficient to contain disruptions, and where alternative responses to deviations outside of work routines and standard operating procedures are required to prevent further spreading.

Post disruption: phase includes the recovery and learning process. This includes looking ahead and examining the long-term impacts of an event while deciding whether to revert to the pre-event norm or adapt to a 'new normal' if there is significant change. (Cockram and Van Den Heuvel, 2012).

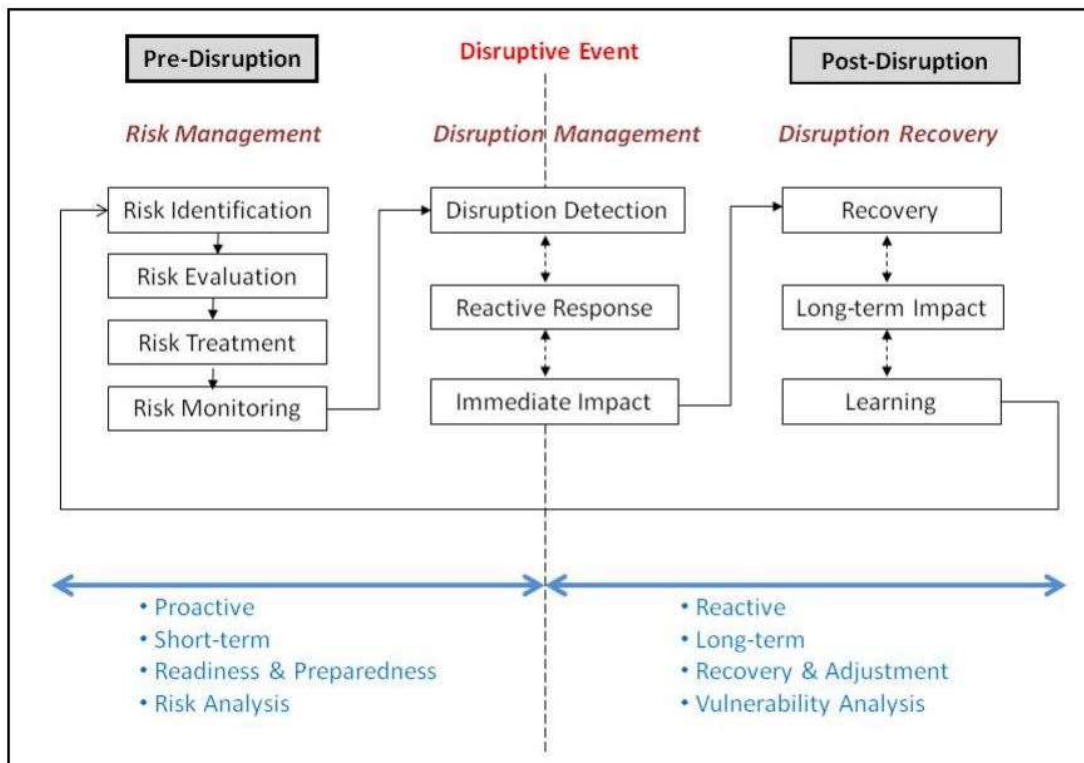


Figure 4 Disruption Response Phases Abidin and Afroze (2018)

3 Inventory management.

Inventory management stands as a fundamental aspect of supply chain management (SCM), with inventory serving as a significant contributor to costs within any supply chain (SC). (Abuhilal et al., 2006). Effective management of materials and inventory is crucial throughout the project timeline since construction materials typically account for 50-60% of the overall project cost (Song, 2005 and Nasir, 2008). Materials must be properly tracked and located to guarantee that they are available when needed and in the right place, which will enable the construction project to move forward smoothly (Song, 2005).

Several factors can influence inventory management in construction projects. These include insufficient storage capacity (Sardroud, 2012), excessive ordering and redundant handling (Donyavi & Flanagan, 2009), and incomplete or outdated information regarding on-site stock levels (Navon & Berkovich, 2006). The absence of inadequacy of up-to-date information on on-site inventory is often attributed to deficiencies in tracking and locating materials within construction sites.

Grau et al. (2009), summarized the traditional method of manual tracking. initially the material is unloaded from trucks and manually marked with delivery details for identification purposes. Then the item codes of each received item and its storage location in the lay down yard are then recorded. Additionally, delivered materials and components are often left scattered across the construction site which raises the possibility of several relocations prior to installation. Hence this may lead to significant time wastage during material searches. The inefficiencies in site inventory management resulting from this scenario are anticipated to lead to delays in project schedules and exceedance of budgeted costs (Kasim et al., n.d.)

Several recent research focused on applying ICT on-site material tracking to enhance the controlling of material management in the complex environment of construction sites. Moselhi and El-Omari (2006) conducted a study that merged barcodes and Radio Frequency Identification (RFID) technology to automate data collection from construction sites. In a separate investigation, Caldas et al. (2004) integrated barcodes with Geographic Information System (GIS) for managing the installation of prefabricated components. Research on technology applications in construction has

also explored the use of Global Positioning System (GPS). Grau et al. (2009) utilized GPS to identify and pinpoint the location of steel components at construction project sites. Conversely, Sardroud et al. (2010) integrated GPS with Geographic Information System (GIS) and Radio Frequency Identification (RFID) to monitor and locate construction resources on-site.

Since The primary objective of supply chain management (SCM) is to meet demand requirements at the lowest possible cost Therefore, inventory management techniques like Just-in-Time (JIT) and Material Requirements Planning (MRP) are essential to achieving this goal.(Abuhilal et al., 2006)

3.1-Just-In Time (JIT) – (Zero Inventory)

Just-in-Time (JIT) is a methodology promoted by Taichi Ohno and his team at Toyota Motor Corporation, the manufacturing division was where the Just-in-Time (JIT) concepts were first implemented. This deployment was a huge success, as evidenced by the increased productivity, lower maintenance costs, and decreased need for storage space in addition to the better quality and dependability of built cars(Pheng & Hui, 1999).

The core of the JIT concept in manufacturing system lies in the timely production and delivery of finished goods precisely when they are required for sale. This includes receiving sub-assemblies just-in-time from suppliers for integration into final products, procuring fabricated parts just-in-time to support sub-assembly requirements, and acquiring materials just-in-time from suppliers to fabricate fabricated parts.. Meanwhile waste encompasses any excess beyond the essential minimum resources such as equipment, materials, workers, and therefore should be removed, as it fails to enhance the value of the product (Low and Tan, 1997a,b).

Since construction and manufacturing are two distinct forms of production, the implementation of Just-in-Time (JIT) principles in construction differs greatly from that of manufacturing. These variations are also further influenced by the increased complexity and unpredictability that are inherent in construction projects.(Ballard, 1995)

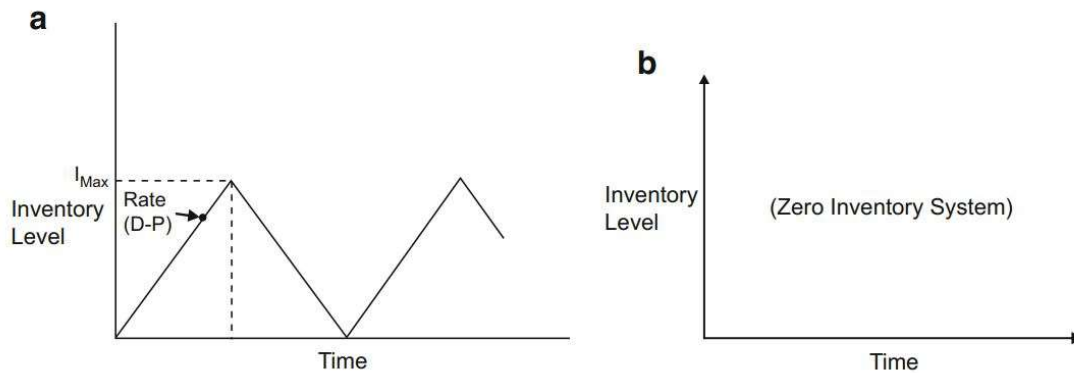


Figure 5 Just in time System (Vrat P,2014)

There are two categories of inventories designed to mitigate fluctuations in downstream construction processes. The more common type is **piles of staff** such as materials, tools, equipment, and labour. Such accumulations can result from decisions made to insert engineering time (buffers) between two planned activities, for instance prior to the fabrication and installation of pipe spools. Therefore, although they primarily consist of physical resources, they frequently signify additional time incorporated into the project timeline. As a result, this is referred to as "schedule buffers(Ballard, 1995).

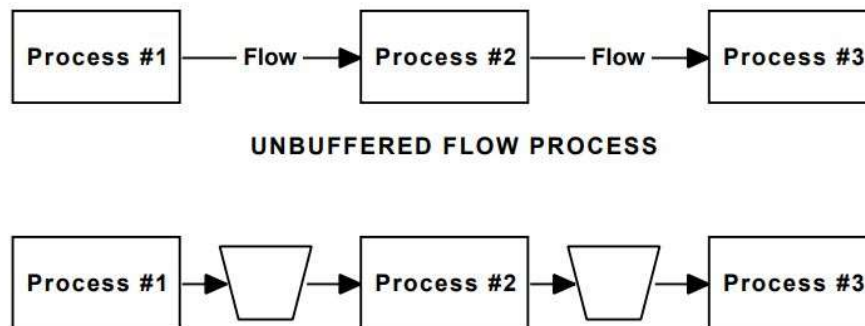


Figure 6 Buffer flow diagram (Ballard & Howell, 1995)

Less often recognised are inventories consisting of actionable tasks, which are produced from planning processes that prepare work for downstream production. These inventories serve as buffers by facilitating a consistent and predictable flow of output from each process. Unlike those of the first type, such physical accumulations are not necessarily involved, depending on whether the flow between supplier and customer processes can be predicted in advance. It can be described as "plan buffers.

In order to achieve this objective, the JIT system operates based on the following seven overarching principles:

- Reducing waste to a minimum.
- Employing the pull system
- Ensuring smooth and uninterrupted workflow.
- Implementing total quality control measures.
- Involving employees actively in the process.
- Maintaining strong relationships with suppliers.
- Striving for continuous improvement in all aspects of operations.

The pull system (kanban) in this context refers to the precise timing and amount of material procurement must be dictated by the demands of the construction site at the time of need. (Monden, 1983; Low and Chan, 1996). While uninterrupted workflows encourage material of the same task to be stored together to minimize the efforts and time a good example for that described in the case study (Pheng & Hui, 1999) materials such as steel bars, formwork, bending bars can be ordered shortly by the site supervisors from procurement departments and then stored nearby to reduce the movements during site operations.

Furthermore, the implementation of JIT techniques requires strong employee coordination and high involvement.

- Employees need to be trained in problem solving techniques, and quality control to ensure the smooth flow between sites' tasks.
- Employees should be encouraged to take part in site planning activities.
- Should be aware of the basics of waste management.as all employees present have a shared responsibility for keeping the construction site clean.

Moreover, JIT application necessitates a sound supplier relationship. The supplier must be capable of delivering the requested orders on time which match the real consumption rate at the site. materials need to be in the high quality to avoid any rework and schedule delays.

3.2 Economic order quantity

The Economic Order Quantity (EOQ) was introduced by Ford W. Harris in 1913, EOQ is a method for managing inventory that reduces costs associated with handling inventory and processing orders. The concept was later developed by R. H. Wilson and K. Andler, who offered in-depth analysis and real-world application. (Hax and Candea, 1984).

EOQ is a method that help to decide optimal number of orders in such a manner that Total Cost of Procurement Material is minimised. Main objective of EOQ is minimum purchasing cost of material, so that entire procurement process will be optimised.

$$EOQ = \sqrt{\frac{2 * S * Co}{Cu * i}}$$

EOQ: Economic order quantity

S=Annual Consumption,

Co= Cost of Order,

Cu=Unit price,

i = Inventory Cost in %

The EOQ method is based on several assumptions:

- 1- The demand quantity is known, relatively constant, and independent.
- 2- The time between placing an order and receiving it is known and fixed.

Inventory arrives just in time and in full – every order resides in one shipment.

As depicted in Figure 7 while ordering bulk quantities may drop the order cost. the material holding price will increase. EOQ defines the optimum quantity which achieve the minimum total combined cost (TOC+THC).

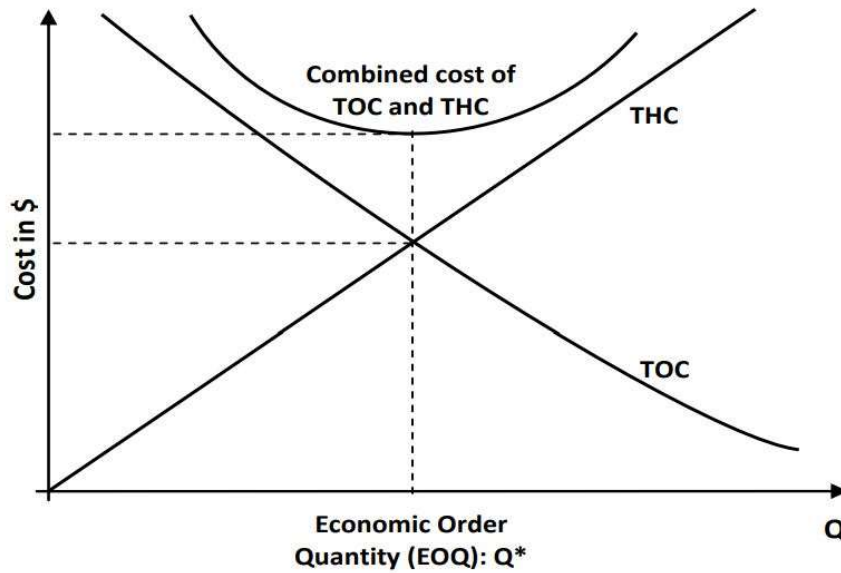


Figure 7 EOQ optimization graph.

THC: Total holding cost

TOC: Total ordering cost

A business can successfully cut costs related to unit procurement, delivery, and storage by achieving this ideal quantity.

4 Construction procurement

Materials and equipment procurement alone constitute 50% to 60% of the total project cost according to B.H.W. Hadikusumo et al. Effective material management can help in saving a considerable amount of project cost by eliminating unnecessary charges, such as extra costs due to time overruns and claims hence, material management is vital to project's success and can significantly increase a company's profitability and reduce avoidable charges.

Construction procurement is structure or framework through which construction projects resources are acquired or obtained. Another common definition by (ISO,2008) refer to procurement as procedure involved in creating, overseeing, and fulfilling contracts. Miller et al. (2009) suggest that in the construction industry, both project owners and project managers often rely on procurement approaches that have proven successful in the past.

4.1 Construction procurement processes

Construction procurement processes work as a road map for procurement activities. It begins with identifying project need and decide what to procure, until ensuring that final product meets the specified requirements (International Organization for Standardization 2008). Fig (2) illustrates the general steps of procurement processes which are intertwined with every stage of the project lifecycle. Depending on the chosen procurement method, several parties share the responsibilities for procurement activities at each project phase as per the office of Procurement Ombudsman (2012).

Moreover, According to PMI,2017 In smaller businesses without a department dedicated to procurement, the project manager may take on the role of purchasing authority and engage in direct contract negotiations and signing which is referred to as (decentralized purchasing).the case is quite different in bigger organizations, who typically have a centralized purchasing departments whose sole responsibility is to purchase, negotiate, and execute contracts.

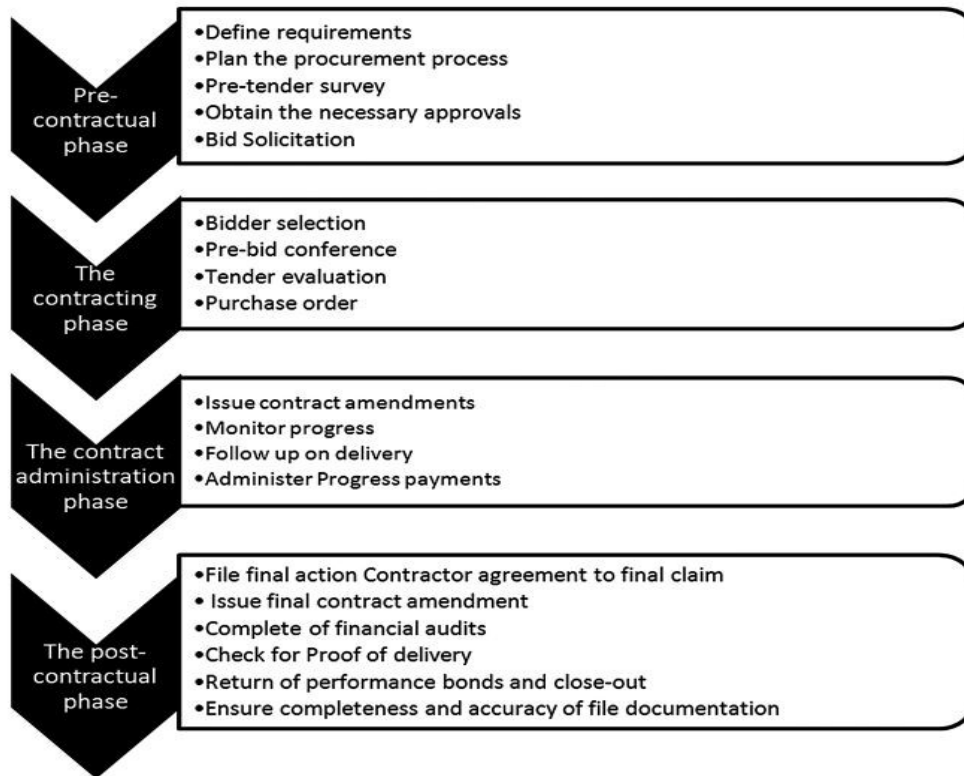


Figure 8 Procurement Processes (ISO 2008)

4.2 Procurement Strategy

The goal of the procurement strategy is to establish the project delivery method, specify the type of legally binding agreement(s) involved, and outline the progression of procurement through its various phases. (Project Management Institute, 2017)

4.3 Procurement Methods

The primary considerations of a procurement method typically include the price formation method, project delivery method, and conditions of the contract. Walker and Hampson (2008) have pointed out that the choice of procurement method has an immediate effect on the risks assumed by contracting parties, which is then reflected in the project price.

4.3.1 Project Delivery method

Project delivery method defines the approach of managing the planning, design and construction of the project which is different from the contract types which is focused on financial and legal terms among the participating parties.

4.3.1.1 Design-Bid-Build (D-B-B)

Generally referred to as traditional project delivery method. In this approach, the owner contracts an architecture/engineering firm to provide design services tailored to the owner's specifications. And based on this design the owner assigns the suitable contractor – typically the lowest bid - to implement the project.

4.3.1.2 Design- Build (DB)

In this method a single contractor is accountable for both the design and construction phases, Chan et al. (2002). This method enables less design mistakes and schedule delays. however, it may cause increased expenses occur due to bidding conducted with limited design or site information.in addition to the quality of the final project outcome highly dependent on the contractor performance Walker and Hampson (2008).

Turnkey is considered a special case of design-build method where client receives the project with minimal involvement. The contractor in turnkey projects takes the responsibility from the design stage to the commissioning stage typically common with standardised projects.

4.3.1.3 Construction management (CM)

Construction management (CM) has become more popular over the past 20 years as an alternative procurement strategy. Under this approach, a design contractor functions as the client's advisor advising on co-ordination, cost control and programme for the construction works. In CM, subcontractors interact with the client directly, in contrast to traditional approaches. However, CM is often confused with management contracting, which is an additional procurement method. Contractors enter a contract with a management consultant who at first acts as the client's advocate (Donohoe and Brooks 2007).

4.3.1.4 Partnering

partnering within construction procurement is a methodical management strategy fostering collaboration, trust, sustained commitment, transparency, shared goals, customer-centricity, and innovation among contractual entities, as outlined by Cox and Townsend (1998).

4.3.2 Contract Types

Project management institute classifies all the contracts under two main categories. This classification is concerned with financial aspects of procurement methods.

4.3.2.1 Lump Sum

Generally fixed price contracts are used when the scope of work is well defined. Mostly the main selection criteria is the lowest bid. Although this type of contract has the minimum risk on the client there are some drawbacks as pointed by Walker and Hampson (2008), such as lower level of involvement between design team and contractor. in addition to disagreement which may arise in case of scope variations

4.3.2.2 Cost reimbursable.

This approach is suitable for instances where the design specifications are frequently changing or not fully settled. As the client takes on the full financial risk in this approach, regulation, vigilant control and independent monitoring become highly necessary. (Walker and Hampson 2008).

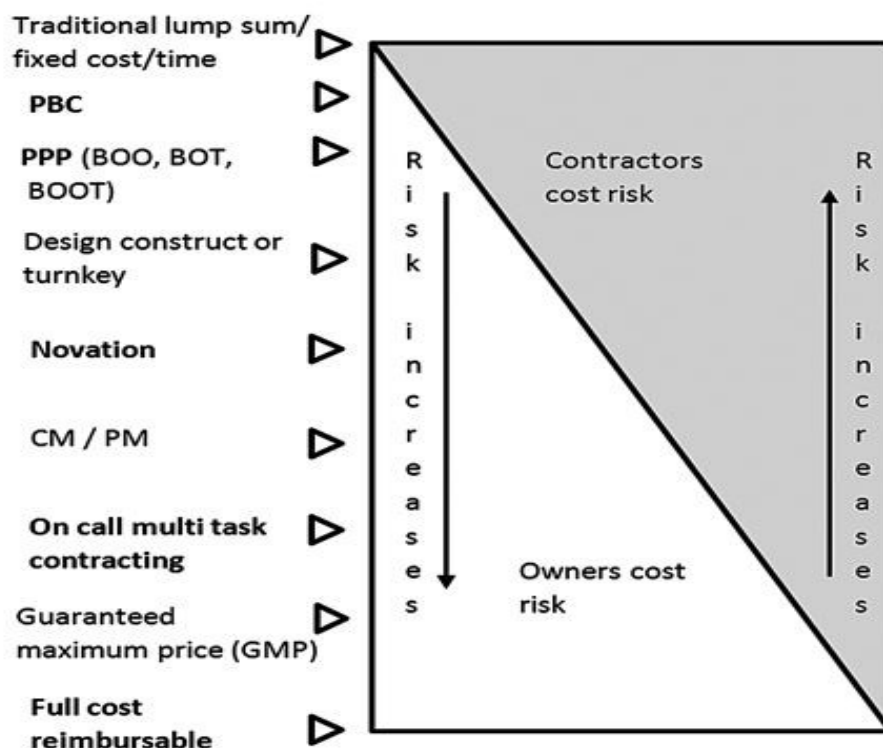


Figure 9 Construction Risk for project delivery. (Walker and Hampson ,2008)

As depicted in Fig. 2, the risk levels for owners and contractors vary depending on the procurement method chosen. For instance:

- A lump sum/fixed cost contract places high risk on the contractor, while protecting the owner from unexpected cost increases.
- Full cost reimbursable contracts entail low risk for contractors in terms of costs but expose owners to all potential cost escalations.

It's crucial for the client or construction manager to select the most suitable procurement method based on the specific project requirements and the risk tolerance of project participants.

4.4 - Procurement Policies & Procedures

Significant progress has been made in construction procurement policy recently, such as e-procurement, green procurement, and standardization. These initiatives seek to increase the value that construction-related activities provide for project stakeholders (Ruparathna & Hewage, 2015).

Procedure	Description
Negotiation procedure	One bidder is asked to submit a tender offer, and the price is negotiated.
Competitive selection procedure	The lowest-priced tender offer or the offer with the most points based on the evaluation criteria
Nominated procedure	A list of qualified bidders is created and based on project-specific requirements and their ranking on the list, they are invited to submit a bid.
Open procedure	Bids are sent in response to a prospective client's advertisement.
Qualified procedure	Bidders who satisfy the objective requirements and have answered to an interest call are invited to submit a bid.
Quotation procedure	Offers for tenders are requested from a minimum of three tenders, as specified by the organization.
Proposal procedure using the two-envelope system	Each bidder submits a technical and financial proposal; the bidder's financial proposal is only opened if the technical proposal is accepted.
Proposal procedure using the two-stage system	After non-financial proposals are requested, tender offers are requested; the contract is negotiated with the candidate who receives the most points.

Shopping procedure	Bids are requested from available supplies
Competitive negotiation procedure	After a round of negotiations, the number of possible bidders is reduced, and the remaining tenderers are then asked to submit their final offers.
Restricted competitive negotiations	EOI are requested, and prospective bidders who meet the objective requirements are encouraged to submit their bids. Following the customers' evaluation of the offers, competitive negotiations are requested.
Open competitive negotiations	After the organization posts an advertisement inviting bids; the customer assesses the proposals and chooses who can engage in competitive negotiations.
Electronic auction procedure	The bids received at the first round are evaluated based on a pre-assigned set of grading criteria; all response bidders are asked to electronically submit, at the same time, new sets of grading criteria and scores.

Table 1 Standard Procurement Procedures [International Organization for Standardization (2008)]

5 Supplier Procurement

The manufacturing sector is familiar with a variety of buyer-supplier strategies, but their relevance in the construction sector is not as well established. Moreover, the emphasis in the construction industry has been on the client-contractor relationship rather than the contractor-supplier one, as Dainty et al. (2001) pointed out.

Moreover, one significant aspect in supplier procurement is to define the optimal number and the suppliers in the buyer's company's supply base. as per Monczka et al. (1993) supply base enhancement can be achieved through raising the bar for performance and directing supplier development. Furthermore, It is crucial to pay attention to the company's supply base policy. An organization may, for example, mandate that it only works with local vendors or that suppliers provide specific certifications. (Bemelmans et al., 2012b)

5.1 Supplier Selection

Supplier evaluation criteria and their weights in the supplier's assessment vary from one organization to another according to the procurement strategies and policies. PMI, (2017) outlined some of the common factors affecting the assessment process.

- Ability and resources
- Cost of the product
- Schedule for delivery
- Technical skills and methodology
- Relevant experience
- Appropriateness of the proposed approach and work plan in addressing the SOW
- Qualifications, availability, and competency of key personnel
- Firm's financial health
- Management expertise
- Effectiveness of the knowledge transfer program, including training

Lam et al. (2010) argues that in order to develop supplier selection model it's essential for organisations to set priorities on factors that should be considered to

determine the feasibility of a new supplier. The quality of the outcome of the supplier selection model greatly depends on the defined criteria and the weight assigned to each. Fig (4) illustrates the proposed model by Lam et al. (2010) as an example.

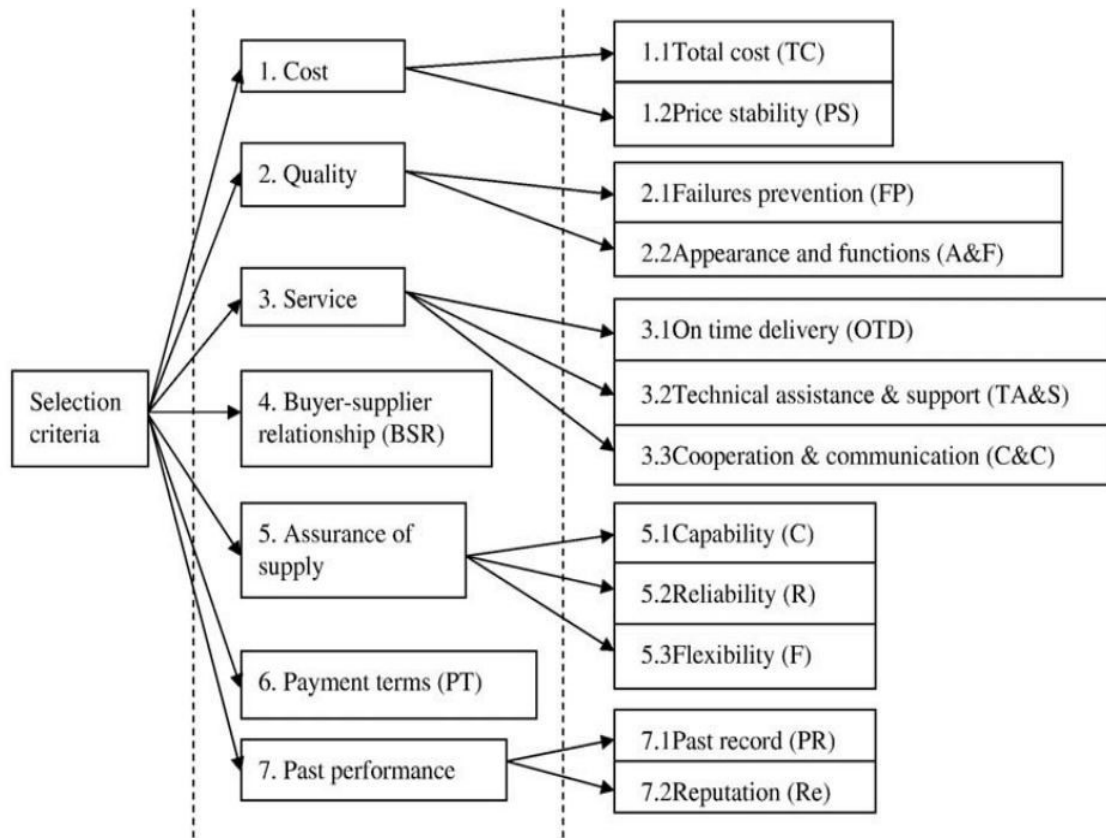


Figure 10 supplier selection model. (Lam et al. 2010)

5.2 Supplier Relationship management

Supplier relationship in construction is often criticized for being a short-term transaction. even if the supplier is frequently engaged in other projects with the contractor.

Price is still the main consideration in contractors-supplier relationship (Hartmann et al. 2009). Forty construction companies participated in a previous study by Akintoye et al. (2000), which revealed that only one-third of these companies valued their

relationships with suppliers more than their relationships with clients, with the other two-thirds making the opposite claim.

Achieving a collaborative buyer-supplier relationship starts with supplier being recognized as a preferred supplier. This kind of relationship involves the formation of annual agreements and increased supplier involvement in the quality control process. (Van Weele 2009).

the Construction Industry Institute's (CII) defines Partnership as "an extended agreement between two or more organizations with the goal of reaching particular business goals by making the best use of the resources available to each party." However, implement partnership can have quite challenging obstacles such as

- Insufficient commitment
- Conflicting corporate strategies and objectives
- Variations in trust and dedication levels across operational and strategic tiers within the company. (Storey et al. 2005)
- Deficit in trust as a significant obstacle to collaborative planning within supply chains. (Barratt .2004)
- Forming and maintaining long-lasting partnerships can demand considerable time and financial resources. (Lee et al. 2009)

According to Bemelmans et al. (2012b) Securing successful partnerships with strategic suppliers requires a great deal of cooperation, trust, information exchange, information sharing, creativity, and support from upper management.

Another important aspect is supplier management is Incorporating suppliers into a buyer company's value creation process. This can be highly beneficial; however, it can be difficult to execute in practical situations (Vonderembse & Tracey). one of the benefits can be realized in a study conducted by Clark (1989) revealed that during the design phase of a project, extensive engagement with suppliers yields benefits in terms of reduced lead times and expenses.

On the other hand, buyers company as well can be involved in supplier development by recognizing possibilities for improvement and then enabling those improvements in performance (Bemelmans et al., 2012b). Krause and Ellram (1997, p. 21) argue

that the following components should be recognized to achieve supplier development.

- Efficient communication,
- leadership engagement,
- cross-functional teams within the purchasing company,
- consideration of price versus total ownership costs, a forward-looking approach,
- significant portion of the supplier's yearly revenue, assessment of suppliers, and acknowledgment of supplier contributions.

5.3 Types of items

Micheli and Cagno (2016) suggest that different procurement strategies should be applied for varied categories of items; that is, each item type should be procured through a distinct contracting mechanism, and the selection of such mechanism is proportional to the item's criticality and the expected risk distribution between the buyer and the supplier.

Kraljic (1983) classified the purchased material or services into four main categories which is known as Kraljic matrix. the matrix categorizes items based on two key factors.

Supply Risk: evaluate the items in term of market availability.

Cost Impact: Defines the financial impact of the item as a percentage of the total purchase cost.

Leverage items: high contributors to profit beside they have a large supply base and hence a low supply risk. In a project, these items have a large influence on project costs and quality but a small influence on the project schedule, as they have a large supply base. The strategy for buying leverage items is to take advantage of the company's buying power to negotiate the lowest price, such as tendering, target pricing and product substitution.

Strategic (S) items: It has a high impact on profit but a low supplier base and thus is characterised by high supply risk. In the project context, these items have an impact both on cost and quality performance. Also, due to their reliance on one or two specialised suppliers, they have a high impact on project schedule, and procurement managers are advised to both create and maintain long-term relationships with these suppliers.

Non-critical (NC) items are generally priced at market-standard rates with multiple suppliers, and do not have a large influence on project profitability. Non-critical items also have limited impact on quality outcomes, schedule performance and supply risk. This is because multiple sourcing options allow non-critical items to have little influence on projects.

Bottleneck (B) Items: these items have low impact on the project cost, but have high supply risk, as they come from limited number of supplies in context of project. These materials barely have any effect over the project cost or quality. However, one or few suppliers of such products can create supply disruption issues, thus impacting schedule performance greatly.

Fig () illustrates the material sourcing matrix known as Kraljic matrix.

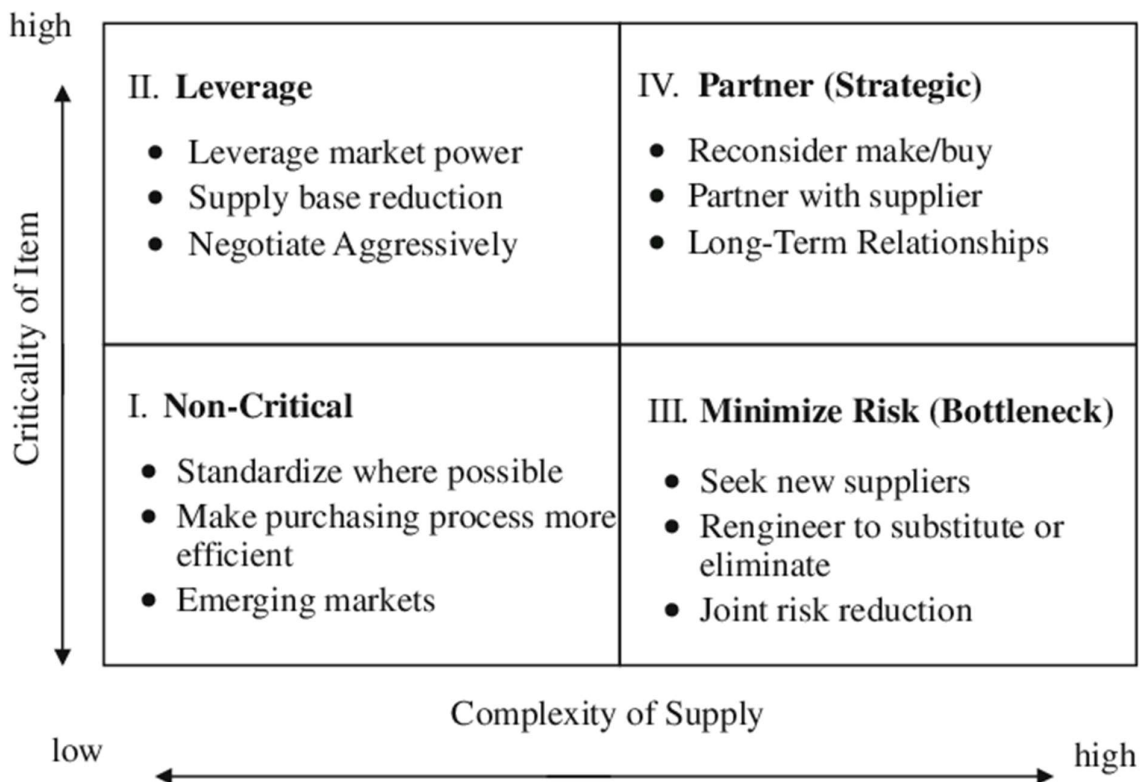


Figure 11 sourcing strategies (Kraljic .,1983)

Kraljic sourcing matrix provides a general insight on the procurement to identify and control supply potential risks. Numerous studies adopted this concept in the construction environment for instance Bildsten et al.,(2010) investigated the application of Kraljic categorization on industrialized housing in Sweden . results can be shown in (Figure 12)

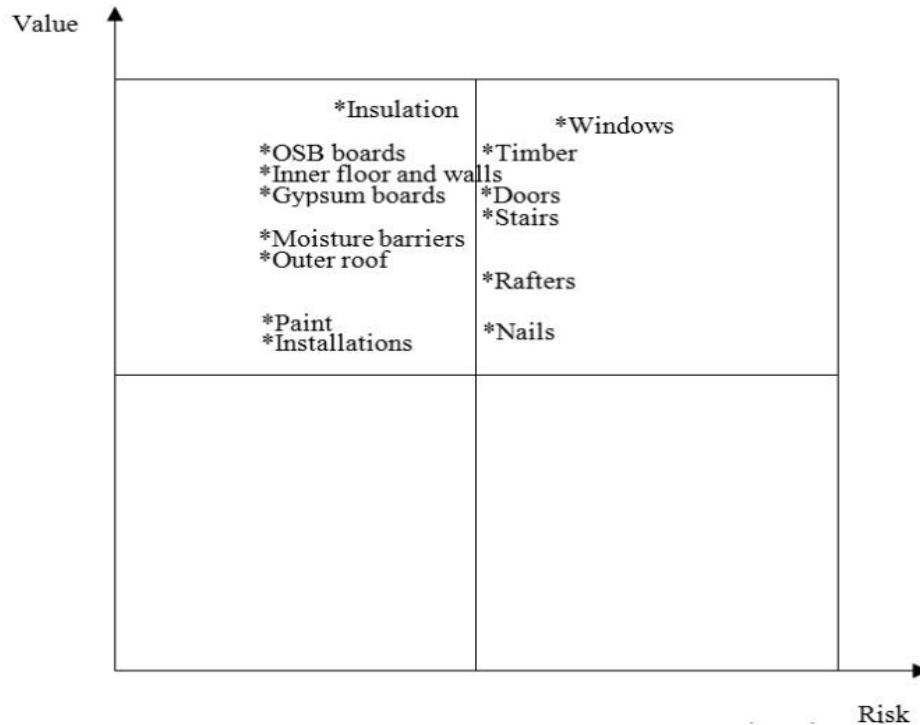


Figure 12 Construction items Kraljic-1983 matrix (Bildsten et al., 2010)

5.4 Buyer- Supplier relationship types

Several types of relationship between buyer and supplier can be realized in the construction market. However, this highly depend on the dimensions on which these relationships are studied. Boyce (2003) examined the supplier relationships within project context. Taking into consideration the control level and risk experienced by the buyer. This provides a rich reference when analysing the risks associated with the supplier procurement processes (Dixit, 2020).

Partnership sourcing: involves the establishment of trust through joint operations and information-sharing between the buyer and supplier and is based on a long-term relationship with a written and fully agreed contractual obligation to shared, long-term objectives Brown et al (1994)

Competitive Arms-Length (CAL) relationships are market-fuelled, competitive interactions that are regulated by market prices. Buyers in such relationships can retain little control, and suppliers of products and services assume most of the risk, keeping the riskiest steps away from buyers.

Non-Competitive Sole-Source (NCSS) relationship: in this type of the sole-source supplier is chosen without ever being subject to competition. The purpose of this type of relationship is to engage a source when there is only one available, to fill an order in the shortest possible time without the ability to competitively select a supplier, or when it is not feasible to establish the competitive basis of selection. In this kind of relationship, the buyer has the least amount of control and is at the highest risk of bad things occurring (Boyce 2003).

Non-Competitive Non-Monopoly (NCNM) relationships: the selection of a supplier from the limited set of alternatives in the market for the corresponding good or service, with the buyer exposed to a moderate level of control and high level of risk.

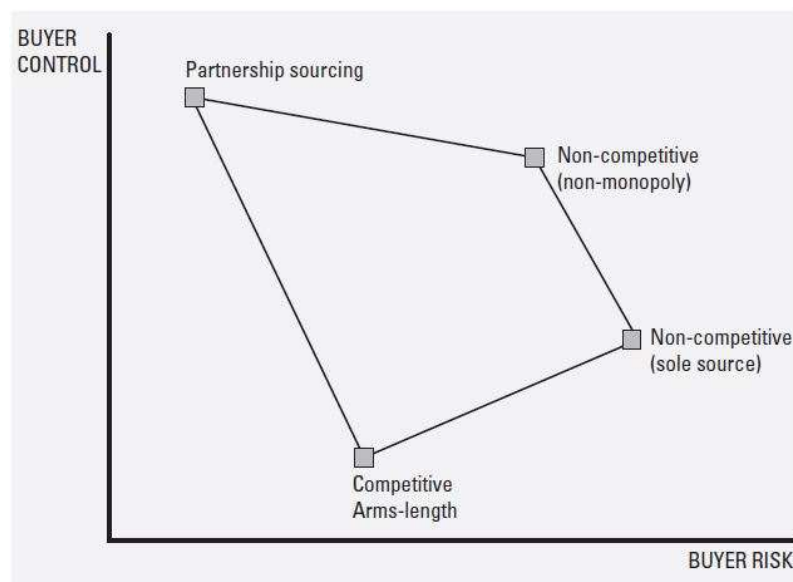


Figure 13 Buyers-Supplier Relationships Risk graph (Boyce 2003)

6 Advanced technologies in construction procurement

There has been notable progress in enhancing tools for managing the various procurement stages of projects. Online procurement platforms now offer a centralized hub for buyers to advertise procurements and for sellers to access and complete procurement documents directly online. Moreover, in sectors like construction, engineering, and infrastructure, the growing adoption of Building Information Modelling (BIM) software tools has proven to yield considerable time and cost savings. Utilizing BIM can significantly mitigate construction claims, resulting in reduced costs and schedule delays. Consequently, numerous major corporations and governments worldwide are starting to enforce the utilization of BIM on large-scale projects. (Project Management Institute, 2017)

An inclusive literature study was conducted by Ibem and Laryea (2014) to survey the technological applications used within construction procurement as defined in ISO 10845 including the methodical search and evaluation of 78 papers that were published in 52 different sources between 1993 and 2014. The outcome is shown in table 3

Table 2 Technology Applications in construction procurement (Ibem and Laryea 2014)

Construction procurement activities (ISO 10845)	Digital technologies
Establishment of what is to be procure	<ul style="list-style-type: none"> • Software applications • Computer Aided Design (CAD) • Building Information Modelling (BIM) • Virtual reality technology
Establishment of procurement strategy	<ul style="list-style-type: none"> • Web-based Enterprise Resource Planning (ERP)
Soliciting for tenders	<ul style="list-style-type: none"> • Web-based Project Portals • Web.2.0 technology • Cloud computing technology • Multimedia technology

Evaluation of tenders	<ul style="list-style-type: none"> • Videoconference • Cloud computing technology
Award of contract	<ul style="list-style-type: none"> • Multimedia technology
Administration of contracts to ensure that they comply with requirements	<ul style="list-style-type: none"> • Wireless technology • 3D scanner or LADAR (laser distance and ranging) • Radio Frequency Identification (RFID) • Project camera • Bar code technology • Multi media technology • BIM technology • Electronic Data Interchange (EDI) • e-Marketplaces • Wireless technology e.g. Wi-Fi networks, WLAN; cameras, long-haul wireless; cellular modems, satellites communications, • Internet-Based Geographic information System (GIS) • Geographic Positioning System (GPS) • Tele, video and desktop conference • Sensor networks

Table 2 Technology Applications in construction procurement (Ibem and Laryea 2014)

6.1 E-procurement

The applications of e-Commerce applications, especially e-Procurement, have become widely acknowledged and recognized across many sectors. However, compared to other industries like manufacturing and retail, the construction industry has a very low adoption rate of e-Procurement (Anumba & Ruikar, 2008). The reason behind the low adoption of e-Procurement in the sector is the need for training people, reshaping process, and investing in technology, as well as the high cost of e-Procurement and the significant changes it necessitates in internal organizational procedures (Björk, 2003).

According to Grilo & Jardim-Goncalves,(2011), the e-procurement can be classified in two main phases, e- tendering and e-awarding as depicted in Figure 14

- e-Tendering: Focus on tendering process. Contain data about supplier capabilities, work history, qualifications.
- e-Awarding: suppliers can be evaluated, and an award is given to the most suitable suppliers.
- e-Order: Allow placing the orders with the required quantities at the planned time.
- e-Invoicing provides automated invoices for the purchased goods and services.
- e-Payments: concerned with payment's transactions between buyer and service provider.

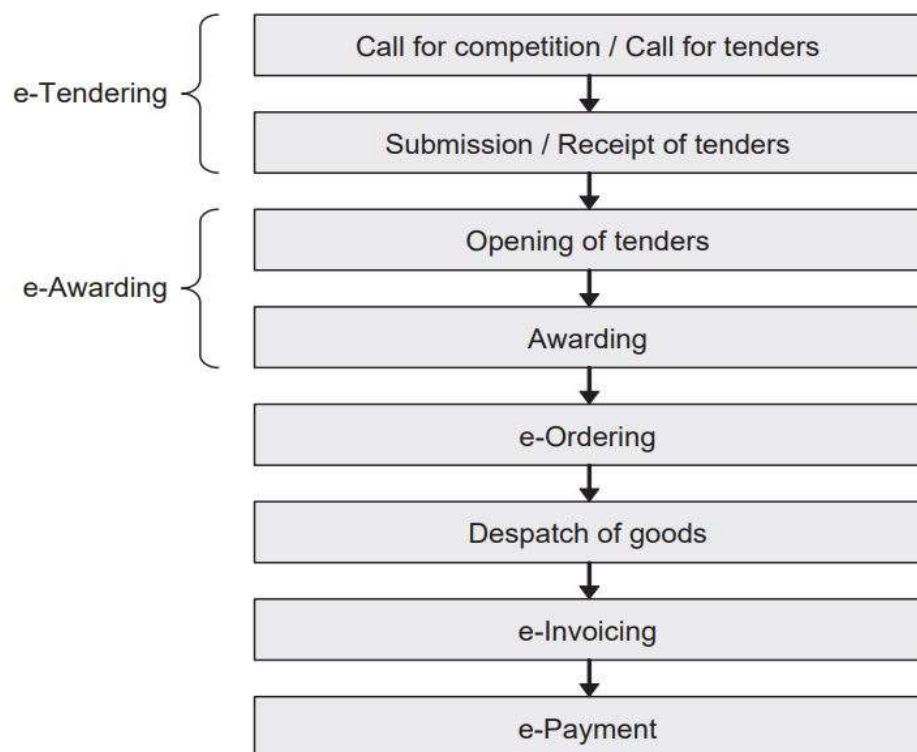


Figure 14 e-procurement procedures. (Grilo & Jardim-Goncalves, 2011)

6.1.1 Opportunities

Anumba & Ruikar, (2008) refer to multiple privileges which can be realized with e-procurement adaption in the construction sector this may include but not limited to

- Faster access to construction-related data,
- Current information on products and industry trends,
- Streamlined procurement processes,
- Cost reductions through the elimination of intermediaries,
- Easier comparison of products based on price and quality,
- Shorter procurement times,
- Reduced inventory levels,
- Increased transparency,
- Enhanced decision-making quality.

6.1.2 Challenges

There are certain restrictions on e-procurement in the construction sector, this can be attributed to the number of specification parameters for building materials which needs to search for to procure the required products, it takes time to enter the parameters into the web-based forms of numerous e-commerce sites. A contractor must compile and keep up to date a list of several online addresses, comprehend the navigational techniques employed in various sites, stay informed about newly launched websites, and manually review all the data gathered from various websites (Kong et al., 2004). Moreover, some items necessitate the relationship between the contractor and the supplier (Grilo & Jardim-Goncalves, 2011).

More studies have been conducted to investigate the limitations of e-procurement in construction. A recent study performed Isikdag, (2019) by classified the obstacles facing e-procurement based on international literature review to 4 main categories as follows Market-related, Technological, strategic, and human and process related.

Market Related obstacles

- Lack of innovative firms
- Mistrust in pricing in e-procurement.

- The ineffectiveness of user-generated material for internet advertising
- Concern about the number of potential clients in the virtual environment

Human and process related obstacles.

- Employee inadequate IT expertise
- Concern about sensitive project's data and information
- Lack of communication between buyer and seller
- Insufficient instruction on e-commerce system setup and usage
- The challenges of business process re-engineering to accommodate e-procurement information flow.

Technological obstacles

- Non-familiarity with electronic signature
- Complications in setting up the online store.
- Issues with e-commerce environments' integration with ERP systems
- Issues with server administration
- Challenges in setting up security measures.

Strategic obstacles

- Shortage of national guidelines for information exchange
- Insufficient legal framework for online e-commerce
- Lack of support from upper management to transition towards e-commerce
- Insufficient knowledge of the national and international tax laws associated with electronic trade.
- Insufficient research on best practices

6.2 E.RP

Enterprise Resource Planning (ERP) is an integrated business management software that manages multiple aspects, integrates and automates various business processes, such as Human Resources (HR), Purchasing ,Sales, Inventory Control (IC), Finance, Production, Customer Relationship Management (CRM), Accounting ,

and more into one and automated system to ensure that business runs seamlessly and smoothly in the high and low periods, as well addressing the business needs and challenges , coherently, effectively, efficiently and productively(Pekša, 2018).

6.3 Supplier relationship management software

Herrmann and Hodgson (2001) define Supplier Relationship Management (SRM) as a process that aims to manage preferred suppliers and identify new ones to lower costs, ensure that procurement processes are predictable and consistent, leverage the collective experience of buyers, and gain benefits from supplier partnerships.

According to Choy et al. (2002) the SRM enhances the competitive advantage of manufacturers through three main mechanisms.

1. enable better business processes across the supply chain,
2. utilise a next-generation type of architecture that can support multi-enterprise processes or business processes that involve more than one enterprise, and
3. enable fast product cycles and creativity for new products and product lines.

Moreover, SRM can be integrated with CRM (customer relationship management system) with the same platform of ERP system which can result in increasing the flexibility, limiting the cost and shorten the procurement cycle period.

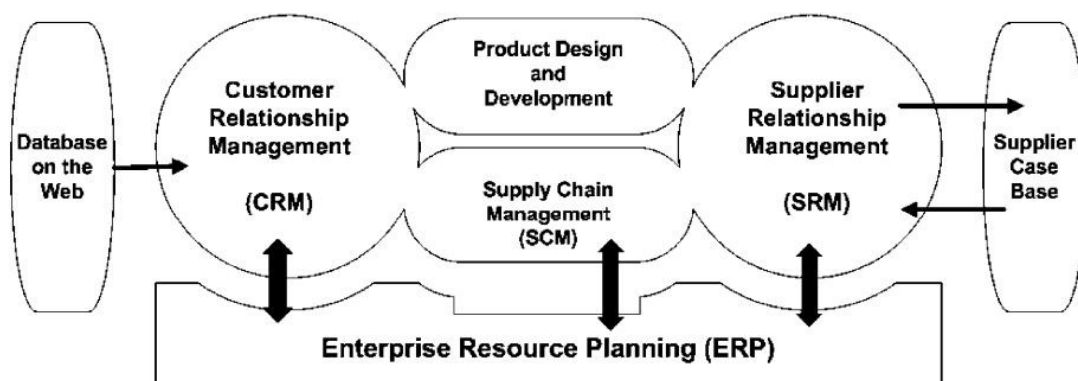


Figure 15 SRM , CRM and ERP integration (Choy et al., 2002)

There are quite various options for SRM utilized construction industry. for instance, most common provider of these systems are SAP and Oracle

7 Procurement-Based Risks

Carty (1995) suggests that project procurement faces numerous risks from the external environment where items are obtained.

PMI, (2017) states in PMBOK that project risk is 'an uncertain event or condition that, if it occurs, has a positive or negative effect on project objectives. That last word is important: risk signifies an innate uncertainty in what has been identified. Risk, as classically defined, has always been associated with negative consequences: loss, danger, harm, accident, and other adverse outcomes. Yet the recent revision of risk guidelines and standards attempt to expand this perspective through the notion of positive risk or opportunity. However, some risks may not be directly identified such as supply chain risks where the risk in this situation is an outcome of another event in the supply chain network. Supply chain risk is defined as 'the possibility that unanticipated events will have negative consequences to the involved company within a supply chain' (Narasimhan and Talluri, 2009)

7.1 Risk management.

The main objective of project risk management is to minimise the probability of the project directly or indirectly involved potentially failing to achieve their objectives. It enables project managers to identify and prioritise activities for completion and to allocate resources and actions that can be put in place to help to decrease the likelihood of the project failing to achieve its goals (Cooper, Grey, Raymond, & Walker, 2005)

Chapman,C. (2003) defines Risk management is a holistic, proactive means of identifying potential occurrences (events; risks) that could impact project objectives, analysing them and creating appropriate strategies to address them in order to increase the chance of positive results and minimise the likelihood of negative consequences.

According to PMI, (2017) Project Risk Management involves the processes of planning for risk management, identifying risks, analysing them, planning and implementing responses, and monitoring risks throughout the project. Fig describes the key stages of risk management process.

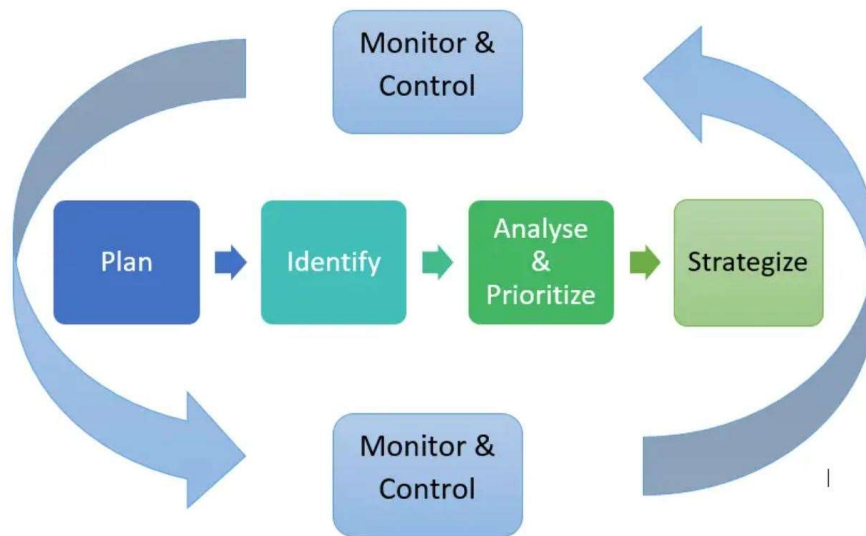


Figure 16 Risk Management Framework (PMI,2017)

7.2 Identifying Procurement-based Risks

Risk identification is an initial stage in risk management. This step is likely the most crucial and time-consuming, as inaccurate identification of risks can lead to incorrect assessments and responses (Simu, 2006). Participants in risk identification activities may include the project manager, project team members, a project risk specialist (if assigned), customers, and external subject matter experts. The involved participants may utilize a number of risk identification techniques, the most common are: Brainstorming Interview Expert Opinion Questionnaires Checklists Delphi technique Expert systems Past experience Documentation review (PMI ,2017).

7.3 Risk Analysis

Kaplan and Garrick (1981) referred to risk analysis as a decision-support process, which combine qualitative and quantitative techniques, to assess future events that might affect achieving objectives. The process aims to identify sources of uncertainty around the events, their potential consequences, and the effectiveness of mitigation strategies. This process typically starts with data gathering from company's historic

data besides communications and meetings to determine risk classification, urgency and priority in addition to risk ownership.

PMI, (2017) explained some of the effective techniques and tools that may be used in this stage which include but not limited to

- 1- Risk categorization: by classifying the risks according to their sources. Risk breakdown structure can be utilized for this purpose.
- 2- Risk probability and impact assessment: Risk impact assessment checks a risk's anticipated consequences on project objectives (eg schedule, cost, quality, performance, etc) Each identified project risk is assessed in terms of probability and impact. This check is done through interviews or meetings with participants informed about possible risk types, which are recorded in the risk register.
- 3- Risk simulation: More advanced software tools can be used in assessing risks simulation such as Montecarlo. This technique requires high-quality data. However, this analysis is not performed to all types of risks.

7.4 Risk Responses

Risk allocation methods typically involve one or a combination of the following strategies: retaining the risk, transferring the risk, reducing the risk, and avoiding the risk (Flanagan & Norman, 1993).

- 1- Accept risks: Typically, this method is chosen when the risk can't be prevented, transferred, or avoided likelihood of an event occurring is low, and impact is insignificant and when transfer of the risk is not cost-effective, retention can be the only option (Williams & Heins, 1989). A common example on this is accepting a new supplier with a lower bid into the company supply base.
- 2- Avoid risks typically seen as impractical because it could result in projects being delayed or contractors proposing unreasonably high bids (Akintoye & MacLeod, 1997).
- 3- Transfer: To outsource risk is to transfer ownership of a threat to a third party, who can manage the risk and bears the impact of the threat, usually after charging a risk premium to the party accepting this risk (PMI, 2017). In

construction context , this often happens when contractors transfer part of the project scope to a specialist or a subcontractor .

- 4- 4-Mitigate risks involves decisions which may decrease the likelihood or the consequences of the risk. This can be achieved by exploring the application of various strategies such as alternative contract methods, diverse construction techniques, project redesigns, and conducting more detailed and comprehensive site investigations (Toakley & Ling, 1991).

7.5 Literature Procurement-related Risks

Summary of Main procurement-based risks identified in the studied literature.

Table 3 Literature Procurement-Related Risks

Risk	Risk classification	Risk management strategies	Literature
Supply chain disruption	Logistical	<ul style="list-style-type: none"> -Develop supplier diversification strategies, -prioritizing local suppliers when feasible to reduce reliance on international shipping. * -Maintain buffer stock of critical materials, considering storage limitations in the local market -Regularly communicate with suppliers, monitoring political and economic instability in the region. 	(Cox, Ireland, & Townsend, 2006) (Panova & Hilletoft, 2018)
Delivery delays	Logistical	<ul style="list-style-type: none"> -Communicating more clearly with suppliers about sticking to deadlines. -Contractual penalties for late deliveries considering legal frameworks. -Contingency plans that include alternative suppliers 	(Khairullah et al., 2022) (Wang & Wang, 2022) (Marzouk & El-Rasas, 2014) (Rahman, Yap, Ramli, Dullah, &

			Shamsuddin, 2017)
Cost overruns	Managerial	<ul style="list-style-type: none"> -Develop a detailed budget with contingency reserves -Explore value engineering opportunities using readily available materials. -Implement effective cost control measures throughout the project. 	(Khairullah et al., 2022)
Quality issues	Technical	<ul style="list-style-type: none"> -Include detailed specifications in the contracts -Ensuring procurement employees are aware of al the required specifications through strong internal info communication network -Set KPI for involved suppliers. -Conduct regular quality inspection on delivered material. 	(Khairullah et al., 2022)

Communication problems	Managerial	<ul style="list-style-type: none"> -Utilize collaborative project management tools that facilitate communication despite physical location. -Incorporate technical data from suppliers and subcontractors into collaborative BIM Model for instance (manufacturing data and item specifications which may be different from the design model) 	<p>(El-Razek, Bassioni and Mobarak, 2008) (Onyegiri & Nwachukwu, 2011) (Decarolis, Giuffrida, Iossa, Mollisi, & Spagnolo, 2019)</p>
Price volatility & Currency fluctuation	Financial	<ul style="list-style-type: none"> -Monitor market trends for construction materials, considering the impact of global fluctuations on local prices. -Budget contingency planning to account for potential price increases of materials -Include price adjustment clauses in contracts, if feasible within local legal frameworks 	<p>(Wang & Wang, 2022) (Kincannon & Franchet, n.d.)</p>
Contractual disputes	Managerial	<ul style="list-style-type: none"> -Develop clear and well-defined contracts that adhere to construction law and standard practices. -Include dispute resolution mechanisms outlined in Egyptian law (e.g., arbitration) within contracts. -Maintain clear and detailed project documentation to support claims if disputes arise. 	<p>(Khairullah et al., 2022)</p>
Hidden Costs	financial	<ul style="list-style-type: none"> -Conduct thorough project planning and cost estimation, considering additional costs for permits, inspections, and potential bureaucratic processes in Egypt. -Identify and include potential 	<p>(Ove, Li, Mandal, & Li, 2015)</p>

		<p>hidden costs in the budget, such as import duties or unexpected site conditions. -Conduct regular budget reviews and cost control measures to stay within budget.</p> <p>- Set up a KPI measure for supplier hidden cost percentage</p>	
Insufficient Capacity	Managerial	<p>-Assess supplier capacity during the selection process, prioritizing established suppliers with a proven track record.</p> <p>-Develop alternative sourcing strategies within the local market or the region to mitigate reliance on a single supplier.</p> <p>-considering potential lead times in the planning phase due to import processes.</p>	(Cengiz et al., 2017)
Supplier selection	Managerial	<p>Develop a robust supplier evaluation process, pre-qualify suppliers based on experience and qualifications.</p>	(Buzzetto, Baulia, & de Carvalho, 2020)

8 Egyptian Construction Market Overview

Egypt is one of the most populated countries in the middle east region with a population over 110 million people. Throughout several decades of the 20th century, Egypt's construction sector experienced significant growth, averaging a 9.7% increase annually, according to the Egypt Economic Report 2015.

The building sector has led economic activity since the 2011 revolution, for instance in efforts to build several 'Mega Projects the Suez Canal new tunnels, constructing power plants of high capacity as well as various new renewable-energy plants, upgrading road infrastructure and metro systems, and building a new city, the New Administrative Capital, and touristic cities on the north coast.

The size of the Egyptian construction market was \$88.5 billion in 2023. It is projected to achieve an average annual growth rate (AAGR) of over 9% between 2025 and 2028. However Construction market have been particularly volatile due to the massive effects of the Egyptian currency devaluation and domestic supply chain disruptions Fig (17) .

Recently, Egypt has been advancing towards self-sufficiency in many key construction materials. However, it still needs to import many raw materials and fuel for cement production (mostly from Europe).

In 2021 Building materials came as second largest imports to Egypt by 11.4 B USD According to (General Organization for Export & Import Control [GOEIC], 2023). In 2022 As a result of the international slowdown in production and construction activities, the prices of electrical supplies, as a sector, faced a marginal increase in shipping costs, in addition to an extension in the procurement lead time, thus leading to an increment in global construction material prices.

The same applies to the local market in Egypt indirectly, as it heavily relies on imported components in the production of reinforcement steel, cement and cables, as well as other construction material categories such as MEP equipment and materials, contributing to a high inflation rate at a range of 7-10% during the same period. (Gleeds, 2023).

Moreover, locally produced building materials, which depend heavily on imported raw materials, were highly affected by inflation: disruptions to supply chains have caused iron ore, steel billets, copper and aluminium prices to rise throughout the year. Prices of reinforced steel went up by 25-30 per cent, cement prices rose by 35-45 per cent. Together these materials account for 15-20 per cent of the total cost of typical building projects (Gleeds, 2023). The overall increase in material price can be noticed in Fig (18).



Figure 17 Egyptian pound VS USD (xe.com)

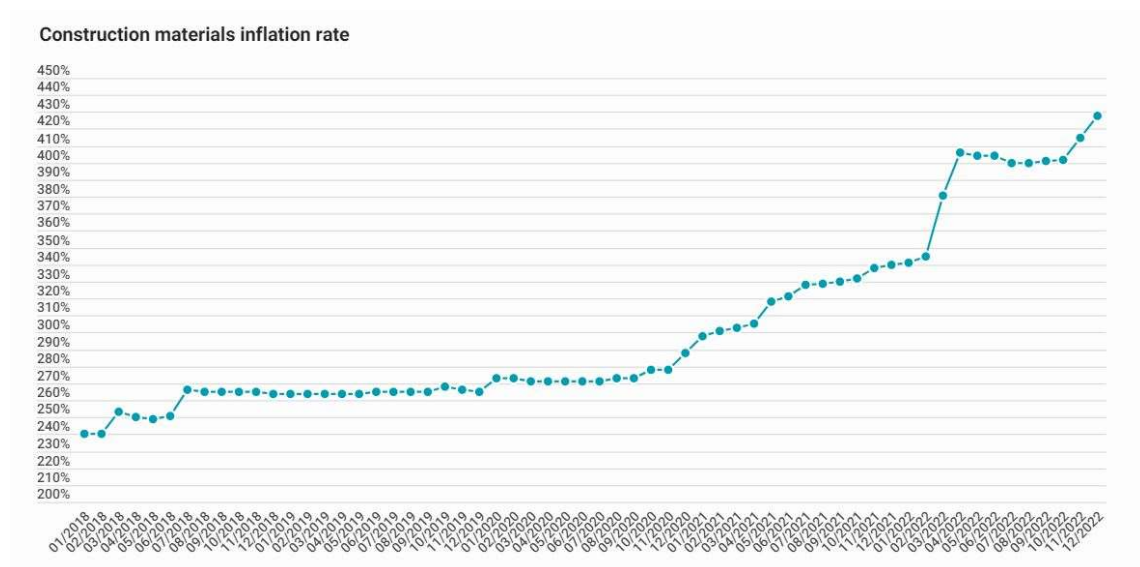


Figure 18 Construction material inflation rate (Campas)

The Egyptian construction industry is presenting a peak. This industry shows the strength to bounce back from unexpected happening. However, it is difficult to predict the impact of external forces. Developers and contractors should build contingency plans to mitigate the adverse future risk.

9 Survey Questionnaire

The questionnaire was designed based on the conducted literature review. The key aim is to provide an insight into Egyptian construction procurement practices by

- Determine the key factors in supplier selection
- Investigate the frequency of common risks in supplier procurement
- Assess the current procurement practices.
- Determine main risk strategies for the identified risks
- Evaluate the adoption of technologies in Egyptian construction procurement

The questionnaire included qualitative and quantitative questions. The questions are divided into 8 parts each

- 1- Respondent professional background
- 2- Company info
- 3- Supplier selection process
- 4- Inventory management practices
- 5- Procurement-related Risks mitigation practices
- 6- Advanced technologies adaption
- 7- Process improvement
- 8- Feedback and further comments

9.1 Questionnaire findings

Respondents background

54 participants from 38 construction companies responded to this questionnaire. The respondents are mainly professionals involved in the construction procurement process, including procurement engineers, managers, team leaders and supply chain managers in leading construction companies. Additionally, some participants such as tender managers, cost engineers and project engineers may have insights into procurement practices and risk management in construction projects.

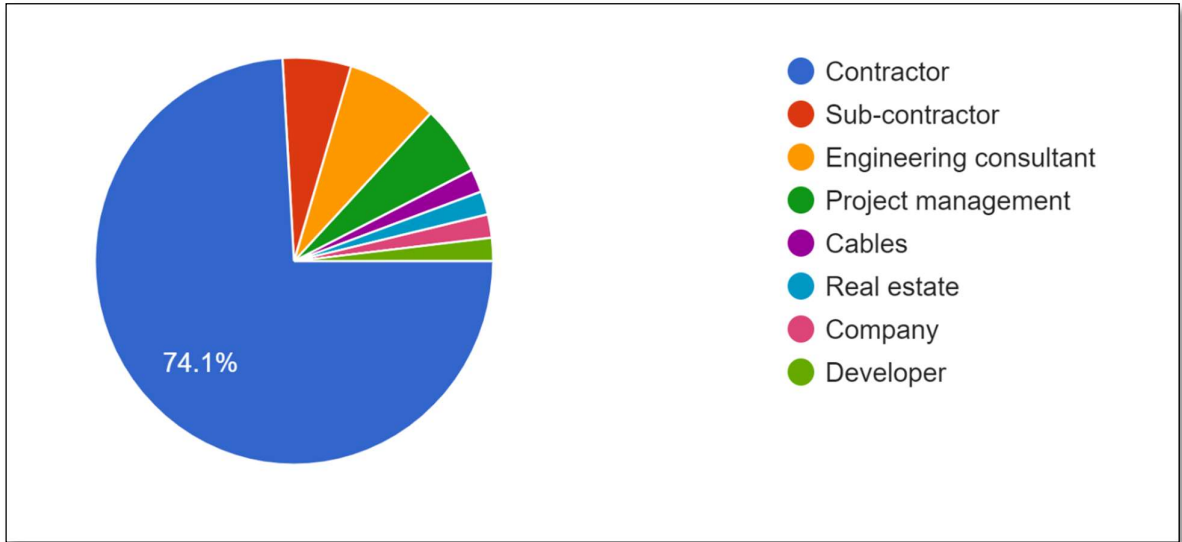


Figure 19 Respondents' roles in construction industry

Most of the respondents come from a contracting company which gives a clear data about contractor-supplier relationship nature.

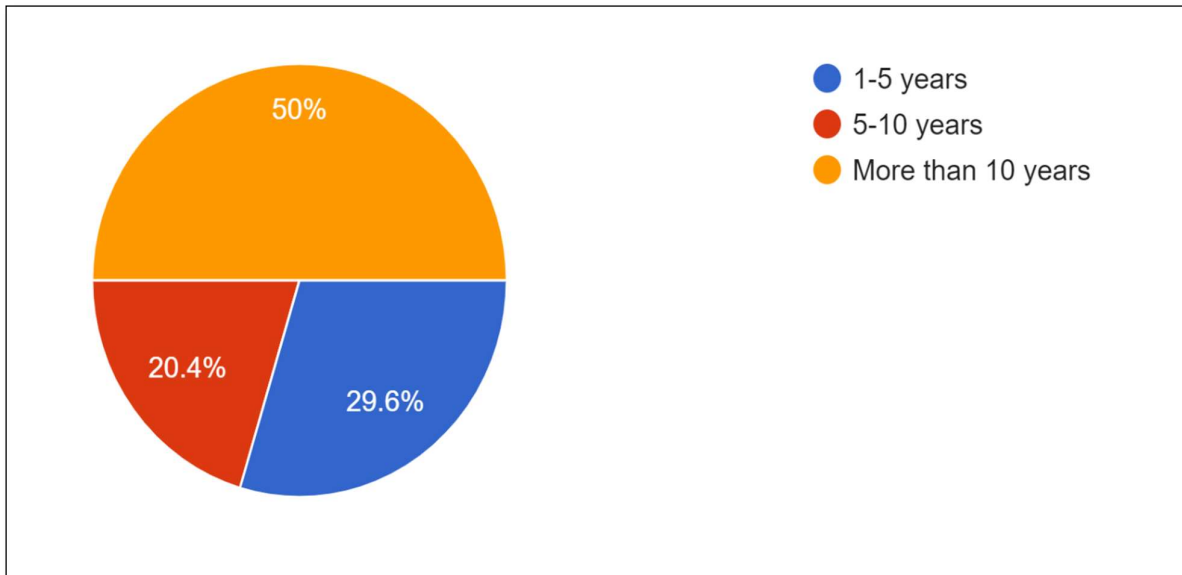


Figure 20 Respondents' years of experience

50 % of the participants has 10 years or more of experience in construction procurement or supply chain management which indicates a solid review on the survey questions.

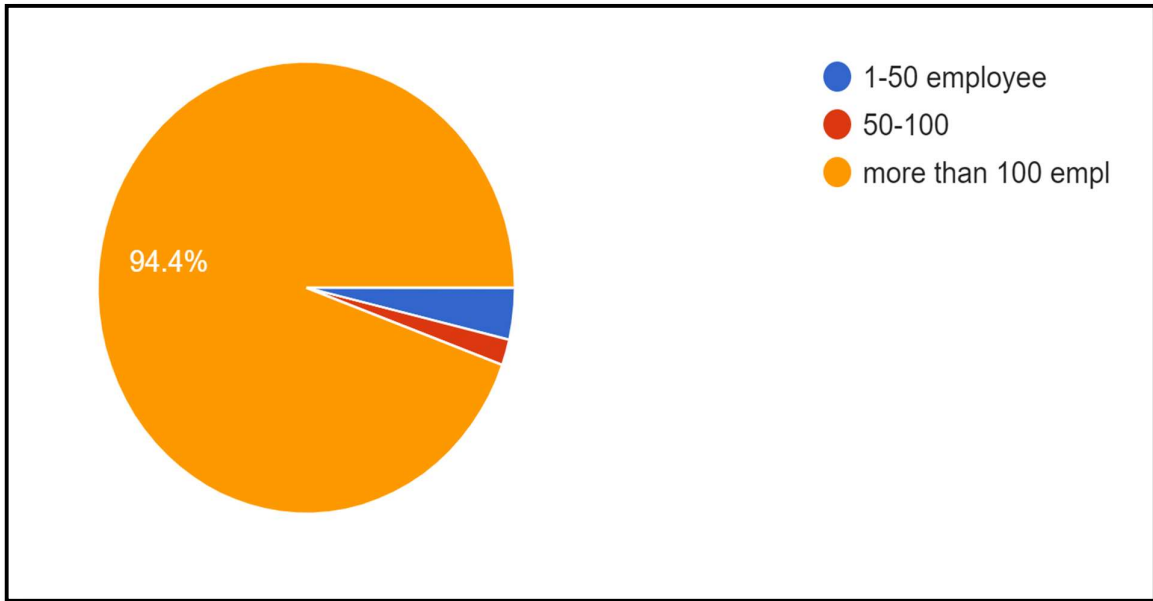


Figure 21 Respondent's Company size

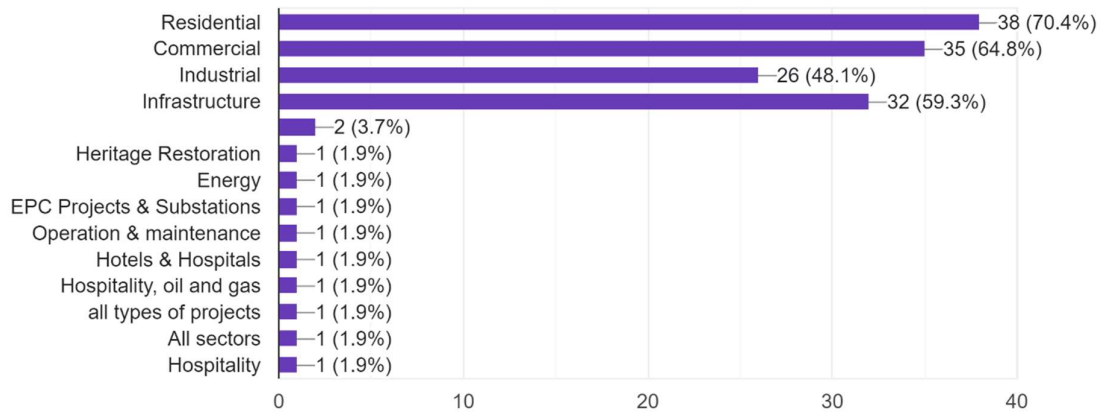


Figure 22 Respondent's Companies' project types

Supplier selection

How do you typically source suppliers for your construction projects? (Select all that apply)

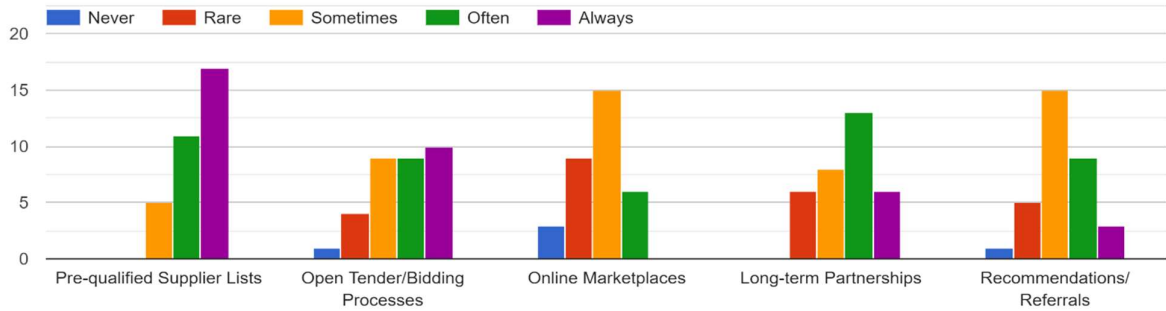


Figure 23 Supplier selection method

AS per Fig 23 prequalified suppliers is the most common practice among other methods. Long-term partnerships are not always used. However, the graph shows low tendency towards e-procurement method

What criteria are most important when selecting suppliers?

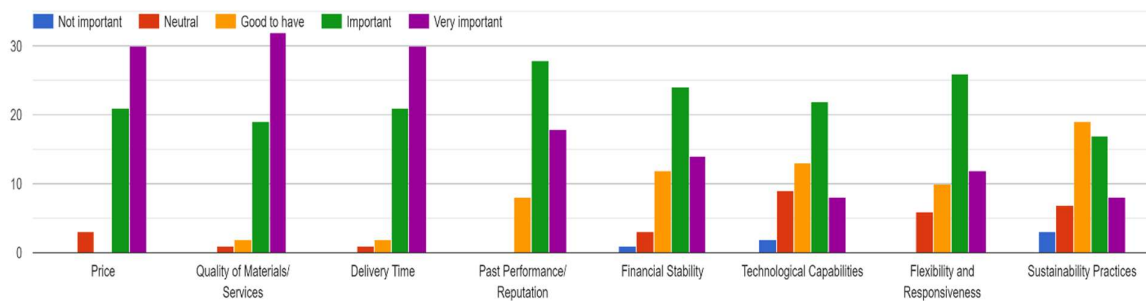


Figure 24 Supplier selection criteria

Fig 24 illustrates supplier selection criteria. Price, Quality and Delivery time are the top three factors among others.

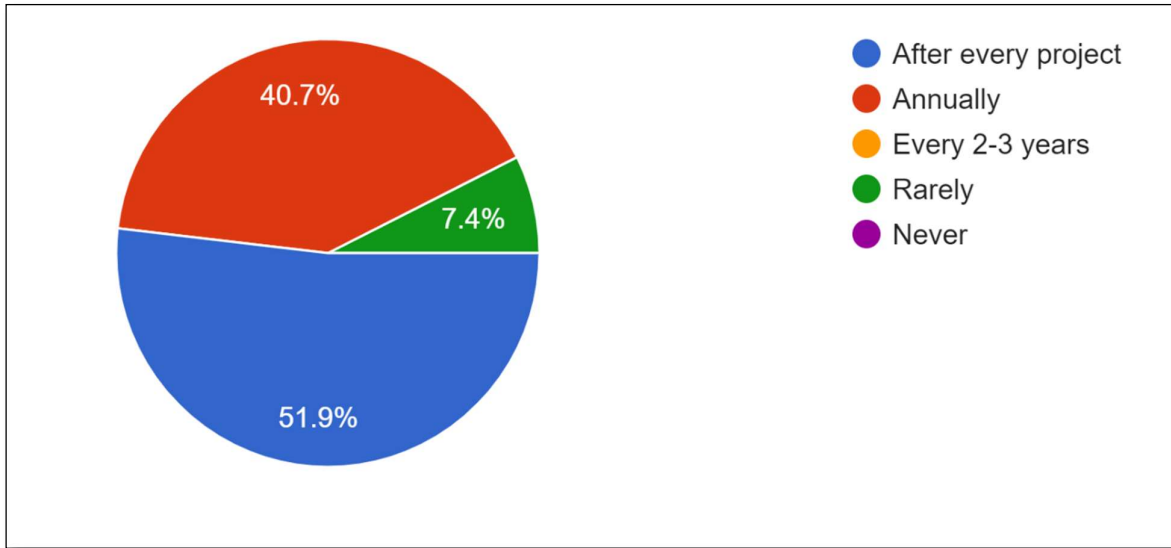


Figure 25 Supplier Evaluation Frequency

Figure 25 shows the frequency of supplier evaluation as per the collected responses.

How often do you face these issues with your suppliers? (Select all that apply)

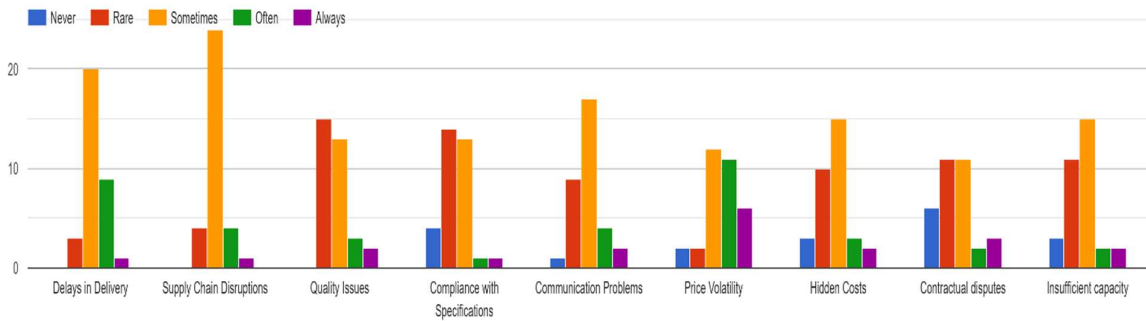


Figure 26 Supplier Risks frequencies

As per Respondents delivery delay and supply chain disruptions are still main concerns to most of them which reflects the importance of determining items supply risk in the project planning stage.

What strategies do you use to build and maintain strong relationships with suppliers? (Select all that apply)

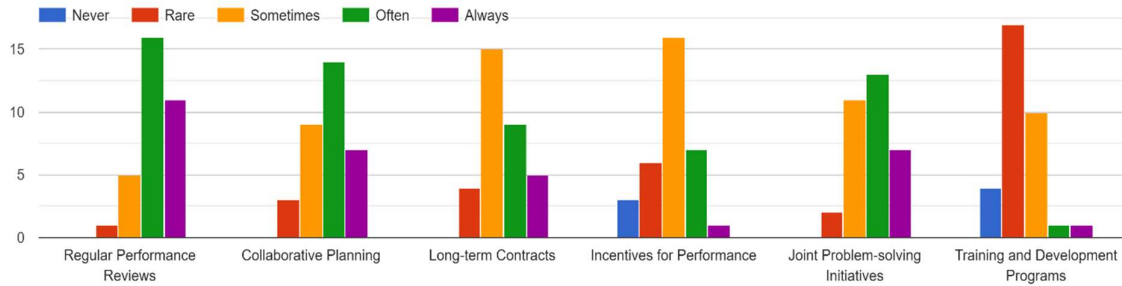


Figure 27 Buyer-supplier preferred strategy

How do you currently manage inventory for construction projects? (Select all that apply)

54 responses

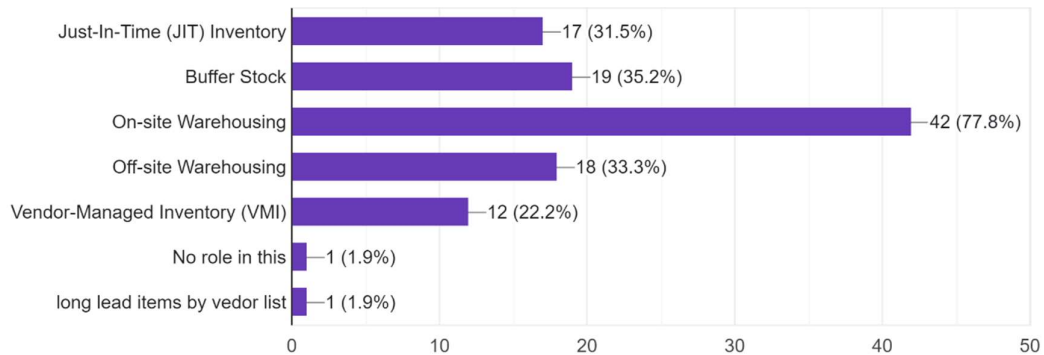


Figure 28 Inventory practices

As shown in Fig 28 Most of the respondents follow on-site warehousing which requires efficient handling of construction site logistics and save transportation time. However, storage limitation is the main challenge of this method.

How do you ensure the accuracy of your inventory levels? (Select all that apply)

54 responses

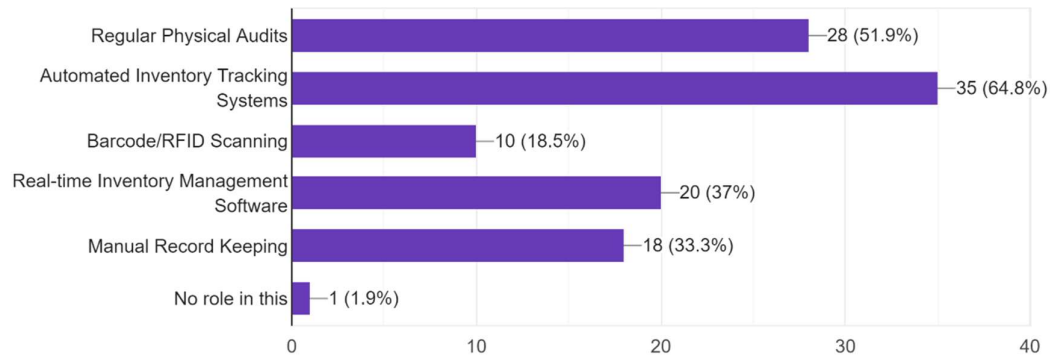


Figure 29 Inventory level measurement

How do you integrate inventory management with your procurement process? (Select all that apply)

54 responses

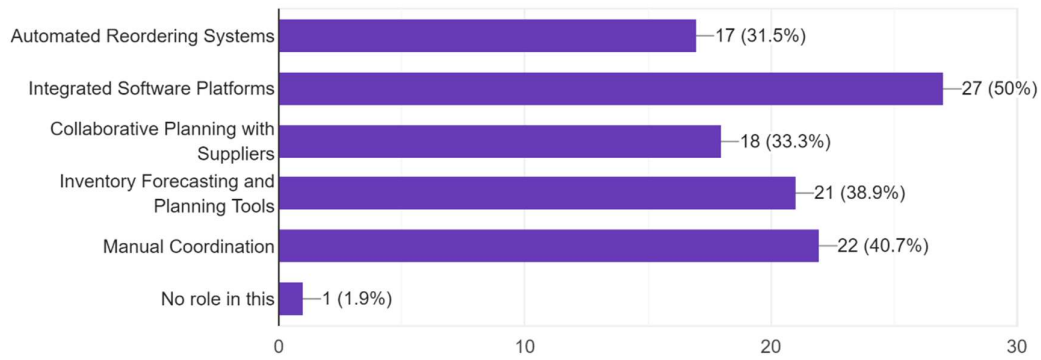


Figure 30 Inventory and procurement integration

According to Fig 30, Responses shows high adaptation of software platforms such as ERP in integrating inventory management with procurement department. However, there are still considerable amounts of respondents who still use manual coordination

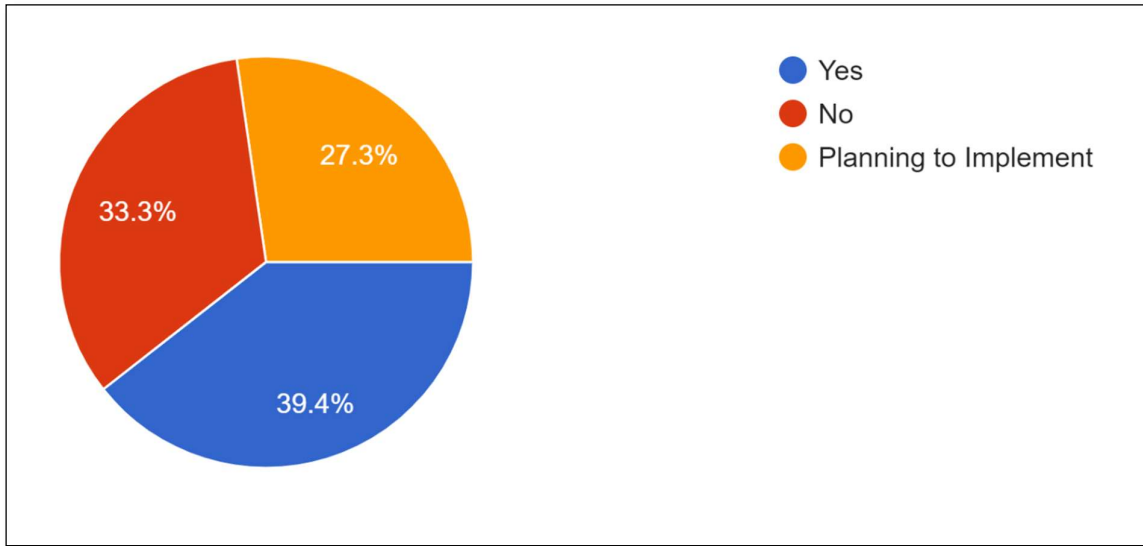


Figure 31 JIT (Just in time) adaption

Fig 31 illustrates that majority of participants showed less adoption of JIT approach

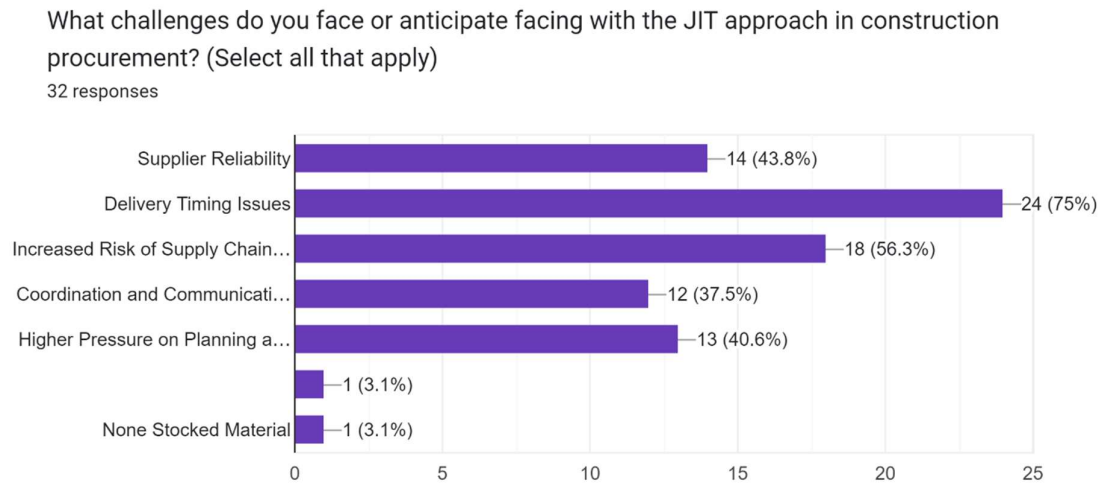


Figure 32 JIT adaption Challenges

How do you rate the effectiveness of JIT in achieving the following objectives?

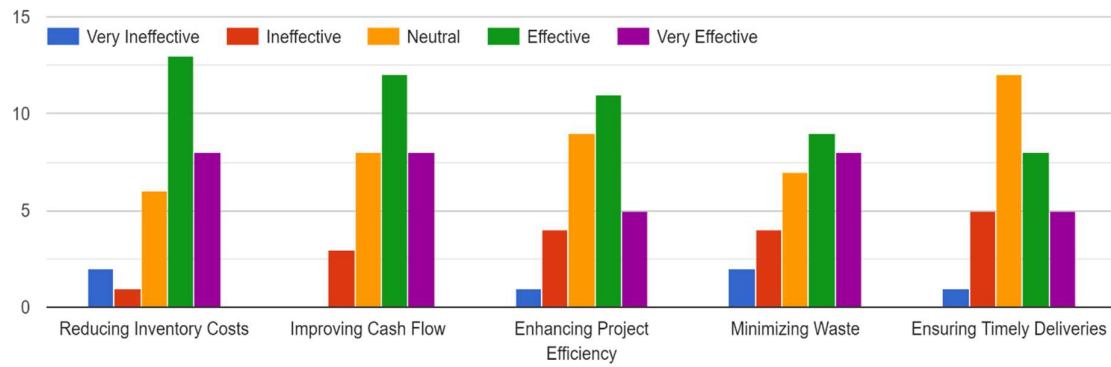


Figure 33 JIT Aspects effectiveness

How often do you apply these supplier-risk mitigation strategies ?

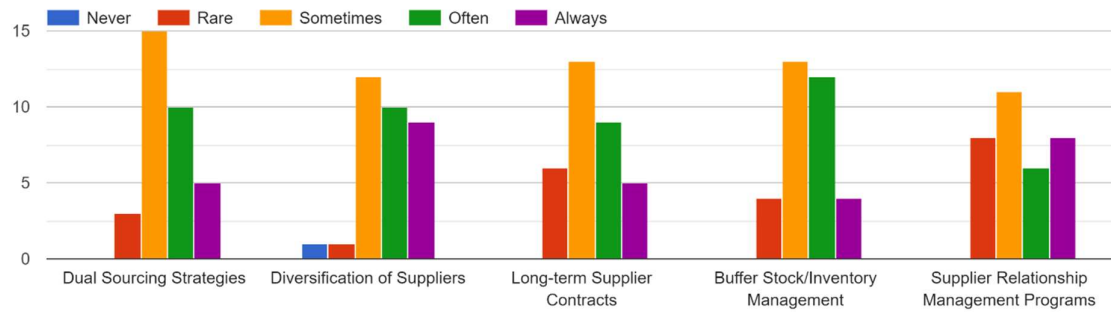


Figure 34 Procurement-related risks mitigation strategies adoption

How do you integrate risk management practices into your supplier selection process? (Select all that apply)

54 responses

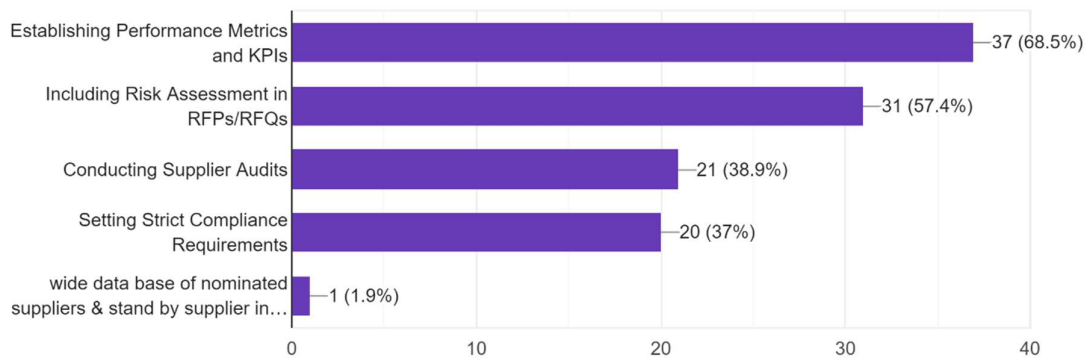


Figure 35 Risk management integration practices

Majority of the respondents (66%) adopt established KPI as a key practice in managing supplier risks. including risk assessment in RFQ and RFP comes as second most used practice .

What challenges do you face when implementing risk mitigation strategies in procurement? (Select all that apply)

54 responses

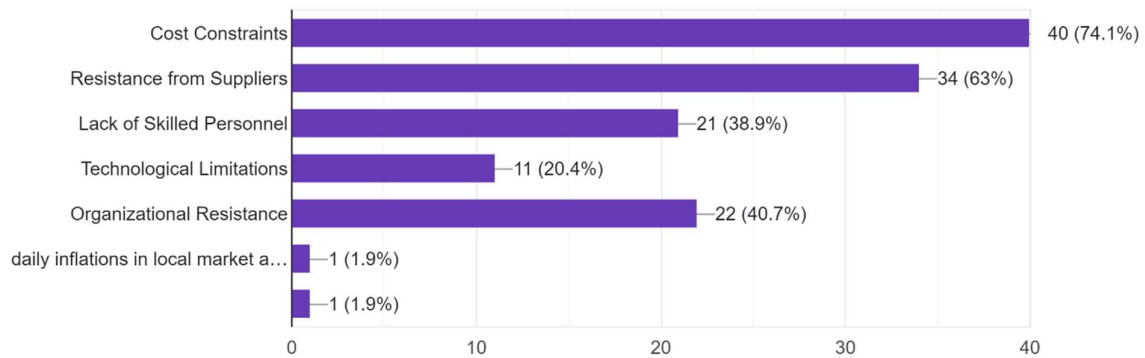


Figure 36 Risk mitigation strategies constraints

Fig 36 illustrates the key obstacles in implementing risks mitigation strategies. Cost constraints are the most prominent challenge as per the survey responds. resistance form the supplier is account as well for a great deal of improving the overall process management

Technologies adaption in procurement

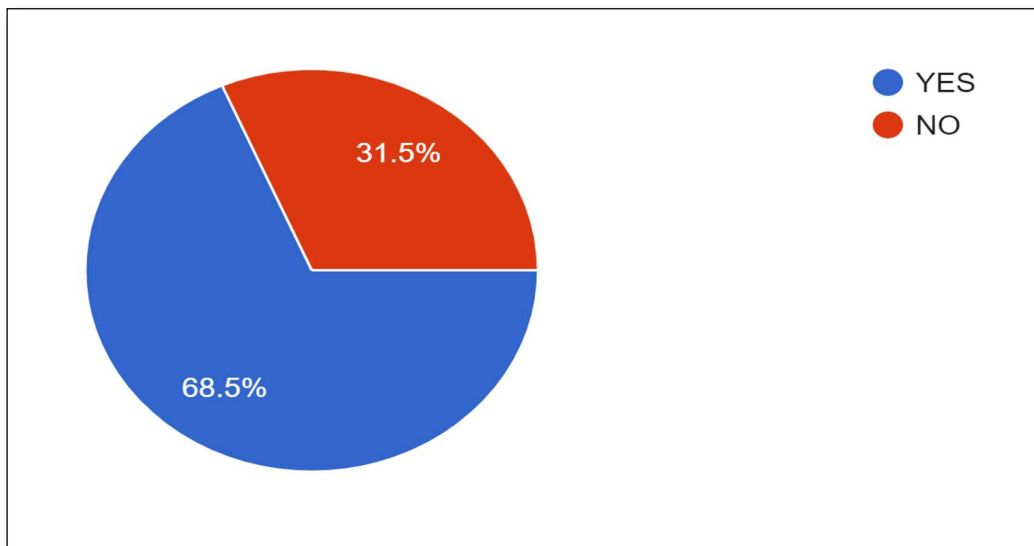


Figure 37 Procurement software utilization

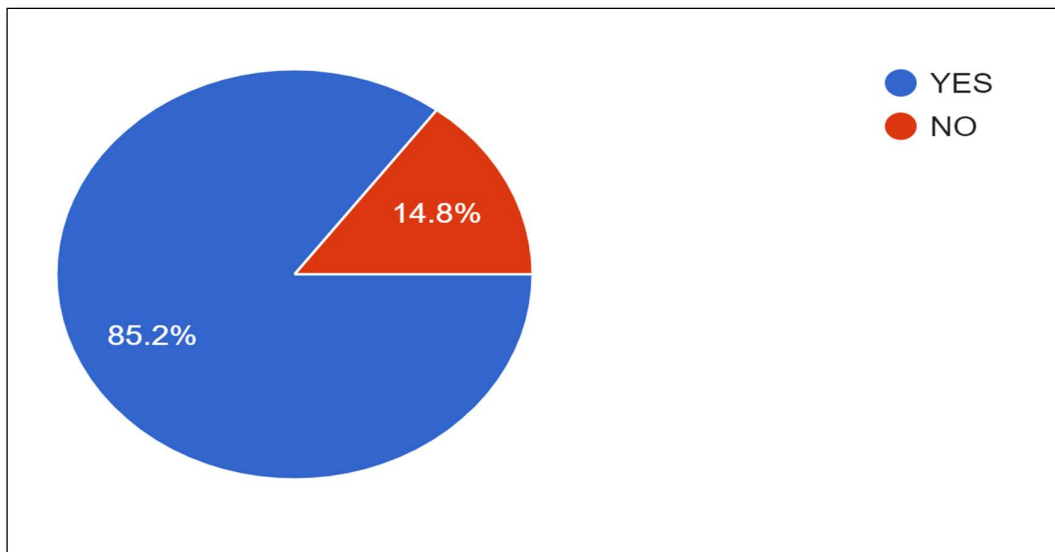


Figure 38 ERP adaption in Procurement

Which technologies do you use in the procurement process? (Select all that apply)

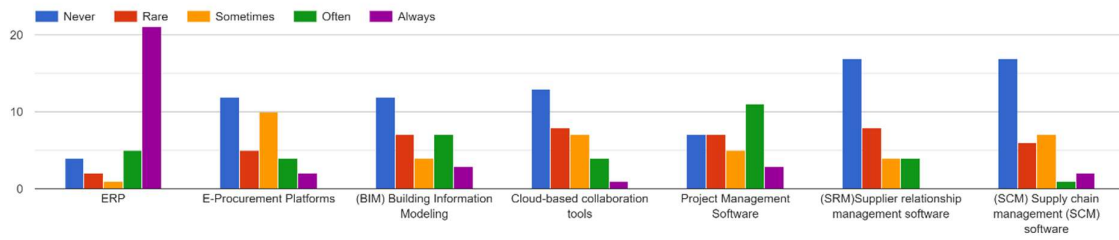


Figure 39 Technologies utilization in construction procurement

AS per the respondents, ERP is the most common tool in the procurement process. The figure shows low dependencies on e-procurement platforms, cloud-based tools and SRM software

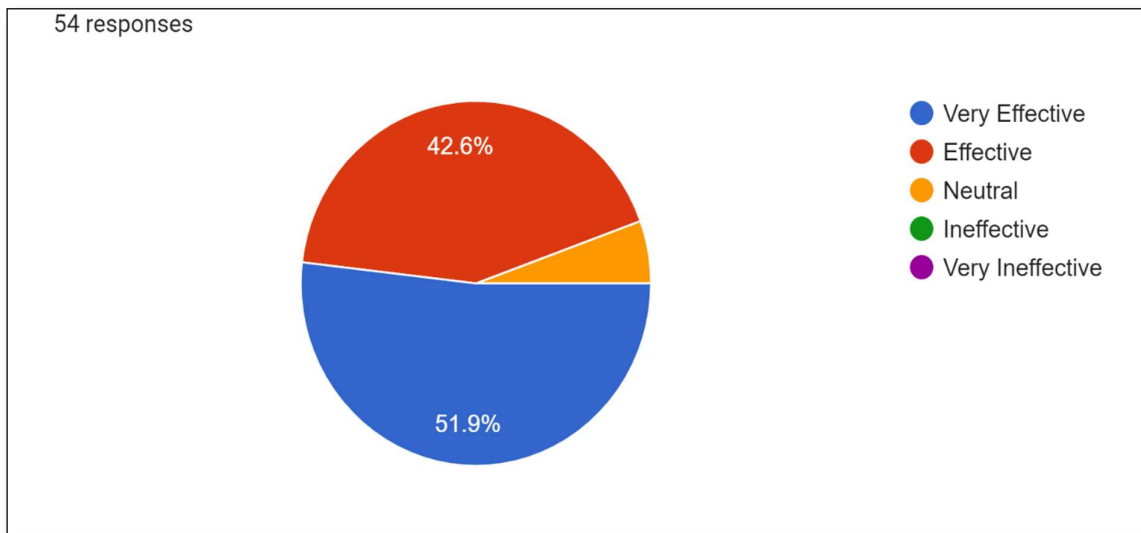


Figure 40 Technologies tool effectiveness pool

Performance Improvement

How do you handle underperforming suppliers to improve overall procurement performance?
(Select all that apply)

54 responses

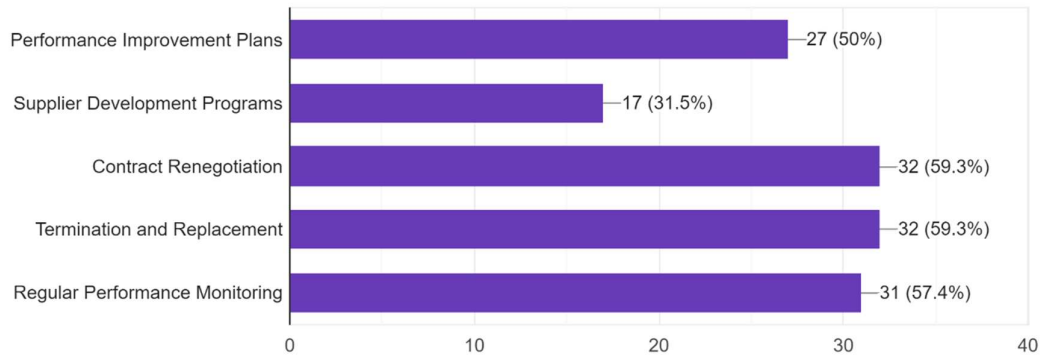


Figure 41 Underperforming supplier correction practices

In your opinion, what are the key factors that can improve the performance of construction procurement? (Select all that apply)

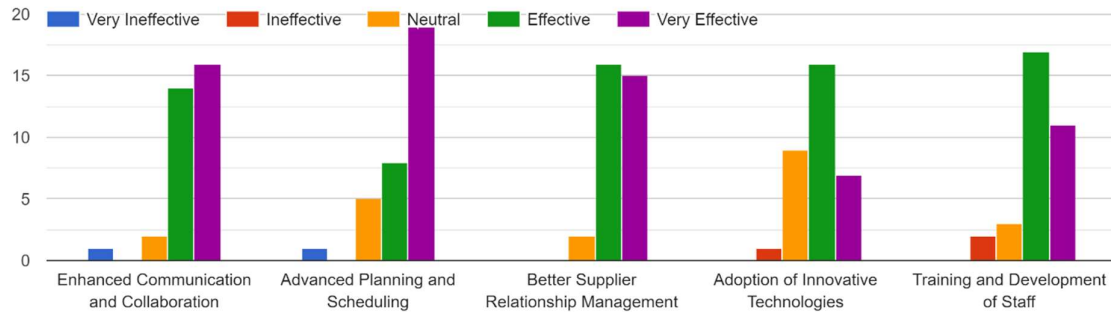


Figure 42 Key factors in improving overall procurement process

Advanced planning and enhanced communication are the most two essential factors in improving the quality of procurement processes as per most of the respondents

9.2 Questionnaire Highlights

The answers provided an insightful data on the current procurement practices in Egypt's construction market. the key findings can be highlighted as following:

- 1- Delivery delays and supply chain disruptions are the most frequent issues encounter contractors even those who works in leading companies and have a well- established supplier selection process.
- 2- Price volatility due to unstable currency rates (Egyptian pound) represent a major threat to many procurement professionals.
- 3- Price, delivery date and quality are the main factors affecting the supplier selection according to the collected responses. However, most of the respondents are less concerned of supplier sustainability practices as only 20% viewed it as an important factor in the selection process
- 4- Over 50% of the Participants showed pre-qualified suppliers as their regular supplier selection strategy. While around 25% only selected long-term partnership as their main strategy.
- 5- Low portion of the respondents considered long-term partnerships with suppliers.
- 6- 30 % percent of the participants considered JIT approach in their procurement practices. The low adoption of JIT due to concerns about price fluctuations and the risk of delivery delays, as indicated by 75% of respondents.
- 7- Majority of the responses declared mainly relying ERP on their procurement process. however, there are still low adaption of e-procurement and other supplier relationship software
- 8- Respondents from larger companies are more likely to adapt new technologies.
- 9- Price constrains is still the key challenge in improving procurement overall processes

10 Developing Procurement Framework

The Framework for the procurement process aim to address the following risks as identified in the literature and further investigated in the questionnaire.

The model focuses mainly on the procurement planning stage encompasses the core processes involved within this phase.

10.1 Concept

The Model focuses mainly on the initial procurement planning stage. the aim is to mitigate the risks which may arise due to delivery delay, supply chain disruptions in addition price fluctuation. This can be achieved by early classifying the material according to their supply-risk and customize the buyer-supplier relationship and procurement approach accordingly.

10.2 Theoretical foundations

Kraljic Matrix: As discussed earlier in the literature review Kraljic Matrix sorts purchased items according to both profit impact and supply risk categories:

Strategic Items: High supply risk, high profit impact.

Leverage Items: Low supply risk, high profit impact.

Bottleneck Items: High supply risk, low profit impact.

Non-Critical Items: Low supply risk, low profit impact.

Just-In-Time (JIT): JIT is a lean management methodology aimed at reducing inventory levels and enhancing efficiency by receiving goods only as needed. In procurement, JIT minimizes waste, reduces holding costs, and improves response times to market changes.

10.3 Objectives

Address delivery delays: by categorizing the purchased items according to their supply and cost risk

Address Price fluctuations: conduct early market forecasting and utilize this forecast as an input into the procurement planning process

Decreasing sorting cost: Implementing JIT in low-supply risk items in case of anticipated steady market price

Gradually Increasing E-procurement: by implementing e-procurement adaption into low-supply risk items. The adaption can gradually increase in the future

Enhance Buyer supplier-relationship: by establishing long term relationships and partnerships with key suppliers of high-supply and cost risk items

10.4 Conceptual Framework

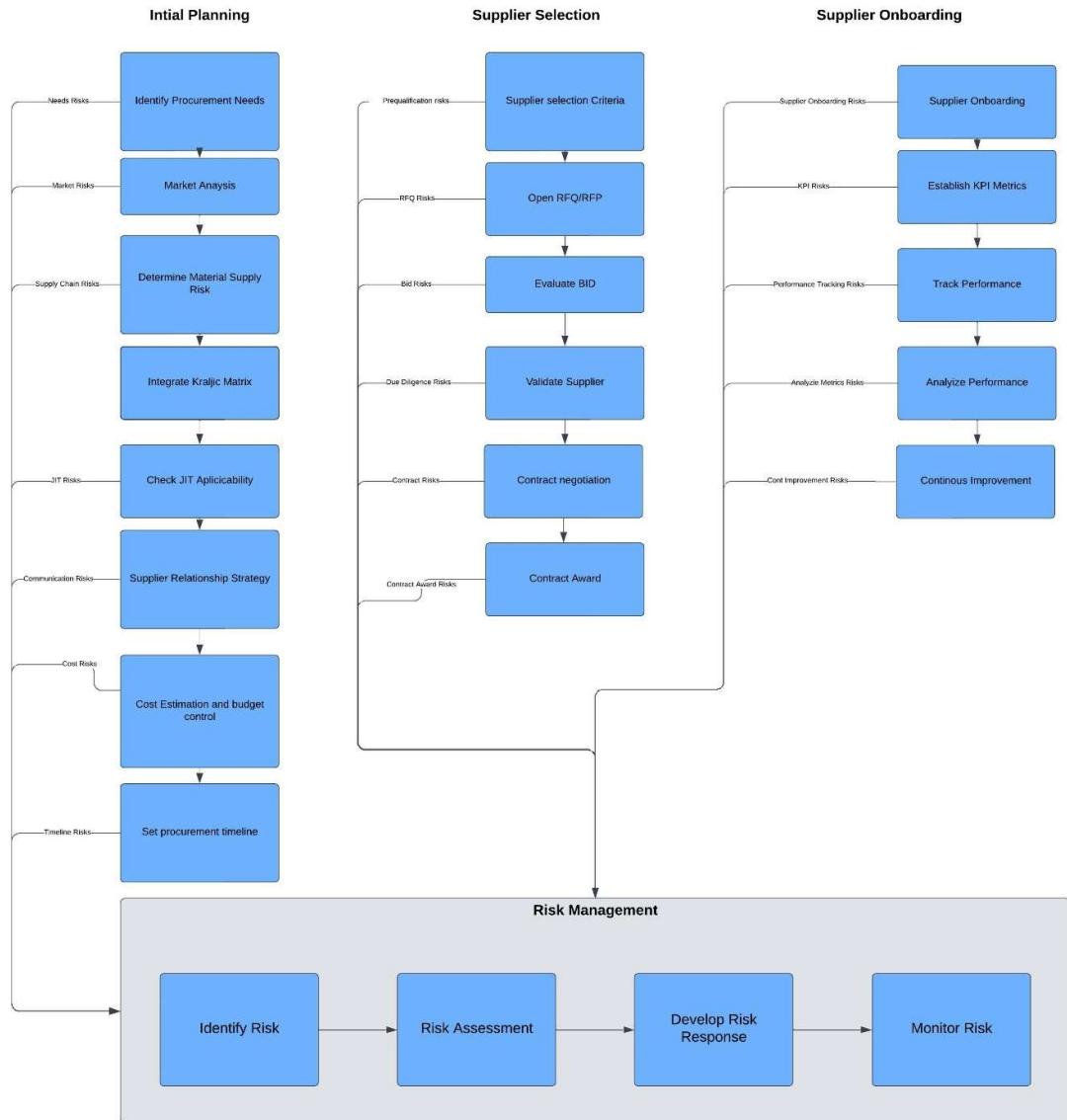


Figure 43 General Procurement Planning Framework

Proposed Initial procurement Planning Framework

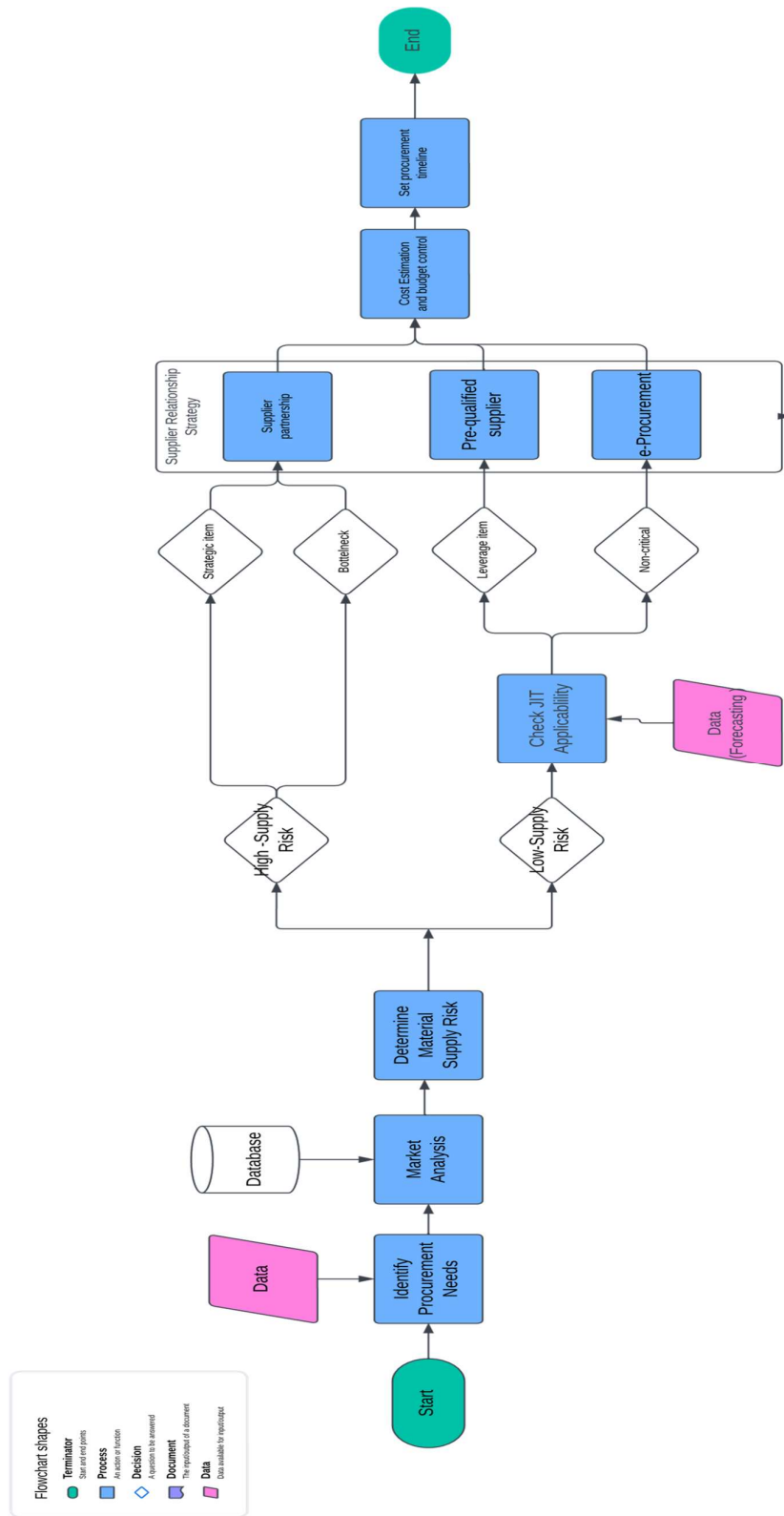


Figure 44 Proposed Initial procurement Planning Framework

Interviews

Discussions

Expert A (Eng Mohammed Megreya –Procurement Manager)

General info

Eng Mohammed Megreya is a procurement manager with more than 15 years of extensive experience in construction fields. he worked in multiple prestigious companies in Egypt and holds a master's degree in construction management. the interviewee is interested in a hybrid decision support system that can learn from real-life examples during the initial project selection phase in bidding. Moreover, the interviewee published a paper on the CSCE 2019 Annual Conference in Laval (Greater Montreal) in the name of "Bid No Bid decision using Fuzzy Risk Assessment

Procurement Risks

The interviewee asserted that the riskiest challenge facing procurement managers currently is the price fluctuation which consequently responsible for high supply risk for some strategic imported items. During the period from 2022 to 2024 there was a huge difference between the official bank exchange rate and the parallel market rate for the Egyptian pound. The government imposed some restrictions on USD transactions. Therefore, many companies couldn't secure enough fund in USD in official bank exchange rate needed for the imported items.

According to the interviewee, there were two main approaches to deal with this issue

- 1- Secure the needed USD with parallel market exchange rate – almost the double.
- 2- Escalate the situation to the developer or owner to apply some contractual changes.

Supplier management

The interviewee noted that most of purchased are conducted through traditional pre-qualified suppliers and sub-contractor bids. however recently many companies

adopted partnership strategies particularly with trades and speciality contractors such as post-tension and steel structure contractors.

Inventory management

The interviewee explained that many companies are not ready for JIT approach due to the concern of supply risk that may occur due to unforeseen events, and unanticipated material prices due to currency devaluation.

Technologies

The interviewee explained that the majority of companies depend mainly on ERP to link inventory records and generate purchase order and supplier invoices

He as well mentioned that recently his company increased the utilization of e-procurement especially in items where specifications are clear and direct contact with supplier may not be required. Examples on these items are paintings, cement, reinforcement steel, and other consumables. The interviewee stated that the scale of items is more likely to increase in the soon future.

Moreover, the interview pointed out that he and his team are currently working on developing and cloud-based website where they can promote the open tenders in their ongoing projects , the interviewee believes that this trend is going to grow in Egypt in the next few years

Model Feedback

Practicality

The interviewee stated that the model is workable in the real-life practice and would help in mitigating supply risk and price uncertainties if adopted and customized with the company's policy

Area of improvement

The Interviewee believes that integrating AI in cost variance forecasting would allow for more sound vision of the JIT approach adoption

Expert B (Eng Ahmed Hamed – Lead procurement engineer)

General info

Ahmed Hamed is procurement engineer with 10 years of experience in construction procurement and supply chain field. He is currently a procurement and tender team leader in AL Sewedy electrical, one of the mega corporations in Egypt with business lines in infrastructure investment, electrical products and engineering and construction unit which is responsible for numerous power stations projects in the middle east region. The interview holds a M.Sc. and international certificates in supply chain and procurement like CICC " Certified International commercial and contracts manager besides working as lecturer of procurement practices and supply chain management.

Procurement risks

The interviewee declared that identification of risks is crucial in the early procurement planning process. However, he referred that most of the risks identifications happens in a manual approach which vary from one company to another. there is still no comprehensive systematic model to cover all the uncertainties.

The interviewee explained that price fluctuations due to currency is still the priority threat to the construction market in Egypt. He also added that in long-term project contracts may include price escalation form to allow for price adjustments according to a pre-defined limit. However, this may not be always applicable in fast-track projects.

Supplier management

The interviewee pointed out that partnership strategy with supplier is highly adopted with trades and strategic items supplier. Furthermore, he mentioned that this strategy is highly recommended in fast track and complex public projects such as power stations, water supply and hospitals.

Inventory management

The interviewee emphasized that forecasting is essential in determining whether bulk purchase or JIT is the appropriate approach. He commented that it's usually more practical in traditional site items and can be adopted as well with vulnerable items vulnerable items where storage conditions might impact their quality.

He added that ERP systems enabled smoother and more accurate inventory record tracking. This enhanced the capability of the company to adopt a Just-in-Time (JIT) inventory management strategy.

Technologies

The interviewee indicated the importance of AI integration in forecasting supply chain and logistics conditions. This can anticipate disruption events such as bad weather and traffic movements in certain areas.

Model Feedback

Practicality

The interviewee viewed model is a practical in real-life scenarios. However, he suggested that other methodologies may work for non-critical items in case of low e-readiness

E-Procurement Platforms: Online marketplaces and portals that allow you to compare prices and capabilities across multiple suppliers. This can increase competition and visibility into the supply base.

Area of improvements

For the procurement of non-critical items, there are a few main options that could be considered:

1. ***Spot Buying***: This involves purchasing items on an as-needed basis from the open market, without any long-term contracts or commitments. This can provide more flexibility but may come with higher unit prices.
2. ***Framework Agreements***: These are longer-term contracts with pre-approved suppliers that allow you to place orders as needed, often at pre-negotiated prices and terms. This can provide better pricing and reliability compared to spot buying.
3. ***Centralized/Shared Procurement***: Coordinating procurement for non-critical items across your organization or even with other companies/agencies. This enables greater economies of scale and negotiating power.

Expert C (Eng Abdulllah Kadry – MEP procurement Head)

General info

Eng is Abdullah Kadry a MEP procurement manager in a prominent comprehensive turnkey solutions company. He has more than 14 years of experience in various types of projects. Moreover, he is a CIPS certified from chartered institute of procurement and supply. in addition to being certified as CIPM (Certificate in Investment Performance Measurement) from CFA institute.

Procurement Risks

Eng Abdullah elaborated that as MEP procurement head, most of MEP products are imported which made the supply risk very high during global supply chain disruption. one of the most recent events is Ukraine war which affected many raw materials such as steel and aluminium which are used in the equipment's manufacturing. Moreover, shifting to an alternative provider in China for example increased the waiting time from 6 to 14 months. The interviewee explained while it's not possible to fully avoid the global disruption impact, securing materials or equipment from local suppliers may be help in mitigating the impact.

Supplier management

The interviewee stressed on the importance of supplier involvement in early stages. However, this may lead later to a high independence on the involved suppliers which consequently makes it harder to replace the supplier during the construction, so supplier diversification can be seen as a mitigation action along with early involvement to avoid any unfavourable events.

The interviewee noted the principle applies to procurement as well where 20% of the items are accounted for 80% of the procurement cost. These items with high-cost impact (strategic and leverage items) are best handled through partnership strategy. he also asserted that in case of sole supplier keeping a close contact with the supplier is a key factor in the project success.

Inventory management

The interviewee stated that while JIT approach is not applicable to all the items it helps the company to maintain a steady cashflow. he also added that some equipment's require huge storing space and are liable to damage such as chillers,

however it's crucial to ensure the supplier reliability about delivery time and adding contingency time in the project schedule as a safety factor.

Technologies

The interviewee stated that e-tendering has become more popular in the last 10 years. and added that most of his newly supplier awards are implemented through their web-based tendering platform.

Eng Abdullah remarked that e procurement is currently highly adopted in traditional items. however, he predicts that this adoption may increase to include not just the non-critical items but also leverage item as well. He also remarked that e-procurement can increasingly improve sustainability in construction through reducing the amount of needed paperwork and reduce the environmental impact of printing and stored paper documents

Model Feedback

Practicality

- The Interviewee stated that using Kraljic matrix in early pre-procurement stage is highly practical to determine the appropriate supplier strategy.
- Routine items don't require prequalified supplier and maybe fully performed through e-procurement

Areas of improvements

- Partnership supplier strategy may extend to include leverage items in some certain cases
- e- procurement can be implemented for leverage items for prequalified suppliers however this required high e-readiness for all the involved parties

Interview findings summary

Supply Risk Analysis Integration

Theme	Expert A	Expert B	Expert C
Early Risk Identification	Identifying risks early is beneficial, but smaller firms may find the process resource-intensive and difficult to sustain	Early risk identification is practical if integrated into existing project management	The model assists in early risk identification but ensuring the proper implementation requires that team has the skills and tools to conduct thorough assessments.
Practical Mitigation Strategies	Practical implementation of mitigation strategies requires clear guidelines and possibly additional resources.	Practicality of these strategies depends on how well they are communicated and integrated into daily operations	Effective mitigation strategies need to be supported by real-time data and monitoring tools to be practical.

Table 4 Supply Risk Analysis Integration

Just-In-Time (JIT) Approach Feasibility

Theme	Expert A	Expert B	Expert C
Feasibility of JIT in Construction	Successful JIT implementation in construction projects has been rare. However, this can be adopted in low supply risk as proposed in the Framework	JIT is highly feasible with low supply risk and vulnerable items.	JIT helps company for enhancing cash flows. Yet this necessitates checking the reliability if the selected supplier

Implementation Challenges	Price fluctuation	Supply chain disruptions	Buyer-supplier relationship
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Table 5 Just-In-Time (JIT) Approach Feasibility

E-Procurement Adoption

Theme	Expert A	Expert B	Expert C
Feasibility of E-Procurement	-Feasibility depends on firm size and resources.	-Integration with existing procurement systems is a major challenge. The framework needs to provide detailed steps for integration.	-e-procurement can increase the procurement sustainability practices - more applicable with traditional items
Integration Challenges	e-readiness Data security	Data security Limited Vendor Participation	Communication and training. Integration issues.

Table 6 E-Procurement Adoption

Model Practicality concern

Theme	Expert A	Expert B	Expert C
Implementation Feasibility	Feasibility is practical with proper planning and phased. Implementation	Assessing the feasibility of adoption for different scales of projects is essential to ensure successful	The overall framework is robust, but the real-world applicability might be limited by the readiness of the existing systems and

		implementation.	processes
Cost and Resource Constraints	Higher management needs to approve a practical implementation plan after conducting cost-benefit analysis	Budgeting for both e-procurement systems and JIT processes might strain financial resources, particularly for mid-sized projects.	The cost-benefit ratio should be carefully analysed to ensure that the long-term savings justify the initial investment and ongoing costs.
Training and Skill Requirements	Extensive training will be required to bring all team members up to speed with the new processes and technologies.	. Adoption might be slow due to the learning curve associated with new systems and the need for specialized skills.	Practicality is a concern if the employees are not adequately trained or if there's resistance to adopting new technologies.
Integration with Existing Systems	Integration with existing procurement and project management systems could be complex and time-consuming	Ensuring compatibility with legacy systems might require custom solutions, and implementation period	The success of integration efforts depends on the flexibility of existing systems and the framework's adaptability to different environments.

Table 7 Model Practicality concern

Framework Strengths

Theme	Expert A	Expert B	Expert C
Framework Clarity	Clear structure; easy navigation	Well-organized; logical flow	Logical connection between Supply risk and JIT
Risk Management	Robust early risk detection	Proactive risk identification	Effective risk mitigation
Vendor Management	Strong supplier relationship focus	Emphasis on vendor partnerships and digitalisation	Early Supplier collaboration

Table 8 Framework Strengths

Recommendations

Theme	Recommendations
E-Procurement	Increase the adoption of e-procurement partially in leverage items where possible.
Cost forecasting	Integrate AI tools in cost forecasting
JIT	-Collaborative Planning with suppliers to ensure they can meet JIT delivery requirements. -Deploy AI tools in supply chain and logistics disruption forecasting
Feasibility	Assess for different firm sizes; provide detailed steps; ensure flexibility; continuously review.
Market Analysis	Incorporate predictive analytics tools to gain deeper insights into market trends and demand forecasts.

Table 9 Model Recommendations

12 Conclusion

This thesis has thoroughly examined the construction procurement process focusing on supplier procurement from three main perspectives: procurement strategies, procurement-related risks, and the adoption of new technologies. Moreover, the research is based on a thorough literature review focusing on the procedures and best practices of construction procurement that are applied in various construction markets worldwide.

While much research on procurement focuses on the owner-contractor relationship, this research highlights the integral role of the contractor-supplier relationship in project success and profitability. Since the construction supply chain is relatively new research field and not well-systematic as in manufacturing field, proactive risk strategies need to be identified in order to mitigate the inevitable risks during the construction stage.

As investigated in the literature review, the procurement risks are highly intertwined and interconnected. Securing items early to avoid supply risk may result in high storage costs. To bridge the gap between theoretical literature and practical practices, a detailed questionnaire was conducted with procurement professionals in Egypt. The questionnaire covered the key themes identified earlier in the literature review. The survey outcomes provided robust data about the adopted practices in the Egyptian construction market. the results can assert that:

Delivery Delays and Supply Chain Disruptions: These were the most common concerns, even for contractors who typically worked with well-structured supplier selection processes. consequently, most of the respondents are still concerned about JIT implementation

Material Price Fluctuation: A major risk exacerbated by current global events, significantly impacting the Egyptian market as well.

E-procurement Adoption: Although majority of respondents acknowledged the benefits of e-procurement adoption, the adoption is still low and exclusive to big companies due to data security and system integration issues.

JIT implementation: High number of the participants declared that there was no systematic methodology to integrate JIT approach in their procurement process.

Therefore, based on data collected from the survey and theoretical foundations studied in the literature. An initial procurement planning framework was proposed to address the issue of material supply risk and price fluctuations.

The proposed model initial procurement planning framework can help integrate a series of crucial components into an effective approach that increases both procurement resilience and economic efficiency as shown in the main model themes:

Supply Risk Determination: based on the conducted survey and interviews. the supply risk detection can significantly affect project cost and timeline if managed in a systematic approach which the model provides

Item Categorisation: Developing strategic category strategies such as the Kraljic Matrix to classify procurement items using supply risk and importance factors. These categories can then be used to implement procurement strategies that are appropriate for items in each category.

Strategic supplier relationship strategies: by developing long-term relationships with strategic material suppliers, using e-procurement systems for transaction processing, and having multiple suppliers for bottleneck items to avoid supply chain disruptions.

Cost Estimation and Budget Control: integrating JIT approach developing cost estimates after allocating contingencies for supply disruptions and market fluctuation in early stage can considerably enhance the cash flow later in the construction stage

Procurement timeline management: incorporating supply risk in early stages beside utilising project management tools leads to clearly identify and realistically schedule the details of procurement, and coordinate activities effectively across all employees and stakeholders.

The framework was validated through interviews with the industry experts. The participants confirmed practical relevance and applicability. and offered further ideas to improve on how it can be applied. The results of the research demonstrate that

adoption of this framework can immensely enhance procurement resilience and enhance the efficiency of supplier management.

13 Recommendations & Further Studies

Based on the findings of our research, several recommendations can be applied to improve procurement processes in the construction industry which address its weaknesses and leverage best practices and new technologies to increase efficiency and resilience are suggested, as well as areas that should be further examined to better understand the dynamics of construction procurement.

AI adoption in market forecasting: All the interviewees agreed on AI adoption in supply chain disruptions and anticipating material cost trends will significantly enhance the early procurement planning, thereby improving overall project outcomes.

Behavioural Dimensions of Supplier Relationships: Identify the behavioural dimensions of supplier relationships, such as the role of trust, negotiation styles and conflict resolution mechanisms, to gain insight into collaboration and enhance supplier performance.

Cost-Benefit Analysis of JIT Implementation: Conduct a project-specific cost-benefit analysis for deploying JIT procurement for various construction projects. The study should examine the trade-offs between inventory costs and the risks of supply chain disruptions.

Impact of Digital Transformation on Procurement: investigate the long-term effects of digitalisation of construction procurement. What impact can, for instance, blockchain, artificial intelligence and the Internet of Things (IoT) have on achieving increased procurement efficiency and transparency.

Through following these recommendations and exploring the suggested lines for further research, engineering and construction firms can improve their procurement strategies, better manage risks, and develop more efficient and resilient operations, ultimately leading to more successful project outcomes and increased profitability.

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Declaration of Authorship

I hereby declare that the attached Master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Berlin, 05.07.2024

Location, Date



Signature of the student

Appendix A (Interview Guide)

<p>General Information</p> <ol style="list-style-type: none">1. Kindly introduce yourself.2. What is the average size of the company's projects?
<p>Risk management</p> <ol style="list-style-type: none">3. What are the most significant risks you encounter in procurement for construction projects, and how do you mitigate these risks?4. How effective is the integration of supply risk analysis in the early procurement planning phase?5. "In your experience, what are the most crucial supply risks that should be identified and addressed during the early stages of construction procurement planning?"
<p>Supplier Management</p> <ol style="list-style-type: none">6. What strategies do you use to collaborate with suppliers to enhance performance and mitigate risks?7. How can partnership enhance the procurement process outcomes?
<p>JIT</p> <ol style="list-style-type: none">8. How feasible is the application of the JIT approach in construction procurement?9. What challenges might arise in implementing JIT in the construction industry, and how can they be addressed?
<p>Technologies</p> <ol style="list-style-type: none">10. What technologies do you use to manage procurement processes, and how have they impacted your efficiency and effectiveness?

11. What challenges have you faced in adopting new technologies for procurement?

12. How well does the framework address the integration of e-procurement systems?

Practical Applicability

13. How practical is the framework for real-world application in the construction industry?

14. Can you provide examples of how the framework could be applied in a real project?

Improvements and Suggestions

15. What improvements would you suggest for better integration of risk management into the procurement process, supplier selection, and relationship strategies?

16. Are there additional elements or considerations that should be included in the framework?

Appendix B (Interviewees' Info)

Name	Position	Company	LinkedIn Profile
Mohamed megreya	Procurement manager	SIAC Construction	https://www.linkedin.com/in/mohamed-maher-megreya-msc-35a54a3b/
Ahmed Hamed	Procurement Lead	Al Sewedy Electrical	https://www.linkedin.com/in/ahmed-hamed-msc%C2%AE-pmp%C2%AE-ciccm%C2%AE-0a972b116/
Abdallah kadry	Head of MEP procurement	Kortech	https://www.linkedin.com/in/abdallah-kadry/

Appendix C (Questionnaire form)

7/4/24, 3:09 PM

Enhancing Resilience in Construction Procurement: Strategies and Technologies for Mitigating Risks and Improving Performance

Enhancing Resilience in Construction Procurement: Strategies and Technologies for Mitigating Risks and Improving Performance

M.Sc -Construction management and
Real-estate Development
Joint Study Programme of
Metropolia Helsinki & HTW Berlin

* Indicates required question

1. **what's your name ? ***

2. **Current Position ***

3. **what's your company's role in the construction industry ? ***

Mark only one oval.

- Contractor
- Sub-contractor
- Engineering consultant
- Project management
- Other: _____

4. How many years of experience do you have within this role ? *

Mark only one oval.

- 1-5 years
- 5-10 years
- More than 10 years

Organizations info**5. Organizations' name**

6. What is your company's size? *

Mark only one oval.

- 1-50 employee
- 50-100
- more than 100 empl

7. What is the average size of company's projects? *

Mark only one oval.

- 0-20 millions
- 20-100 milions
- More than 100 milions

8. **What's your company's main projects' types? ***

Tick all that apply.

- Residential
- Commercial
- Industrial
- Infrastructure
- Other: _____

Supplier/ Subcontractors' selection process

9. **How do you typically source suppliers for your construction projects? ***
(Select all that apply)

Mark only one oval per row.

	Never	Rare	Sometimes	Often	Always
Pre-qualified Supplier Lists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Open Tender/Bidding Processes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Online Marketplaces	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Partnerships	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Recommendations/Referrals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10. **What criteria are most important when selecting suppliers? ****Mark only one oval per row.*

	Not important	Neutral	Good to have	Important	Very important
Price	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quality of Materials/Services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Delivery Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Past Performance/Reputation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Financial Stability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technological Capabilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flexibility and Responsiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sustainability Practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. **How often do you re-evaluate your supplier base? ****Mark only one oval.*

- After every project
- Annually
- Every 2-3 years
- Rarely
- Never

12. **How often do you face these issues with your suppliers ? (Select all that apply)** *

Mark only one oval per row.

	Never	Rare	Sometimes	Often	Always
Delays in Delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Supply Chain Disruptions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quality Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Compliance with Specifications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Communication Problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Price Volatility	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hidden Costs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contractual disputes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insufficient capacity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. **What strategies do you use to build and maintain strong relationships with suppliers? (Select all that apply)** *

Mark only one oval per row.

	Never	Rare	Sometimes	Often	Always
Regular Performance Reviews	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaborative Planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Contracts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Incentives for Performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Joint Problem-solving Initiatives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training and Development Programs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Inventory Management

14. **How do you currently manage inventory for construction projects? (Select all that apply)** *

Tick all that apply.

- Just-In-Time (JIT) Inventory
- Buffer Stock
- On-site Warehousing
- Off-site Warehousing
- Vendor-Managed Inventory (VMI)
- Other: _____

15. **How do you ensure the accuracy of your inventory levels? (Select all that apply)** *

Tick all that apply.

- Regular Physical Audits
- Automated Inventory Tracking Systems
- Barcode/RFID Scanning
- Real-time Inventory Management Software
- Manual Record Keeping
- Other: _____

16. **How do you integrate inventory management with your procurement process? (Select all that apply)** *

Tick all that apply.

- Automated Reordering Systems
- Integrated Software Platforms
- Collaborative Planning with Suppliers
- Inventory Forecasting and Planning Tools
- Manual Coordination
- Other: _____

17. Are you currently implementing the Just-In-Time (JIT) approach in your procurement processes?

Mark only one oval.

- Yes
- No
- Planning to Implement

18. What challenges do you face or anticipate facing with the JIT approach in construction procurement? (Select all that apply)

Tick all that apply.

- Supplier Reliability
- Delivery Timing Issues
- Increased Risk of Supply Chain Disruptions
- Coordination and Communication Problems
- Higher Pressure on Planning and Scheduling
- Other: _____

19. How do you rate the effectiveness of JIT in achieving the following objectives?

Mark only one oval per row.

	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
Reducing Inventory Costs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving Cash Flow	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Enhancing Project Efficiency	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimizing Waste	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ensuring Timely Deliveries	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Risk mitigation practices

20. **How often do you apply these supplier-risk mitigation strategies ? ***

Mark only one oval per row.

	Never	Rare	Sometimes	Often	Always
Dual Sourcing Strategies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Diversification of Suppliers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long-term Supplier Contracts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Buffer Stock/Inventory Management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Supplier Relationship Management Programs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

21. **How do you integrate risk management practices into your supplier selection process? (Select all that apply) ***

Tick all that apply.

- Establishing Performance Metrics and KPIs
- Including Risk Assessment in RFPs/RFQs
- Conducting Supplier Audits
- Setting Strict Compliance Requirements
- Other: _____

22. **What challenges do you face when implementing risk mitigation strategies in procurement? (Select all that apply)** *

Tick all that apply.

- Cost Constraints
- Resistance from Suppliers
- Lack of Skilled Personnel
- Technological Limitations
- Organizational Resistance
- Other: _____

23. **How do you assess the financial stability of your suppliers/sub-contractor? (Select all that apply)** *

Tick all that apply.

- Financial Statements Analysis
- Credit Checks
- Payment Histories
- Other: _____

Technologies

24. **Do your company use software for procurement?**

Mark only one oval.

- YES
- NO

25. **DO your company have ERP system ? ***

Mark only one oval.

YES

NO

26. **Which technologies do you use in the procurement process? (Select all that apply)**

Mark only one oval per row.

	Never	Rare	Sometimes	Often	Always
ERP	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E-Procurement Platforms	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(BIM) Building Information Modeling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cloud-based collaboration tools	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project Management Software	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(SRM)Supplier relationship management software	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(SCM) Supply chain management (SCM) software	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

27. **How effective are these technologies in enhancing procurement management?** *

Mark only one oval.

- Very Effective
- Effective
- Neutral
- Ineffective
- Very Ineffective
- Other: _____

Performance Improvement

28. **How do you handle underperforming suppliers to improve overall procurement performance? (Select all that apply)** *

Tick all that apply.

- Performance Improvement Plans
- Supplier Development Programs
- Contract Renegotiation
- Termination and Replacement
- Regular Performance Monitoring
- Other: _____

29. **In your opinion, what are the key factors that can improve the performance of construction procurement? (Select all that apply)** *

Mark only one oval per row.

	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
Enhanced Communication and Collaboration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Advanced Planning and Scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Better Supplier Relationship Management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adoption of Innovative Technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training and Development of Staff	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Feedback

30. **What do you consider the greatest strengths of your current procurement system?**

31. **What areas of your procurement process do you believe need the most improvement?**

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