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Understanding the complexity of materials procurement in construction projects to build a conceptual framework influencing supply chain management of MSMEs

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ABSTRACT

Purchasing is a fundamental step of materials procurement in the construction sector, and since materials can represent up to 70% of the project's construction costs, reducing wastage and improving productivity can have big benefits, both for the environment and the economy, especially for Micro, Small and Medium-sized Enterprises (MSMEs). This manuscript will focus on the process of purchasing materials from these companies' perspective, seeking to investigate the impact of effective materials management on site. In light of the acknowledged absence of system thinking for MSMEs, this research aims to build a new conceptual framework that illustrates the complexity of the materials purchasing process in construction and embodies the risks linked to materials, relationships, information and cash flows. The conceptual framework aims to influence supply management in construction and is based on the recognition of five main levels, going from the specification of materials to data management and feedback. It is designed to illustrate the sequence, logical structure and complexities of the purchasing process. Data from the literature, followed by on-site observations, feeds into the framework.

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Construction materials; purchasing process; MSMEs; procurement; supply chain

Introduction

The practice of purchasing materials is part of the construction materials management, which refers to the systematic planning, organizing and controlling of materials throughout the construction project lifecycle. Both purchasing materials and construction materials management are essential to the supply chain management, as this involves the coordination and integration of various activities, processes and stakeholders involved in the sourcing, procurement, production and delivery of materials to the construction site. To better comprehend the complexities of the purchasing process in the construction industry, it is crucial to expand the concepts of both supply chain and materials management.

Regardless of the importance of the matters, the latter has not been given sufficient consideration when contemplating the phases from ordering to on-site production (Navon and Berkovich 2006). Various researchers have focused on the management of design, procurement processes and labour productivity. Since most of the costs of construction projects is expended on materials, their effective management is one of the main constraints of the sector (Agapiou et al. 1998). Materials management is an integrated process of construction planning. Monitoring all the variables ensures that the quality and quantity of materials and equipment are appropriately and timely specified, procured at a reasonable cost and available when required (Business Round Table (BRT)), 1982). An effective materials management system can generate benefits to construction companies by reducing avoidable costs, including those due to delays. According to Lambert et al. (1998) supply chain management is a key solution for enhancing productivity and efficiency and avoiding wasted time and money. Harland (1996), on the other hand, states that supply chain management is predominant term for materials management and that it is inherently part of it. The below categories have been identified accordingly:

- Internal supply chain: It consists of material and information flows in business functions from inbound to outbound. Hayes and Wheelwright (1984) defined it as a chain linking raw materials producers to end users. This concept is related to existing materials management (Ammer 1968; Lee and Dobler 1965) and value chains (Porter 1985; Johnston and Lawrence 1988; Kogut 1985).
- Dyadic or a two- party relationship with immediate supplier: The concept entails closer, longer-term connections than are typically more apparent in other sectors such as the automotive industry (Lamming, 1989; Womack and Roos 1990).
- External supply chain: Management of business chains.
- Network interconnected business: Management of a network of interconnected companies involved in delivering the product and service packages required by end clients, as highlighted in Figure 1.

A proper supply chain management has the ability to create a virtual organisation. It is made up of various stakeholders with the shared goal of effectively managing all operations, from ordering to delivering and placing the materials on site.

Supply chain and its management entail complex, ongoing processes where several stakeholders are interconnected. Most importantly, the process begins at the start of the project and

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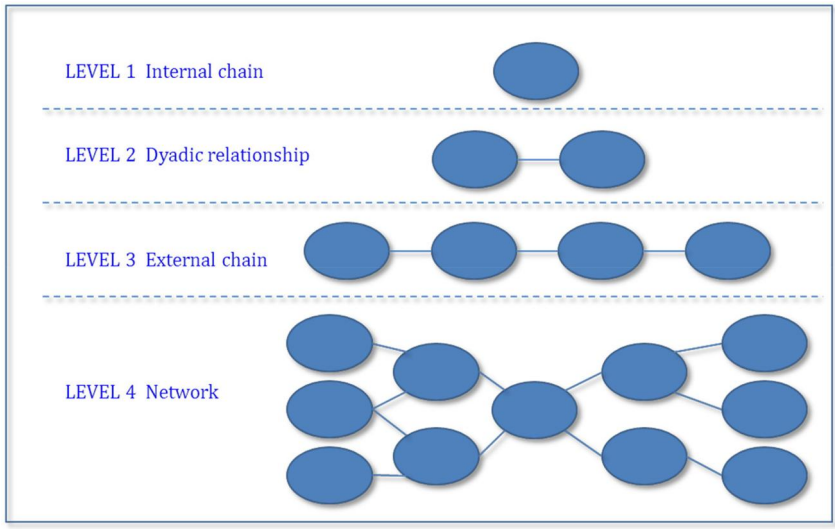

Figure 1. Four main terms of supply chain management. Source: Harland (1996).

lasts until its completion. It is about managing the streams of information, materials, services and money throughout all the activities to maximize the efficacy and efficiency of the processes.

This manuscript intends to create a new conceptual framework to provide an overview of the complexities of the materials purchasing process in construction and to exemplify the risks associated with materials, information, cash flows and relations. A set of beliefs, ideas or rules used as the basis for judgments and decisions underly the new conceptual framework (Oxford English Dictionary 2011). It requires systems thinking with logical structures and specific processes.

The new framework is intended to influence supply management in construction and is based on the acknowledgement of five key levels, from materials specification to data management and feedback.

The process begins with the requirements based on the purchasing order list and ends up with a preliminary plan for the next purchasing order. This study follows a qualitative approach, where observations of chosen MSMEs shape the essence of the process. Useful lessons about the materials purchasing process will be drawn.

Defining MSMEs

Micro, Small and Medium-sized Enterprises (MSMEs) account for about 95% of all enterprises, provide 65 million jobs in the European context and contribute significantly to innovation and entrepreneurship (Cantafio and Parisi 2021). Because they are entrusted with the long-term growth of the local economy and are integrated into local communities, they have the potential to let the social capital thrives (Cantafio and Parisi 2021).

MSMEs can therefore be seen as growth engines that underpin competitiveness, efficiency and job creation (OECD (Organisation for Economic Co-operation and Development) 2004). A robust body of knowledge combines this with the concept of proximity to share knowledge and resources and drive innovation faster (Bevilacqua et al. 2017, 2018, 2019; Parisi and Eger 2020; Parisi and Biancuzzo 2021).

To define MSMEs, it is vital to refer to the number of employees, turnover and balance sheet total (Burns 2011). Companies qualify as MSMEs if they stand below a maximum ceiling for staff numbers and a specific level of turnover or balance sheet ceiling (Table 1).

Table 1. MSMEs classification in Europe. Source: European Commission (2010).

Enterprise category	Headcount	Turnover € m	Balance sheet total € m
Medium-sized	<250	≤50	≤43
Small	<50	≤10	≤10
Micro	<10	≤2	≤2

For companies of this size, production is the key to their organization (Tommaso and Dubbini 2000). Furthermore, by creating a gap between revenues and costs, they try to maximize profits. Competition as well has a significant impact on their decision-making processes. With a solid competitive framework, they must not only increase their profits, but also reinvent themselves in the long run by adapting to the offerings (Hawkins 1973).

Given this definition of MSMEs, for the purpose of this research, it is important to consider the fact that MSMEs compete with different resource pools and follow different approaches. This led the study to focus on the company's production capacity and capabilities.

Supply chain and its management

Improving the performance of the supply chain has become one of the key issues for companies (Cai et al. 2009). However, despite the importance of supply chains, a universally accepted definition is not in place yet. Some scholars see it as a form of competition (Ellram 1991), whilst others have considered it as a tool for improving both optimization and efficiency (Tan 2001). Stephen (1998), for example, defines the supply chain as the set of interrelated activities involved in planning and controlling of raw materials, elements and finished products from suppliers to end-users. Mabert and Venkataramanan (1998), on the other hand, describe it as a system of activities accomplishing the purposes of product development, materials procurement, materials transfer between facilities, manufacturing of goods, distribution of finished products to end-users and aftermarket support. Lambert et al. (1998) considers the supply chain to be a network of multiple companies and relationships rather than a series of one-to-one connections between different companies. It clearly emerges then that this evolving concept is subject to multiple interpretations (Green et al. 2005).

Two points of view can be emphasised: traditional and new. Regarding the former, according to Tsai (2007), the supply chain refers to the control of materials flow with the aim of

minimising/optimising the total cost of procurement, supply and inventory, tackling matters such as production capacity, lead-time, demand and orders. Three main stages can be distinguished: procurement, production and distribution, each having additional steps and embedding four costs:

- Cost of procuring the product from the manufacturer.
- Shipping costs from the manufacturer to the warehouse.
- Warehouse inventory costs.
- Transportation costs from warehouse to distribution centre.

Thus, the traditional view of supply chain management is linear, with the different functions suggesting a flow of information, materials and finances to customers through each participant in the supply chain (Kopczak and Johnson 2003).

The new perspective, instead, indicates that the activities in the chain should be more combined, involving a collaborative endeavour between the supply chain players. Greater integration would let different channels of communication and feedback processes. For instance, the manufacturers might deliver supplies directly to the end-user or the retailers/builders' merchants may be more engaged in the choice of the most suitable materials (Kopczak and Johnson 2003).

In light of the existing competitive pressure, several companies try to expand their supply chain to boost their production and sales at an economical and reasonable cost. Figure 2 illustrates the activities and firms usually involved in a construction supply chain.

Supply chain management

Supply chain management is the work of manufacturing and delivering finished goods from the suppliers' suppliers to the customers 'customers (Kranz 1996). Danese et al. (2004) provided another definition where supply chain management is seen as the combination of core business processes from end users to the original supplier of products, services and information that add value to clients and other stakeholders. These supply chain management definitions acknowledge the connections between supply chain members, the processes enabling these links and the level of integration involved.

According to Christopher (1992), supply chain management is a system of organizations that are embedded in upstream (money and information) and downstream (materials) connections through various activities and processes, to create value in the form of goods and for the end users. According to Handfield and Nichols (1999), then, supply chain management is the combination of activities related to materials and information flows, as a result of enhanced supply chain relationships to attain a sustainable competitive advantage.

Tommelein et al. (2003), instead, define it as the practice of a set of both firms and individuals working collectively in a network of interconnected processes formed to best serve the needs of end users while rewarding all the other players of the chain. Supply chain management, then, has the potential to enhance the discipline in a company, while saving costs and time.

For the purpose of this research the following definition has been adopted: supply chain management is the exercise of blending the activities connected to materials flow, information streams and communication channels amongst the different suppliers and the other stakeholders involved in order to procuring and supplying materials, logistics and transportation, with the final objective to add value to the entire activities chain through a Just-In-Time strategy.

Materials management

Construction is the practice of physically constructing a project by assembling construction equipment, materials, regulation and management necessary to complete the work (Clough et al. 2000). Building materials management is a vital and complex act that requires significant enhancements (Ibn-Homaid 2002). Thomas and Napolitan (1995) indicate that materials management can affect the efficiency of construction and Proverbs and Xiao (2002) found that material handling costs can account for 30% to 80% of total construction costs. Effective materials management is therefore essential to the success of any construction company and can highly affect labour productivity (Hanna, 2005). Without an effective system, the overtime rate can be 18% (Thomas et al. 1989).

A simple material management system can itself enhance labour productivity by 6%; in addition to this, when more sophisticated systems are installed, a further 4% to 6% increase in labour saving can be attained (Construction Industry Institute (CII) 1986).

MSMEs constantly suffer from working capital shortages (Donyavi et al. 2022); however, little attention has been given to the impact of materials' purchase and supply especially on firms' working capital needs. Borcherding et al. (1980) found that 27.7% of the working time spent by craft workers is unproductive in light of a lack of tools and materials in the right place and at the right time. O'Brien (1998) found that 42% of a field workers' time is spent handling materials and preparing the different operations. Efficient materials management, then, contributes not only to increased productivity and profits for companies, but also to eased and smooth completion of construction projects.

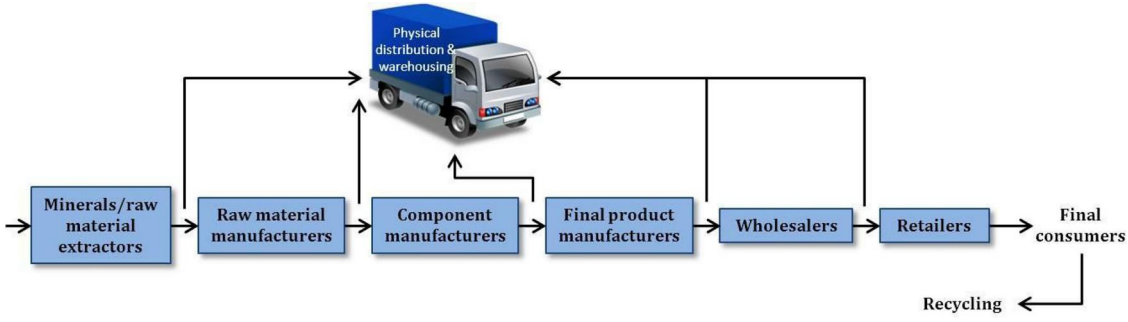

Figure 2. Activities and firms in a supply chain. Source: New and Payne 1995.

The ability to manage materials, then, has a significant influence on a company's profitability (Tavakoli and Kakalia 1993).

On the other hand, inefficient materials management can trigger complications in construction projects, such as late delivery of building materials and poor materials planning. Wong and Norman (1997) emphasize the urgent need for an improved materials planning approach. It emerges how materials management is a result-oriented process, evaluating process performance by comparing actual results to planned or targeted ones.

Plemmons and Lansford (1995) identified 12 key measures and 6 key attributes for communicating the effectiveness of the materials management processes.

The following attributes, then, have been tailored on this research to highlight the measures related to materials purchasing, as shown in Table 2: accuracy, quality, quantity, timeliness, cost and availability.

Materials management systems in construction projects

By analysing the construction project costs, it emerges that materials make up a large portion of the total costs. Hence, materials management is essential to success. For example, buying materials at an early stage can lead to a problem where capital is tied up and interest charges can incur on the surplus of materials.

Additionally, materials can deteriorate or be stolen during their storage. In addition, delays and additional costs may occur if materials required for certain activities are not available. Materials flows and related data such as quantities and inventory levels are key factors during the phase of purchasing. Nevertheless, one of the main difficulties is the lack of up-to-date information.

Waste accounts for a large part of the costs in the materials flow due to poor management of materials on-site (Chau, 2003). Yet, it can be dramatically reduced and better managed if supplies adequately reflect project needs. Some projects can cost much more than originally estimated and efficient materials management can help in reducing costs and increasing productivity. It is possible to highlight a systematic materials management process that can be used in construction projects. The main five categories are underlined below:

- Measurements and specifications of materials and components required and the order in which they are required.
- Procurement and purchasing processes, namely, best supplier selection taking into account the best price and delivery time, credit facilities, capacity, delivery schedule and interface with the production programme. Orders are often double routed from the manufacturer to the retailer, the factoring company or the wholesaler before the delivery to the site.
- Assist in the off-loading, on-site delivery, logistics, order management, by providing on-site mechanical equipment and storage.
- Payment management and financial processing.
- Transportation of materials from storage, handling and using the materials in the on-site production and disposal of waste.

Therefore, material tracking continues to represent a great issue on current construction sites (Saidi et al. 2003). Lack of communication and coordination environments impact materials management by making it poor and inaccurate (Navon and Berkovich 2006). According to Thomas et al. (2005), materials management issues are the most commonly documented source of disruption. For some projects, material shortages represent the major problem hidden behind low productivity and delays (Construction Industry Institute (CII), 1987; Bell and Stukhart 1986; Gould and Joyce 2000; Makulsawatudom and Emsley 2003). Unavailability of materials and failure to effectively plan the correct volume of construction materials needed on-site (due to the aforementioned lack of up-to-date information) is the cause of further delays and inefficiencies in construction projects. Navon and Berkovich (2006) indicate several barriers to purchasing and supplying materials, as shown in Table 3.

Table 2. Key effective measures. Source: Authors' elaboration (2022), based on Plemmons and Lansford (1995).

Attribute	Measure
Accuracy	Materials receipt problem Warehouse inventory accuracy
Quality	Job site rejections of supplied equipment and components
Quantity	Amount ordered Amount delivered
Timeliness	Procurement lead time Bid/evaluate/commit lead time Purchase order to material receipt duration Materials receiving processing time Materials withdrawal request lead time
Cost	Construction time lost Waste caused by over-ordering of materials Working capital tied up in materials purchases
Availability	Materials availability

Effective materials management

Construction work is distinguished by poor planning which usually leads to time overruns and inadequate waste management, in addition to low levels of productivity and health and safety problems (Kometa et al. 1995). An effective material purchasing requires a systematic process able to maximize productivity over the long term.

The external (uncontrollable) and internal (controllable) factors that impact productivity levels are connected to both hard (product, plant, equipment) and soft (personnel organization and management) factors. Other aspects that can contribute to continuous productivity enhancement on the project's site incorporate: reducing and simplifying work processes to lessen labour,

Table 3. Obstacles in the purchasing and supply of materials. Source: Navon and Berkovich 2006.

Materials supplied not matching the order	Lack/unavailability of information for the order
Wrong arrival time of materials to the site or wrong quality	Lack of information about materials arrival to the site or site stock
Over ordering or under ordering materials	Missing or over ordering of materials
Waste of labour in searching for materials on site	Unavailability of storage space for material on site
Lack of communication between contractor and supply chain companies	Early or late arrival of materials, lack of a JIT strategy
Forgetting to order the materials by the due date	Stolen or lost materials
On-site control of materials such as wastage	Lack of storage
Incomplete information for ordering material	Materials arrivals are not registered
Delays in payment and subsequent problems with suppliers	Untargeted materials i.e. materials arrive on site, but no one knows who ordered them

Table 4. Effective supply of material purchasing. Source: Navon and Berkovich 2005.

List of existing stocks for searching materials on site	Comparison between the purchase order and the materials on site
Checking materials ordered against materials	Providing a list of required materials including quantities and time of usage
Weekly meeting for details scheduled	Approving the bill of lading and sending it to the main office
Checking quantities of materials	Recording incoming materials
Checking all the faults such as wrong ordering quantities of material	Prepare a list of required materials which should be ordered in the future
Calculation of variables of materials e.g. the difference between available materials and materials needed	Prepare a detailed list of materials, including all materials on site or in stock
Issuance either directly or via the main office	Prepare a list of cumulative materials flow
Planning for handling materials such as time of arrival materials to the site	Prepare a list of all open purchase orders and materials
Confirming materials ordered	

Table 5. Selected MSMEs characteristics. Source: Donyavi et al. (2022).

MSME	Project types	Headcount	Turnover (£ m)		
			2005	2008	2010
1	Established in 1992, the company focuses especially on hard and soft architectural landscape	≤65	4.9	0.7	5.8
2	Established in 1987, the company focuses especially on building and civil engineering	≤135	9.1	1.4	8.9
3	Established in 2001, the company focuses especially on construction—building extensions and refurbishment	≤8	2.2	0.09	1.5

materials and equipment; arranging the construction site to facilitate the movement of materials; and connecting with all personnel in planning and problem solving to advance the disciplinary setting of the site.

Martin (2011) proposes five ways to increase construction productivity: empowered foremen or site managers; incentives; training; planning; and security. On the other hand, El-Haram and Horner (2003) consider good engineering and management tools, including BIM as the best means to meet the need for good performance and support requirements during building projects. Hudson et al. (2001) instead trust that project productivity improvements depend on project type, project execution and senior managers commitment. According to him, several other factors have the potential to enhance and maximize project productivity, as listed below:

- A record of all project ideas and goals;
- A breakout of projects into smaller components;
- An improved engagement and training of new Green Belt Project Leaders;
- An implementation of toolkits and techniques encompassing three different domains: statistical analysis, team and stakeholder management and meeting facilitation;
- A project acceleration due to shorter timeframes;
- A resourcing of distributed teams;
- A speedier training process, even for complex processes;
- A focus on soft skills;
- An improved buy-in and commitment;
- A more effective communication plan to be implemented.

Low productivity levels, then, can be the result of low trust, lack of skilled labour, shortage of materials and project complexity. Tools and equipment failure, material shortages or delays, assessing errors, constant rework, lack of training, high levels of turnover, unskilled foreman, together with other aspects can impact productivity (Koontz, 2008).

According to Christian and Hachey (1995), employees spend 29% of their day productively, then 18% handling materials and 17% waiting for materials, transportation or receiving instructions.

Navon and Berkovich (2005) suggest several components (highlighted in Table 4) for accomplishing an effective procurement of materials.

Nevertheless, the listing fails to reveal that construction projects are dynamic, with different variation orders, altering details and clients changing ideas at different phases. In many cases, purchased materials cannot be employed because variation orders change the project specifications and returning materials back to the manufacturer or supplier would mean incurring in inventory replenishment and administrative costs. Additionally, suppliers are reluctant to accept second-grade inventory after being on site for several weeks.

Methodology

The research has adopted a mixed methodology to gather information and data from observations and document reviews. From the outset, the purpose of conducting on-site observations was to conduct a longitudinal study so that data could be collected from construction companies working on multiple projects at various stages. Three MSMEs have been selected (see Table 5 for details) skimmed after an initial screening of twenty companies. All of these companies are based in the Southeast of England and have been selected based on their areas of work. They are all privately owned, have short-term plans only and work on projects ranging from small civil engineering developments to renovation schemes and new constructions. The nineteen projects carried out by the selected MSMEs have been observed across the different lifecycle phases, with an emphasis on material specification, procurement, delivery and handling.

Development of a framework

The literature review revealed a lack of systems thinking in MSMEs. This is partly due to the way these companies are structured and work, but mostly to the lack of resources to organize their approach to get feedback loops and connected systems. For reference, different frameworks for ordering and purchasing materials were investigated and their pertinence to MSMEs was taken into account to shape the framework of this study. Based on the following principles:

- Demonstrate the materials purchasing process and its sequencing, considering arrival on site, movement across the site, related paperwork and ordering process.

- Show the ability to meet material procurement requirements and payments.
- Establish the capacity to emphasize inquiries and issues associated to the purchasing process and the flow of materials and information.
- Set up the capability to track materials throughout the purchasing process.
- The following frameworks have then been chosen as the most suitable and robust ones:
- Navon and Berkovich (2006),
- Lander et al. (2013),
- Hadikusumo et al. (2005),
- Vrijhoef and Koskela (2000),
- Ala-Risku and Karkkainen (2006).

Nevertheless, each one presents some drawbacks when the focus is on their application to MSMEs. For example, Navon and Berkovich's framework does not have a satisfactory level of detail. Five stages are used to illustrate the top-level process: input, purchase, track, analyse and output. Various phases require large data management and recording, which, while important, do not often occur in MSMEs. Lander et al.'s framework (2013), on the other hand, does not include the opportunity to trace the purchasing process from the perspective of MSMEs.

The focus is on tender arrangements and evaluation, material sourcing constraints and invoice payments, rather than the ordering process. Conversely, Hadikusumo et al.'s framework (2005) raises matters related to the purchasing process, but without the possibility of tracking it. The framework of Vrijhoef and Koskela (2000), instead, explores the supply chain of the manufacturing industry including all the flows of information such as orders, schedules and forecasts. Finally, Ala-Risku and Karkkainen (2006) framework targets the process of materials delivery. It stands then as a materials logistics framework for construction projects that gets a tracking-based approach.

MSMEs only use the procedures they feel secure with, based both on their characteristics and the external and internal conditions.

The focus of materials purchase and delivery is scheduling, order of delivery and discrepancies between requested materials and components and materials delivered to the site.

The new framework established for this study exemplifies the complexity of the materials purchasing process. It exemplifies the matters associated with material flow risks, flows of information and cash and more crucially, relationships. The new framework is built on the previously investigated existing models and the processes examined in the three selected MSMEs. It goes in the direction of explaining the purchasing process and identifying any weak spots during the process.

The framework begins with the specification of materials at level 1 and ends with materials placement on the site and feedback at level 5.

The five main levels of the new framework are founded on Navon and Berkovich (2006), the matters regarding the purchase process are based on Hadikusumo et al. (2005), while the constraints linked to materials procurement and payment are grounded on Lander et al. (2013), Vrijhoef and Koskela (2000) represents the reference for materials and information flows, and Ala-Risku and Karkkainen (2006) provide the basis for the tracking approach.

The new framework breaks down each unit into a number of sub-units which have been acquired as a result of the undertaken observations on the chosen MSMEs. This new framework can be followed across the purchasing tasks, simplifying this way the whole process and enhancing the chances of getting the best value out of the construction projects. The framework encompasses aspects of materials purchasing, from the specification stage to ordering, on-site delivering, placement and use. It consists then of five main levels and sixteen stages (see Figure 3):

- Level 1: Input (4 stages). This phase comes after contract awarding. MSMEs at this point have already the data and information used to plan and estimate resources, time and profitability, along with specifics of the statements made when formulating the offer.
- Level 2: Purchasing process (4 stages). Starting from all the specified information and drawings provided, it is associated with the purchasing process.
- Level 3: Tracking (4 stages). It examines the materials from on-site delivery to project integration.
- Level 4: Data management (1 step). This entails a system for communicating the materials status to MSMEs for future projects.
- Level 5: Feedback (3 stages). It encompasses feedback and recommendations.

Input

The input unit is the first level of the framework and consists of four main phases:

- Materials Specification (MS)
- Materials Planning (MP)
- Materials Classification (MC)
- Unforeseen Events/Changes (UE)

Materials specification (MS)

This stage involves listing the materials for the project on the basis of the sequence of ordering and the given design. Either the site manager or the person responsible for purchasing orders the materials specified in the design.

This often represents the beginning of a delay in the materials purchasing process with long lead times or lags due to inventory shortages at suppliers.

The role of the designer here is to establish the standards of quality, variety and performance needed for the materials. Price, disposal and pace of delivery will be the key deciding factors. Nevertheless, designers are very often not qualified in purchasing materials, thus specifications are grounded on national standards and not necessarily on the specific purchasing requirements, including minimum order quantity or special handling.

Materials planning (MP)

The success of the project is immediately affected by how well the materials planning is managed. It includes features about materials, including type, quality, quantity, performance criteria, selected suppliers and disposal. In this step, materials' quantity and quality evaluations are made and the total cost of materials is taken into account, in order to ensure the project stays within budget.

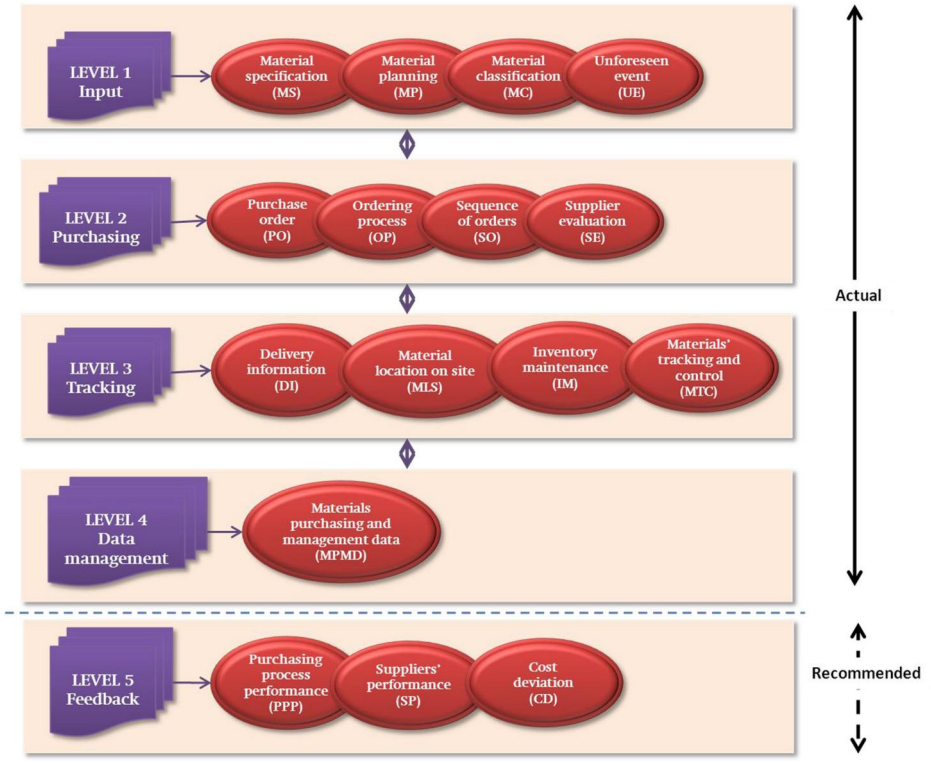

Figure 3. The new framework. Source: Authors 'elaboration (2022).

Materials classification (MC)

Materials classification is based on project description, scope, design and specifications. When ordering, it is paramount to get a good understanding of the various kinds of materials needed, including information about quantity and time schedule. Size and classification are the most important features at this stage.

Unforeseen events/changes (UE)

Because of the complexity of the construction industry, projects often experience unexpected events or changes. Unforeseen materials unavailability during the Materials Planning process, for instance, can stall or slow down the job, resulting in lost productivity, time and money. If changes are made by the owner or the design team after materials have been already delivered on site, a change order needs to be released to compensate the contractor, but this does not automatically reflect the impact on the delivery of materials.

Purchasing

The purchasing process stands at the second level of the new framework of this research and is based on the following four stages:

- Purchase Order (PO)
- Ordering Process (OP)
- Sequence of Orders (SO)
- Supplier Evaluation (SE)

These stages are vital as a function of the procurement process of materials for procuring materials and determining jointly acceptable conditions between contractors and suppliers. Long-term relationships then play an important role at this specific stage. Contractors need credit lines and will count on regular suppliers for materials.

Purchase order (PO)

This phase includes generating a bill of materials which embed their delivery schedules/sequences. Each project is unique and delivery depends on a number of factors, such as access, storage space, workflow and labour availability.

Ordering process (OP)

The stage is prolonged, complex and often non-sequential. It may vary on the basis of material types and supplier services. The process begins with the requirements of the purchasing order list and ends with a preliminary plan for the next purchasing order. A few issues can arise during the process.

Sequence of orders (so)

The Sequence of Orders stage talks about the series of materials to be ordered according to the progresses of the project. Every project is different, but the same procedures apply to ordering materials and performing on the site. Suppliers and contractors need to develop good communication channels and fully appreciate the ordering procedure. An updated inventory of the chosen materials is required for every ordering phase. Yet, very often this is not available, representing the key issue of this step.

Supplier evaluation (SE)

This phase is focused on suppliers' evaluation. A default assessment sheet can be attached to the materials ordering register so

that it can be completed at every step of the order and saved for future supplier evaluation.

The foreman or site manager can take charge of this task. The assessment is built on some aspects, including: timely delivery of materials, their appropriate quantity and quality and prices. MSMEs can adopt this as a model for selecting suppliers in the future, which can be precious, especially considering the fact that MSMEs usually do not have feedback systems in place to support their future planning.

Tracking

Tracking is the third stage of the framework and is built around four main phases, as highlighted below:

- Delivery Information (DI),
- Materials' Location on Site (MLS),
- Inventory Maintenance (IM),
- Materials' Tracking and Control (MTC).

Received materials are usually arranged at the most suitable location on the site by the supplier's delivery vehicle, trying to avoid double handling, theft or loss. The contractor does not have control on quantity, quality and type of the materials arriving on site. The primary purpose of this part in the MSMEs structure is to track the type, quantity, quality and placement of materials on site and to manage information about these materials on-site. The latest information about materials and construction site conditions are paramount at this point.

Delivery information (DI)

An expert and reliable person, such as a site manager or foreman, should be allowed to review incoming materials and store data and information for potential future usage. In order to ensure that materials respect the specifications of the project as noted in the purchasing order, it is necessary to perform different checks.

Materials' location on site (MLS)

This phase starts by reviewing the incoming materials based on the list of the purchasing order and concludes with the schedule of the following order. It is a sort of guideline for arranging the materials in the proper location on site.

Inventory maintenance (IM)

All materials shipped for usage on site are recorded and then removed from inventory either upon their arrival or at a later stage. The foreman holds these inventories. This is an essential step in determining materials losses and highlighting any possible discrepancy between materials site priorities and actual needs.

Materials' tracking and control

This step includes evaluating all the incoming materials, considering existing stocks, in use items, deadstock, namely the discrepancy between the materials received on site and those shipped for use and standing materials. MSMEs can trace the materials through regular inspections on-site. This stage entails a competent person, which can be the site manager, to know all the parts of the project at every phase.

Data management

This stage is not flexible per se, as it is built on the data produced by the previous three levels of input, purchasing process and material flow process. It includes only the below step:

Materials' purchasing and management data (MPMD)

Reports can be produced on the basis of the available data on input, purchasing and materials flow processes. It will then feed the feedback step to nurture the next project.

Feedback

This level is the fifth and final one and is centred on the following three stages:

- Purchasing Process Performance (PPP);
- Suppliers' Performance (SP);
- Cost Deviation (CD).

Purchasing process performance (PPP)

At this stage, reports from the aforementioned levels are reviewed and assessed against the criteria for what concerns planning, information flow, tracking and data generating, throughout the process, from ordering to site arrangements. This phase also works as a warning system, as it is based on the planned and actual performance of materials management on-site to prevent any issue during the materials purchasing process.

Suppliers' performance (SP)

This stage gives suggestions for evaluating and selecting future suppliers. It represents a feedback loop for MSMEs. The evaluation process notifies MSME about the performance of suppliers, and as a result, a recommendation for the next orders is released.

Cost deviation (CD)

This final phase measures the performance of the purchasing process by comparing the estimated costs at the bidding step with the actual costs in the actual project.

Conclusions

The study underlines the areas where MSMEs can enhance their materials management, especially during the procurement process. It shows the complexity of the process and the challenges that can occur and at what stage. The work is grounded on deductive reasoning. It started with the intention of designing a new framework for the material purchasing process of Micro, Small and Medium-Sized construction Enterprises. The next step was to identify any matter arising and finding means that could enhance the process.

Based on the data obtained from literature review and those coming from the observation process, it can be assumed that the materials procurement and purchasing process for materials supply is complex and comprises numerous important concerns.

The conducted research revealed a lack of standardized systems, planning and management, and a formal scheme understood by site managers. MSMEs work on a project base with short-term objectives. Their focus then is mainly on securing new jobs and ensuring projects meet clients' satisfaction. They

give little consideration to the disposal of materials and the lead time required to organize the logistics of transportation. Materials arrive on site, following a Just-In-Time strategy, often from the lowest cost provider. Little attention is paid to splitting the project into sub-systems or expanding existing approaches and this is due mainly to the low project value, the short-term relationships established with the involved clients and the insufficient MSMEs resources. In other words, MSMEs often fail to develop their internal management systems and procedures properly as a consequence.

The study revealed that improving a more systematic approach for materials management in construction would be beneficial, especially for MSMEs, for implementing purchasing processes, tracking materials and their use on the site.

The complexity of the materials purchasing process has been explored using a comprehensive framework able to cover many aspects of materials ordering, from their specification to order, delivery and on-site storage. It embedded five levels or units and sixteen steps.

The study then developed a purchasing process framework tailored on MSMEs features. This framework demonstrated an understanding of the practices adopted to place orders with suppliers and track material handling and use on-site, including materials monitoring.

The framework confirmed that the purchasing process is long, complex and often neither sequential nor integrated. There are often dependencies between ordered materials, yet the estimating phase and the final materials cost are not connected and fully integrated.

Due to the nature of the work, the analysis had to be general in nature. Therefore, certain traits have not been given sufficient attention in the detailed analysis of this study. The investigation was intentionally limited to three MSMEs with nineteen construction projects. The purchasing process framework developed is therefore strictly dependent on the project type. This means that the matters identified in this study may not be generalized to all types of projects.

The study identified the main challenges faced during the purchasing process by MSMEs working on civil and building construction projects.

This can push the body of knowledge and will require further investigation by those wishing to understand how to overcome the identified challenges both in the short and in the long term.

From various perspectives, information and communication technologies may have an enormous potential for MSMEs by changing the corporate cultural structure from basic communication to site operations. Future research could focus on the implementation of these technologies on the construction site.

Further study is also needed on eviscerating and developing a systematic approach to ordering construction materials for MSMEs and automating the purchasing process using portable devices.

Data availability statement

The manuscript titled 'understanding the complexity of materials procurement in construction projects to build a conceptual framework influencing supply chain management of MSMEs' is based on a comprehensive analysis of secondary data obtained from industry reports, academic publications and government regulations pertaining to construction project procurement and supply chain management and primary data collected through on-site observations of construction projects.

Due to the nature of this study no specific datasets were collected or used in the analysis. The findings and recommendations presented in this manuscript are based on the synthesis and interpretation of qualitative information gathered through on-site observations and extensive review of relevant literature.

The manuscript provides a detailed description of the research methodology and the thematic analysis approach used to derive key insights. Additionally, a comprehensive list of references is provided to guide interested readers to the relevant sources of information.

Researchers and practitioners interested in further investigating the topic are encouraged to replicate this study using their own datasets or conducting additional primary research to validate and build upon the findings presented in this manuscript.

The authors affirm their commitment to promoting transparency and reproducibility in research and are available to respond to any queries or requests for clarification regarding the methodology or findings presented in this manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

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