



## **ANALYSIS OF HISTORICAL BOQ DATA FOR CASE-BASED REASONING IN PRELIMINARY COST ESTIMATING**

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### **ABSTRACT**

**Purpose:** This study utilises historical cost data of priced bills of quantities to analyse the cost breakdown of new public building projects in Ghana as a case study in preliminary cost estimating. Leaning on relevant conceptual/theoretical frameworks, the study analyses the distribution of costs (i.e., direct costs of measured works and project allowances) in a typical work section bill of quantities.

**Design/Methodology/Approach:** The study adopted a quantitative research approach. A total of 367 SMM5- and SMM7-based work section bills of quantities obtained from public quantity surveying firms were used for the study. The data was organised in Microsoft Excel and analysed in Stata Version 17 using descriptive statistics.

**Research Limitation:** The study was limited to 367 bills of quantities from SMM5 and SMM7-based work sections for public buildings in the Western and Central Regions, which may not fully represent the entire spectrum of quantity surveying practices across different project types, scales, and geographic regions.

**Findings:** Mean and median values of the analysis show that, for both SMM5 and SMM7, substructure and finishes constitute the two cost-significant measured works in order of magnitude. For project allowances, preliminaries, and contingency sums, averages 6% and 8% in both SMM5 and SMM7 projects, while provisional sums constitute about 11% in SMM5 projects but 2% in SMM7 projects. Consultancy fee is approximately 8% but can reach a maximum of 16%. The observed significant gap in provisional sum in SMM5 and SMM7 bills of quantities sheds light on efficiency in cost estimate build-up resulting from the effectiveness of the Standard Method of Measurement (SMM7) as an instrument of measurement.

**Practical implication:** The study's results provide valuable insights for quantity surveyors during cost evaluation, budgeting, and planning of new building projects.

**Social Implication:** This improved cost predictability has significant social benefits, including better allocation of public resources, reduced burden on taxpayers, and enhanced delivery of essential infrastructure such as schools, hospitals, roads, and housing projects that serve community needs.

**Originality/Value:** The study grounds a useful but otherwise intuitive professional practice in theory and supports this with empirical data.

**Keywords:** *Bill of Quantities. case-based reasoning. case knowledge. new buildings. preliminary cost estimating*



## INTRODUCTION

Cost is arguably the most important concern of all clients in building construction projects. Accordingly, at various stages of the development lifecycle for new building projects, quantity surveyors prepare cost estimates to meet the diverse needs of clients. For example, at the early stages of a new building project, before detailed costs are prepared, quantity surveyors typically prepare preliminary estimates to assist clients in forecasting and managing their financial commitments. This involves determining the project's total costs based only on general early concepts of the project (Kan, 2002). Preliminary estimates help determine whether a project is feasible – technically and/or economically – and to select optimal design concept/ solution among alternatives (Abdelaty, Nesselhauf & Munie, 2022; Arage & Dharwadkar, 2017). They also serve to better define the scope of work, given the greater influence project owners have in the initial stages of development (PMI, 2016). As both budgeting and planning tools, preliminary estimates are critical to effective cost planning and evaluation of project development. For these reasons, preliminary estimating must be quick, realistic, and reasonably accurate (Yang et al., 2022; Matela et al., 2022; PMI, 2016; Kim et al., 2012).

Preliminary estimates can, however, be challenging to prepare because they occur at the early stages of a project, where minimal information is available, and many factors affecting project costs are unknown (AACE, 2020, 2022; Elmousalami, Elyamany, and Ibrahim, 2017; Hegazy, 2002). For example, on occasion, a client may require a cost estimate based on information such as the number of persons, seats, or beds in a project, without requiring more detailed information. A common approach adopted by quantity surveyors in such situations is to allocate a cost, albeit imprecise, to each accommodation unit of the particular building using a unit rate usually obtained by a careful analysis of the unit costs of some fairly recently completed buildings of similar type, cognisant of differences in cost that have risen since the buildings were constructed, including any variations in site conditions, designs, method of construction and materials (RICS, 2012). Where sketch designs are available to permit the determination of the gross floor area of the building, cost may be determined by taking the cost per square meter of floor area of several similar type of buildings from cost analyses and cost records and interpolating a unit rate/cost for the proposed building (RICS, 2012; Thompson, 2007).

In other instances, the cost of the different elements of the building, such as the foundation, walls, floors, or roof, may be used, referred to as an elemental cost analysis. To the direct costs resulting from these measured works, project allowances are added to cover indirect costs, such as the main contractors' preliminaries (site overheads), contingency, consultancy fees, and fluctuations or cost escalations (Brook, 2016; Collier, 2005), often through percentages. The African Association of Quantity Surveyors in its guide to elemental cost estimating, observes that the principal contractor's preliminaries, for example, may be treated as a separate cost element and added "*as a percentage*" to the total cost of the estimate derived from analyses of past projects of a similar nature and construction period, or through a lump sum (AAQS, 2016).



While useful, this percentage approach is only anecdotal and arbitrary, rooted in experience and intuitive judgment (Abdelaty, Nesselhauf & Munie, 2022; Cheng et al., 2010). The practice is barely grounded in any theory or methodological framework. This paper submits that, in principle, the method and/or practice where quantity surveyors, based on experience, estimate the cost of new building projects using cost data of similar past projects is *case-based reasoning* – an experience-based approach to solving new problems by adapting previously successful solutions (Leake, Ye & Crandall, 2021; Kim & Kim, 2010).

It is noteworthy that among the many methods and techniques that have been researched and applied in estimating project costs, techniques/models based on users' experience have become preferred based on the simple understanding that cost estimation is the prediction of the cost of an artefact, process, or project by using experience and/or a methodology (Leake, Ye and Crandall, 2021). It is a view that has popularised case-based reasoning (CBR) as an experience-based approach to solving new problems by adapting previously successful solutions to similar problems (Kim & Kim, 2010). Compared to many currently used knowledge-based systems for cost estimating, case-based reasoning (CBR) has become widely preferred (Ayhan & Tokdemir, 2019; Virulkar, 2004). A fundamental advantage of CBR is that the reasoning process, which is by analogy, is familiar to humans (Goel, Navarrete, Noveck, & Prado, 2017), and can, therefore, be easily followed compared to rule-based systems such as Artificial Neural Network (ANN) (Ozorhon et al., 2006). CBR facilitates the acquisition/retrieval of knowledge, both because cases are easier to elicit than rules (Leake, 1996) and because, in some domains, cases are routinely captured as a by-product of other processes, providing a readily available knowledge resource (Virulkar, 2004).

Case-Based Reasoning (CBR) lends itself easily to addressing unstructured problems by using historical cases instead of pre-defined rules, as defining such rules is complex and time-consuming (Leake, 1996). The experience-oriented nature of CBR allows practitioners to address issues by using their accumulated professional experience and knowledge (Xiao, 2020; Mohammed et al., 2018; Brown & Gupta, 1994). Due to this similarity of mindset, CBR has proven to be a convenient method/approach to solving construction management problems (Hu et al., 2016), which are often unstructured and are, therefore, solved by utilising experience and experts' knowledge in practice (Okudan, Budayan & Dikmen, 2021; Ozorhon et al., 2006). CBR has proven to be a valuable method for early construction cost estimation through retrieving and reusing either historical cost values (e.g., Doğan et al., 2006) or quantities of representative items (e.g., Hong et al., 2011). Kim and Shi (2014) investigated the suitability of CBR for cost prediction. They found it to be particularly beneficial at the preliminary design stage, where the lack of detailed information forces estimators to use cost models based on previous similar projects. Given its numerous advantages, CBR has garnered considerable research interest in its applications to construction management in general, and construction cost estimation in particular (Xiao, 2020; Hui et al., 2016; Jin et al., 2014; Kim, 2013).

The effectiveness of case-based reasoning, nevertheless, depends on *case knowledge*, that is, the database of similar cases from which a potential solution can be retrieved (Wang, Lin, and



Zhang, 2022; Markatou et al., 2012). Fortunately, in regions and contexts like Ghana, where traditional bills of quantities are still in use, many building construction and quantity surveying firms store vast amounts of historical cost data in the form of bills of quantities that can be analysed to provide case bases for effective case-based reasoning during preliminary cost estimating (Uysal & Sonmez, 2023). Using historical bill of quantities data from building projects prepared based on the Standard Method of Measurement (5th and 7th editions), this study explores the cost breakdown – including direct costs of measured works and indirect costs (i.e., project allowances) – as a case-based knowledge source for preliminary cost estimating. By first providing a theoretical context, the study examines the distribution of costs (measured works and project allowances) in a typical work section bill of quantities.

The study is useful because it provides a theoretical context for an otherwise intuitive yet valuable professional practice. The resulting cost profiles can also provide insight into the distribution of costs for informed decision-making, such as the evaluation of tenders (Xiao, 2020). Collier (2005) notes that it is good practice to build a database of prices from several priced bills and to examine critically the range of variation between these prices, establishing the underlying reasons and the relationships between the net cost of the main components. This helps develop an instinct for forecasting the total cost of small projects, a process that enables quantity surveyors to acquire a sense of building prices and build up expert intuition (Flinn, 2009). The remaining sections of the paper present the conceptual/theoretical framework (Section 2.0), methodology (Section 3.0), results (Section 4.0), discussion (Section 5.0), and conclusions (Section 6.0).

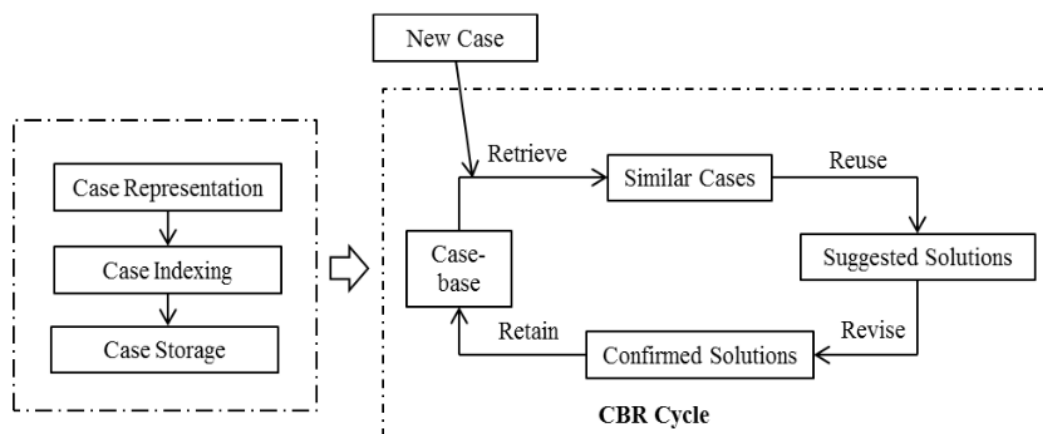
## **CONCEPTUAL/THEORETICAL FRAMEWORK**

### **Case-based reasoning**

Case-based reasoning is a problem-solving technique that mines established experience and knowledge to provide solutions to new problems/situations on the basic assumption that the solution of a problem in the database is close (or “similar”) to the unknown solution of the new problem (Uysal & Sonmez, 2023). Typically, a reasoner remembers a previous situation similar to the current one and uses that to solve the new problem. The four-step CBR cycle, which includes case retrieval, case reuse, case revision, and case retention (Li, Paraschiv, & Sermpinis, 2022) assumes case bases (Figure 1). Against the backdrop of this assumption, an important first step in any CBR system is the development of “case bases” (case knowledge), which is the collection (case representation), characterisation, and storage of cases. Case bases describe the database of similar solutions from which a potential new solution can be drawn or suggested. Due to their immense significance, some researchers have argued that the most crucial task prior to implementing CBR is establishing case bases (Wang, Lin, and Zhang, 2022; Markatou et al., 2012). Compared to many rule-based knowledge systems for cost estimating, CBR is now generally preferred (Ayhan & Tokdemir, 2019; Ozorhon et al., 2006; Virulkar, 2004). This is not only because CBR is easy to use (because of its reasoning by analogy), but also because its experience-oriented nature allows practitioners to address issues by referencing their accumulated professional experience and knowledge, an attribute which



makes it particularly useful in preliminary cost estimating (Xiao, 2020; Mohammed et al., 2018; Brown & Gupta, 1994).



*Figure 1: Case-based reasoning process*

*Adapted from Aamodt and Plaza (1994) and Watson and Marir (1994)*

### **Cost analysis for case-based reasoning**

In the practice of quantity surveying, bills of quantities are widely recognised as historical databases of price information for estimating the cost of similar future projects, particularly those that were organised based on the rules of Standard Methods of Measurement (SMM) (Davis et al., 2009; Nani & Adjei-Kumi, 2007; Ashworth & Hogg, 2007). Because they follow specific rules of measurement and format, SMM-based bills of quantities provide a storehouse of information, albeit uncharacterized. To characterise them, cost analysis is useful.

Cost analysis is the “systematic breakdown of cost data to facilitate examination and comparison” (Seeley, 1996, p. 211). Among other things, cost analysis helps reveal “how costs of a building are distributed over elements and groups of elements” (Seeley, 1996, p. 212), permitting not only a detailed comparison of the costs of different projects but also the costs of the same elements/trades in different building projects. From a cost accounting point of view, cost analysis helps in the identification of cost drivers/centres (Xiao, 2020; Elmousalami, Elyamany & Ibrahim, 2017; Chicoca & Utomo, 2019; Gupta & Debnath, 2022), that is, those cost elements/factors that have significant impact on total cost (Blocher, Stout & Cokins, 2010).

While no two buildings are the same, and the cost of one (building) project may vary significantly from another for various reasons design, constructional, locational, contractual and administrative in principle, every component of the *General Summary* of costs in any bill



of quantities, and the cost of each work section of the *Summary* of the measured works, represent a certain proportion/percentage of the estimated project value or contract sum. This general characteristic of bills of quantities conforms to the Component Unit Pricing theory (Cattel, 2012) and Proust's law of definite proportions, as well as its extension, the law of multiple proportions.

The component unit pricing theory (Cattell, 2012) suggests that the overall price of an item can be distributed among its constituent components. Cattell (2012) used the component unit price theory to show that different distributions of mark-up among the items of a project, for example, produce different levels of reward. This paper argues that, by extension, the total cost of a new building can be broken down into the costs of the different work sections/components as presented in a priced bill of quantities. In other words, the cost of every work section or component can be expressed as a proportion or percentage of the total cost.

Proust's law, which finds application in stoichiometry in chemistry, posits that, when elements combine to form compounds, they do so in specific, well-defined proportions, rather than in just any proportion. It states that a given chemical compound always contains its component elements in a fixed ratio (by mass), irrespective of source, method of preparation, or any other factor. The law is based on the fact that an atom of a particular element is the same as any other atom of that element; that an atom of oxygen is the same, whether it comes from silica or oxygen in the air. Useful though it was to the foundation of modern chemistry, the law of definite proportions was found not to be sufficient (i.e., universally true) because there exist compounds whose elemental composition can vary from sample to sample. Such compounds follow the law of multiple proportions – a law proposed by Dalton, which states that when elements combine, they do so in simple whole-number ratios (Masterton & Hurley, 2011). In addition, in the case of isotopes, the composition of an element can vary depending on its source; hence, its contribution to the mass of even a pure stoichiometric compound may vary. As an extension of the law of definite proportions, therefore, the law of multiple proportions posits that even though elements combine to form compounds in defined proportions, this is not necessarily linear; the proportions may vary, albeit in proportion, with due regard to source and other factors.

Following logically from the law of multiple proportions, this paper argues that, as a proportion (or percentage) of the estimated project value/cost, the different components of the general summary of costs for any new building measured based on SMM, will always be in a certain definite proportion, though not linearly. These proportions represent the characteristic features of specific project cases that are critical to CBR. The supposition is that the cost of the different components or sections in a typical work section bill of quantities will always be within a specific fixed percentage range of the total cost, within a certain margin of error. Theoretically, given a statistically significant sample of buildings of a particular similar characteristic, for purposes of preparing preliminary estimates, each component of cost or work section represents a certain fixed percentage of the total cost. This can be established through cost analysis.



Fragkakis and Lambropoulos (2004) collected actual cost information from a sample of 119 concrete bridges and overpasses constructed between 1999 and 2003 as part of the Egnatia Motorway in Greece. The study divided the actual bridge construction cost into five elements: earthworks, foundation, substructure, superstructure, and accessories, and concluded that the average cost percentages for these elements are 4.70%, 26.70%, 15.90%, 34.40%, and 18.30%, respectively. Menn (1990) used a small sample of 19 motorway bridges built in Switzerland between 1958 and 1985 to investigate the cost of prestressed concrete bridges. Breaking down the costs of the bridge into four components, mobilisation, substructure, superstructure, and accessories, the study concluded that the contribution of each of these components to the total bridge construction cost is 8.00%, 23.50%, 54.50%, and 14.00%, respectively. Such a breakdown produces a cost profile that highlights the major cost components and, therefore, the cost drivers for action. For case-based reasoning, this breakdown helps provide a comprehensive understanding of the costs of different components/elements of a building, serving as a basis for making ‘over-the-head’ decisions quickly and with reasonable accuracy. In preliminary cost estimating, cost analysis provides a means of establishing case knowledge for such quick decisions.

### **Structure of work section bill of quantities**

As a source of historical cost data, bills of quantities present a detailed and structured breakdown of the costs of different items, elements and/or work sections in a project such that the sum of the different parts/components establishes the total cost of the building. By content, all BoQs, irrespective of format, will contain some, or all, of the following items: (1) Preambles, (2) Preliminaries, (3) Measured quantities/works, (4) Prime Cost Sums, (5) Provisional Sums, and (6) Contingency Sums. *Preambles* are generally a preface or introduction to the bill, and do not contain priceable items (Kodikara, Thorpe & McCaffer, 1993). In terms of cost representation, therefore, preambles are not counted. *Preliminaries* on the other hand, cover items in the preliminary section of a contract ISO 6707-2:2014; ISO 6707-2:2017), and refers to that part of a bill of quantities or specification that describes not the work itself, but associated matters such as site use and facilities, access to site, security, supervision, health and safety requirements, temporary accommodation, insurance, and attendance on employer’s staff (ISO 6707-2:1993; ISO 6707-2:2017; Kodikara, Thorpe & McCaffer, 1993).

The *measured (or main)* works refer to the priceable items identified by sections based on the SMM and represent both the direct costs of materials, labour, plant, and subcontractors, as well as the associated indirect costs of executing and completing those works. While some variations exist between SMM5 and SMM7 in the identification/classification of measured work by work sections, typical examples include substructure/groundworks, concrete/reinforced concrete works, masonry/blockwork, finishing works, plumbing installations, electrical installations, and external works. In the total system of the estimated cost of a building, measured works consist of the collection of costs for specific work sections in the bill of quantities, which are then summarised across various work sections of the project.



*Provisional sums*, which may be defined or undefined (Chan & Kumaraswamy, 1997), refer to works for which the full extent and character cannot be determined precisely at the time when the bill of quantities is prepared (Seeley, 1997), and include, for example, work or services to be executed by a statutory authority. *Prime Cost (PC)* sums cover aspects of work usually undertaken by specialist contractors (Seneviratne, Arar & Hakim, 2016) while *Contingency Sum* refers to the amount of money added to the base budget to account for work that is difficult or impossible to identify at an early stage of the project life cycle (Tseng, Zhao & Fu, 2009). ISO 6707-2 defines contingency sum as a sum of money budgeted for or included in a contract to cover construction work that may be required but cannot be foreseen or predicted with certainty. It differs from provisional sums, which can be anticipated but cannot be accurately specified at the time the tender documents are issued (ISO 6702-2:1993). In a typical work section bill of quantities, the sum of the different parts/components described above is aggregated in a *General Summary* section of the bill to determine the total or detailed estimated cost of the building.

### **Accuracy of preliminary cost estimates**

Distinguished from a detailed /definitive estimate, a preliminary estimate may variously be described as a feasibility estimate, a conceptual estimate, an early-stage estimate, an order-of-magnitude estimate, or a budget estimate (Ashworth & Perera, 2015; PMI, 2016; RICS, 2012; AACE, 2022; Castro Miranda et al., 2022). They refer to estimates prepared at the feasibility or conceptual stages of a building project, when only outline, conceptual, or sketch designs are usually available. The quality of preliminary cost estimates (degree of accuracy), measured in terms of the consistency between estimated and actual values, however, largely depends on the amount of project information available and/or required to produce the estimate (AACE, 2021, 2022). For example, where sketch designs are available for establishing floor areas, the floor area method may provide accuracy ranging from -15% to +25% (Abourizk, Babey, & Karumanasseri, 2008; Ashworth, 2008). Figure 2 summarises the degree of accuracy/approximation (uncertainty) associated with estimates at various stages of project development, defined in terms of the available project information. It shows that the margin of error associated with estimates in general can range from +/- 40% at the feasibility stages to +/-5% at the tender stage.

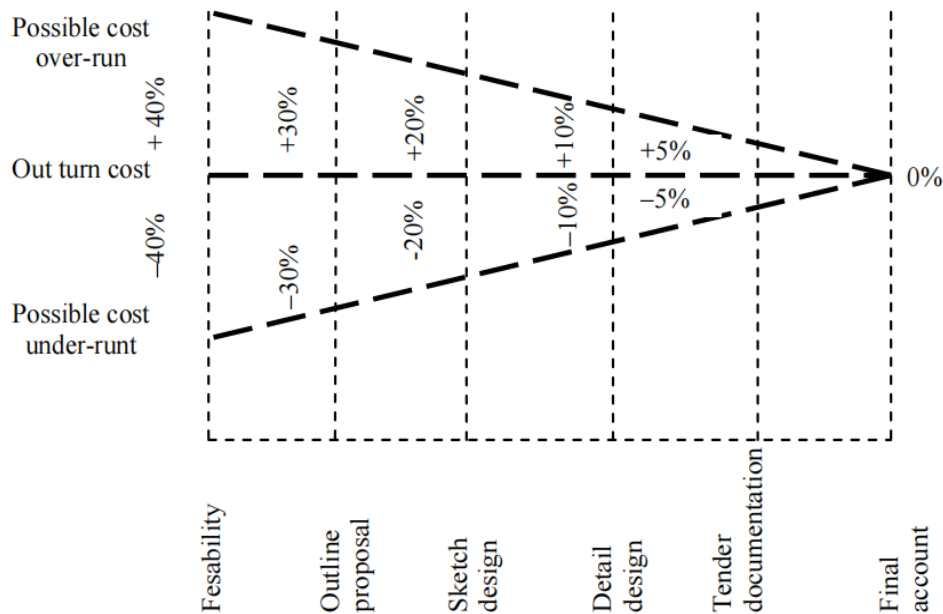


Figure 2: Degree of uncertainty for a construction project (Anthonie, 2009)

In the class categorisation of cost estimates by the American Association of Cost Engineers (ACostE) in the UK, and the American National Standard Institute (ANSI), preliminary estimates refer to estimates used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval (AACE, 2022). At this stage, project definition typically falls within the range of 0-2% (with an accuracy of -30 to 50%) to a project definition of 10-40% (with a level of accuracy of -15 to +30%). A preliminary estimate may thus be primarily conceived as an order-of-magnitude estimate with a project definition level of 0 to 40% and an accuracy of  $\pm 40$  to  $\pm 30$  %.

## RESEARCH METHODS

This section presents details of the methods followed in this study. It describes the research design, research data and method of collecting the data. It also presents data cleaning and analysis processes.

### Design and data

The study employs quantitative research design, utilising bills of quantities as the primary source of data. Cost data from bills of quantities for public building projects from 1990 to 2022 were collected and analysed. The bills were obtained from public institutions in Cape Coast and Takoradi. Contract values/sums (and not final project account figures) were used in the analysis. Purpose-designed, self-reported data sheets were used to collect the data. Due to differences in the arrangement of works by sections in the SMM5 and SMM7-based BoQ,

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separate data sheets were used. The basic information collected includes project characteristics, specifically the building type and the year of project execution, as well as cost summaries, namely the General Summary and Summary of the measured works (or main works).

Given the high possibility of variability in the dataset, it was considered to use as large a sample as possible. This is because while larger samples may be prone to outlier effects, they produce means that approximate the average of the whole population, consistent with the Law of Large Numbers (Douglas, 2015). In all, 428 bills of quantities were collected and analysed. For consistency within and similarity of the dataset, 61 bills were rejected for various departures. The selected bills of quantities consisted of new works (i.e., type of project) that were single-storey buildings (building type) located in the Western and Central Regions of Ghana (project location) and administered using a lump sum contract based on firm bills of quantities (contract type) following SMM5 and SMM7 (standards of measurement). Of the remaining 367, three hundred and nine (309) bills were based on SMM5, representing 84.2% of the data, while the remaining fifty-eight (58) were based on SMM7, representing 15.8%. Although the SMM7 bills of quantities are relatively low, they were considered necessary for purposes of comparison and triangulation.

### **Data cleaning and analysis**

The resulting data were first prepared/organised using a Microsoft Excel spreadsheet. This involved coding the costs of the different components/work sections identified in the general summary and the project cost summary. These were then converted into percentages. From this point, Stata – a general-purpose statistical software package – was used to analyse the data. To ensure the quality of the data for analysis, the data were subjected to cleaning in Stata. This involved dealing with missing values and outliers in the dataset. Missing data refers to valid omitted values on one or more variables that are not available for analysis (Bannon Jr, 2015). Like all other studies, missing data should be adequately handled by fixing or deleting error values before analysis (Hair et al., 2017, p. 48).

Case deletion, a widely used method for handling missing values (Pallant, 2013), was employed in this study. The total percentage of missing values was approximately 8% in this study. Since the percentage of missing values was small, removing these cases was deemed to have little influence on this study. The next step in data cleaning involved dealing with outliers. Outliers are extreme values in a data set that are located far above or far below other values, significantly deviating from the mean (Pallant, 2013). While there is no single, reliable method for identifying outliers, it is common practice to detect outliers by determining an interval spanning the mean plus/minus three standard deviations (Howell et al., 1998; Leys et al., 2013). This study employed this method to identify and remove outliers from the dataset. After cleaning, the data were analysed descriptively using mean values with standard deviations, median, and interquartile range (IQR), as well as the maximum and minimum values.



## **RESULTS**

This section of the paper begins with a description of the sample characteristics used for the study, illustrating the distribution of projects by type and year. It is followed by an overview of the breakdown of costs by work sections as provided for in SMM5 and SMM7. The presentation of the General Summary cost breakdown for both Standards then follows, along with the detailed cost breakdown by work sections. The results section ends with a summary of key findings.

### **Sample characteristics**

Table 1 presents the distribution of the projects by building type for both the SMM5- and SMM7-based bills of quantities. It categorises the buildings by function into eight classes, namely schools (typically classroom blocks), health facilities (such as CHPS compounds), residential units, sanitary facilities, offices, service amenities, commercial buildings, and others (including rest stops, market stores, etc.). For projects based on SMM5, school buildings represent 40% of the total sample, followed by the sanitary facilities and the multi-purpose buildings (with 13.8% each).



Table 1: Distribution of projects by building type

Class	Building Type	Unit scope	N	
			SMM 5	SMM7
1	Schools	1No. 3-Unit classroom blocks 1No. 4-Unit 1No. 6-Unit 1No. 7-Unit 1No. 12-Unit 1No. 14-Unit 1No. 18-Unit KG Block	125	11
2	Health facilities	CHPS Compound Hospitals Clinics Dispensary	35	13
3	Residences/ Police station	Staff quarters Bungalow Houses Police Stations	34	9
4	Sanitary facilities	2-Seater WC 3-Seater WC 4-Seater WC 5-Seater WC 6-Seater WC 8-Seater WC 12-Seater WC 14-Seater WC Lavatory KVIP 2-Bay Urinal 4-Bay Urinal	43	11
5	Offices	Office blocks Administration blocks	14	-
6	Multi-purpose buildings blocks	ICT block library complex, ICT centre/ block, training centres, dormitory block, science block, assembly hall, theater, demonstration blocks, computer labs, arrival hall, workshops, kitchen and assembly halls, mortuary	43	12
7	Commercial buildings	Market complex, shops, stores	14	2
8	Others	Rest stops, bus terminals, parking lots, church	8	-
<b>Total</b>			<b>309</b>	<b>58</b>

Source: Field Survey, 2023



Similarly, Table 2 presents the distribution of projects according to the period during which they were executed, as well as the standard (SMMs) used. The data is significant because it speaks to the prevalence of SMM5 and SMM7 for public sector building projects in Ghana. It is noted, as Nani and Adjei-Kumi (2007) observe, that in Ghana, the 5th edition of the Standard Method of Measurement (SMM5) remained the most widely used SMM until July 2007, when the Ghana Institution of Surveyors (GhIS) directed all its members to use SMM7. This directive notwithstanding, the Table shows that for public building projects, SMM5 is still very much used, representing 73% of the total projects between 2016 and 2022. This gives a cost analysis based on SMM5.

*Table 2: Distribution of projects by year of execution*

Period	N	SMM5	SMM7
1995-2000	51	-	-
2001-2005	7	-	-
2006-2010	17	2	1
2011-2015	85	45	10
2016-2020	135	10	58
2021-2022	14		
<b>Total</b>	<b>309</b>		

*Source: Field Survey, 2023*

### **Elements of cost in a typical SMM-based work section bill of quantities**

Like any cost classification, the elements/components of cost in any typical work section bill of quantities include the cost of the measured works (direct cost) and project allowances (indirect costs). For the SMM5 bill of quantities studied, the measured works for new works identified consist of Substructure, Concrete works, Block work, Roofing, Carpentry, Joinery, Metal work, Walls, floor and ceiling finishing, Plumbing installation, Electrical installation, Glazing, Painting and decorating, and External works.

In the SMM7, there are a few modifications to these labels and classifications. For example, substructure is referred to as Groundworks, while concrete work is classified as in-situ/Large precast concrete. In SMM5, blockwork is categorised as Masonry works, whereas in SMM7, it is classified as Masonry works. Plumbing installations in SMM5 are divided into Disposal systems and Piped Supply Systems in SMM7, while External works in SMM5 are identified as Pavings/Plantings/Fencing in SMM7.

The identified elements of cost however include Groundwork, In-Situ Concrete, Masonry, Structural Carcassing, Cladding/Covering, Waterproofing, Lining/Sheathing, Windows/Doors, Finishes, Furniture/Equipment, Building Fabric/ Sundries, Disposal Systems, Piped Supply Systems, Mechanical Heating/ Cooling, Ventilation /AC, Electrical Supply, and Mechanical/Electrical Systems. The two work sections/elements not included were Pavings/Plantings/Fencing and Communication/Security, as well as Transport Systems. In

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terms of project allowances, the study identified Preliminaries, Provisional Sum (undefined) and Contingency Sum as elements in both the SMM5 and SMM7 bills of quantities studied. In addition to this, the SMM5 bills of quantities had provisions, albeit a few, for Consultancy Fee, Insurance and Fluctuation.

### **Distribution of total project cost (General Summary)**

Tables 3 and 4 present the distribution of total project cost as captured in the General Summary in the SMM5 and SMM7 bills of quantities, respectively. These are discussed in the sections that follow.

*Table 3: Distribution of total costs of new buildings (SMM5)*

<b>Variables</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Median</b>	<b>IQR</b>	<b>Min</b>	<b>Max</b>
%Preliminaries	309	6.124166	2.064578	5.883896	2.846345	2.047056	10.83381
%Measured	309	84.11203	7.951243	84.99611	12.73645	65.16389	95.97907
%External Works	126	11.91844	5.485543	11.41919	7.44585	5.019706	30.7331
%Contingency	130	7.110157	3.819393	9.090906	5.776941	0.261238	16.63082
%Insurance	30	2.612897	2.409204	1.848713	3.209355	0.210804	8.086069
%Consultancy Fee	62	8.253276	2.694621	7.736524	2.286701	2.238038	16.16613
%Provisional Sum	48	11.85229	6.386442	11.1021	9.724736	1.427889	25.96378
%Fluctuations	29	9.485232	4.51209	8.840157	4.971269	3.990581	22.48647

*Table 4: Distribution of the total cost of new building projects (SMM7)*

<b>Variables</b>	<b>N</b>	<b>mean</b>	<b>SD</b>	<b>median</b>	<b>IQR</b>	<b>minimum</b>	<b>maximum</b>
%Preliminaries	48	6.280824	2.564634	6.731204	4.438738	1.068426	11.80966
%Measured works	38	78.46638	9.868511	77.62161	10.26195	44.61866	90.90909
%External work	28	12.62214	4.605843	14.36528	3.50653	1.135026	16.37662
%Contingency	11	8.900661	1.608043	9.090909	1.09006	4.574971	11.51216
%Provisional Sum	2	2.153513	0.269672	2.153513	0.381374	1.962826	2.344199

#### *Preliminaries*

In the SMM5 dataset (N=309), Table 1 shows that, expressed as a percentage, preliminaries constitute on average, 6.12% (SD=2.1) of the cost of the works (grand total cost). This value is not significantly different from the median value of 5.88 percent and compares well with the distribution in SMM7 with a mean of 6.3 percent (SD= 2.6). Thus, taken broadly, the preliminary component of the cost of new building projects can be estimated to be



approximately 6 percent (SD=2) even though this can be as low as 2% and as high as 10%.

#### *Measured/Main Works*

Table 3 shows that in the SMM5 dataset, the measured works can constitute on average, 84.11% (SD=7.95) of the works and a median percentage is 84.99 even though the data shows that this can range between about 65 to 95 percent. In the SMM7 dataset, however, these values are less by almost 6 percent compared to the mean (78.45 with SD=9.86).

#### *External Works*

Table 2 shows that in the SMM5 dataset, external works constitute 11.42 percent of total cost at the median, and 11.92 at the mean with a standard deviation of 5.49. Values may, however, range from as low as 5 percent to as high as 31 percent. In the SMM7 dataset, the mean percentage external works is 12.62 (SD=4.61) with a median of 14.36 percent and ranging from 1 to 16 percent. Though surprising to find external works as a separate component of the general summary in SMM7-based bill of quantities, it indicates as Nani et al. (2007) found that to fit purpose, quantity surveyors in Ghana use the different SMMs in combination of modifications. Overall, the results show that as a percentage of the total cost, external works represent approximately 11 percent.

#### *Provisional Sums*

From Table 1, Provisional Sum represents on average 11.85 percent (SD=6.39) of total cost with a median of 11.1 percent and could range from 1% to approximately 26%. This observation is consistent with some literature findings. In Nigeria, Okuwoga (1998) found that provisional sums make up about 25% of the contract sum. Similarly, the maximum percentage recommended by most survey and interview respondents in the United Arab Emirates for contracts based on FIDIC Redbook was 20% (Seneviratne, Arar and Hakim, 2016).

#### *Contingency Sum*

Table 3 shows that in the SMM5 dataset (N=130), the median allowance for contingency as a percentage of total cost is 9.1 percent with a mean of 7.11 (SD=3.82) and can range from 2.6% to 16.6%. In the SMM7 dataset, the median and mean percentage allowances are 9.1 and 8.9 (SD=1.6) respectively but ranging from 4.5 to 11.5 percent. Gunhan and Arditi (2007) suggest allowing 10% across the entire project as a contingency allowance. Based on 48 road construction projects in Australia, Baccarini (2004) found that construction contingency was on average 5.24% of the contract value, while variations accounted for 9.92% of the contract sum.

The study concluded that because contingency was allowed to cater for project variations, 5.24% was inadequate. In another study, Otali and Odesola (2014) found that the percentage allowed for projects as contingency by consultants and contractors in Nigeria ranges between 5 and 20, averaging 10.4 %. Based on 61 project cases, Aibinu and Jagboro (2002) estimated the average project cost overrun to be 17.34%. Using this as a basis, the study argued and recommended that an allowance of 17.34% should be used to cater for contingencies in building projects, as opposed to the usual practice of 5% and 10% commonly applied in

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Nigeria, often based on intuition and isolated project experiences. This estimate was found to fall within the 15–20% allowance recommended by the United States Department of Energy (DOE) for budget estimates of new buildings (Aibinu & Jagboro, 2002).

### Other project allowances

While insurance, consultancy fee and fluctuations are not characteristic components of the general/grand summary of SMM7-based bills of quantities, in some SMM5-based BoQs, these are allowed for separately (N=30). Regarding insurance, Table 3 indicates that the median allowance for insurance as a percentage of the estimated contract sum is 1.8%, although the average is 2.6%. *Consultancy fee*, on the other hand, constitutes on average 8.2% (SD=2.7) with a median of 7.7% and this ranges between 2.2% and 16.2%. The mean percentage *fluctuations* according to the SMM5 dataset are 9.5 (SD=4.5; N=29), ranging between approximately 4% to 22%. The median percentage allowance for fluctuations on the other hand, is 8.8 percent.

### Distribution of measured works in a typical work section bill of quantities

Tables 5 and 6 below present the descriptive statistics for the distribution of the cost of different work sections as a percentage of the total measured works based on SMM5 and SMM7, respectively. In SMM5, these sections include Substructure, Concrete Works, Blockwork, Carpentry, Roofing, Joinery, Metal Works, Electrical Installation, Finishes, Plumbing Works, Glazing, and Painting/Decoration. SMM7, on the other hand, adopts the Common Arrangement of Work Sections (CAWS), and classifies the measured work into sections shown on page 6.

Table 5: Distribution of costs measured works (SMM5)

Variables	N	Mean	SD	Median	IQR	Min	Max
%Substructure	304	24.05248	4.765565	24.29027	7.560795	15.01502	32.86697
%Concrete work	307	11.25597	5.100292	9.619534	5.436755	6.518511	31.265
%Blockwork	309	9.914333	2.303603	9.447247	2.768315	6.526679	16.31201
%Carpentry	306	6.678959	1.942733	6.264069	2.829907	4.006009	12.49881
%Roofing	303	10.48446	2.47919	10.33553	4.027348	6.042452	15.42817
%Joinery	305	8.45294	2.407085	8.229031	3.31049	5.010317	15.48849
%Metal work	269	3.773774	2.438475	3.172752	2.547851	0.3013959	16.03645
%Electrical Installation	304	4.272483	1.829742	4.018796	2.911639	1.008202	8.861345
%Finishes	308	12.85761	3.114254	13.10652	4.651036	5.591474	17.83828
%Plumbing work	187	4.053166	2.163441	3.639042	2.374291	1.013912	10.79999
%Glazing	209	2.513637	1.170337	2.185441	1.37588	1.008701	8.462704
%Painting/Decor	304	4.455298	1.189224	4.352211	1.934143	2.604285	6.85439



*Substructure/ groundworks*

Table 5 shows that in the SMM5 dataset (N=304), the Substructure constitutes on average 24.05 percent of the measured works (SD=4.76) and can range from 15% to 32.86%. The median value in this respect is 24.29%. In the SMM7 dataset, where substructure is referred to as Groundwork, the mean cost of groundwork as a percentage of the measured works is 24.17 (SD=3.71) with a median value of 24.89%.

*Concrete work/ In situ Concrete*

In the SMM5 dataset (N=304) as presented in Table 5, Concrete work constitutes on average 11.26 percent of the measured works (SD=5.1, N=307), and could range from 6.5% to 31.3%, with a median of 9.6%. In the SMM7 dataset, in-situ concrete represents a mean of 13.14% (N=41, SD=7.4) with the median at 10.5%.

*Table 6: Distribution of the costs measured works (SMM7)*

<b>Variables</b>	<b>N</b>	<b>mean</b>	<b>SD</b>	<b>median</b>	<b>IQR</b>	<b>minimum</b>	<b>maximum</b>
%Groundwork	37	24.16833	3.705107	24.88938	5.077345	16.29207	30.32272
%In-Situ Concrete	41	13.13769	7.356539	10.4901	8.967712	6.545306	29.43897
%Masonry	45	11.01692	2.11282	11.19647	2.25027	6.576209	15.78737
%Structural Carcassing	42	7.701671	1.995909	8.026378	2.746221	4.225688	11.80668
%Cladding/Covering	33	10.5805	1.738053	10.9987	2.709462	6.524805	13.061
%Waterproofing	10	1.683936	1.467058	0.88388	2.289158	0.295456	4.299503
% Lining/Sheathing	39	3.295955	1.399691	3.001365	1.696075	1.234942	6.790211
%Windows/Doors	44	7.633422	2.084401	7.332971	2.808948	4.170869	12.49334
%Surface Finishes	51	15.30844	4.963987	15.24699	8.578595	6.193144	22.21883
%Furniture/Equipment	40	4.143374	2.644247	3.255893	1.336122	1.352236	13.96649
%Building Fabric/ Sundries	23	1.709413	1.133922	1.268243	1.645501	0.5096407	4.536686
%Pavings/Plantings/ Fencing	-	-	-	-	-	-	-
%Disposal Systems	7	3.539815	1.227039	3.505317	2.233424	2.264677	5.390571
%Piped Supply Systems	12	3.599735	1.569351	3.619489	2.541345	0.7739774	5.483709
%Mechanical Heating/ Cooling	2	4.472062	5.990403	4.472062	8.471709	0.2362074	8.707917
%Ventilation /AC	5	3.611619	1.507477	3.319672	1.093094	2.154392	6.067983
%Electrical Supply	22	6.900849	3.77259	7.085181	7.500875	1.414627	12.24423
%Communication/ Security							
%Transport Systems							



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%Mechanical/Electrical	18	3.892761	2.607676	2.819309	3.788718	1.077196	9.296886
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### *Blockwork/Masonry*

Table 5 shows that in the SMM5 dataset (N=304), the Blockwork constitutes on average 9.9 percent of the measured works (SD=2.3) and can range from 6.52% to 16.31% with a median value of 9.44%. In the SMM7 dataset, Masonry is on average 11.02 percent of the measured (SD=2.11) and a median value of 11.2%.

### *4.3.4 Carpentry/ Structural Carcassing/Timber*

Concerning Carpentry, Table 5 shows that in the SMM5 dataset (N=306), this constitutes on average 6.68 percent of the measured works (SD=1.9) with a median value of 6.3% and can range from 4.0% to 12.5%. In the SMM7 dataset, Carpentry which is referred to as Structural Carcassing/Metal/Timber constitutes an average of 7.7 percent of the measured (SD=2.11) with a median 8.0% and ranging from 4.2% to 11.8%.

### *Roofing/ Cladding/Covering*

Table 5 shows that in the SMM5 dataset (N=303), Roofing constitutes on average 10.48 percent of the measured works (SD=2.5) with a median value of 10.3% and can range from 6.04% to 15.43%. In the SMM7, Roofing is referred to as Cladding/Covering and constitutes an average of 10.58 percent of the measured (SD=1.7) with a median 10.99% and ranging from 6.5% to 13.06%.

### *Joinery*

With respect to Joinery, Table 5 shows that in the SMM5 dataset (N=305), this constitutes on average 8.4% percent of the measured works (SD=2.4) with a median value of 8.2% and can range from 5.0% to 15.4%. In the SMM7 dataset, Joinery, which is captured as Windows/ Doors constitute an average of 7.6 percent of the measured (SD=2.08) with a median 7.3% and ranging between 4.1% and 12.5%.

### *Metal work*

Table 5 shows that in the SMM5 dataset, Metalwork constitutes on average 3.77 percent of the measured works (SD=2.41, N=269) with a median value of 3.17% and can range from 0.30% to 16.03%. In SMM7, Metalwork is measured under Structural Carcassing/Metal/Timber.

### *Electrical Installations*

Table 5 shows that in the SMM5 dataset (N=304), Electrical Installation constitutes on average 4.27% percent of the measured works (SD=1.8) with a median value of 4.0% and ranging between 1.01% and 8.86%. In the SMM7 dataset, Electrical Installations is dispersed in different work sections including Electrical Supply, Mechanical Heating/Cooling, Ventilation/Air-Conditioning, Communication/ Security, etc.



*Finishing works (wall, floor, and ceiling finishes)*

Table 5 shows that in the SMM5 dataset (N=308), Finishing works constitutes on average 12.86% percent of the measured works (SD=3.11) with a median value of 13.1%, and this can range from 5.59% and 17.83%. In the SMM7 dataset, Finishing constitutes on average 15.3% (SD=4.96, N=51), with a median of 15.2% and ranging between 6.19 to 22.2% of the total cost of measured works.

**Summary of findings**

The summary of findings from the study can be presented as in Tables 7a and 7b. This is further discussed in Section 5. It provides an overview of the main cost drivers/centres in a typical work section bill of quantities as well as a summary distribution of project allowances.

*Table 7a: Cost centres of new building works (measured works)*

Work Section	SMM5		SMM7	
	Mean	Median	Mean	Median
Substructure / Groundworks	24.05	24.29	24.16	24.88
Finishing works	12.86	13.11	15.31	15.25
Concrete work/ In situ concrete	11.26	9.61	13.14	10.45
Roofing /Cladding/Covering	10.48	10.33	10.58	10.99
Blockwork /Masonry	9.91	9.44	11.02	11.20

*Table 7b: Cost drivers in a typical work section bill of quantities (estimated contract sum)*

Project allowance	SMM5		SMM7	
	Mean	Median	Mean	Median
Provisional Sum	11.85	11.10	2.15	2.15
Contingency Sum	7.11	9.10	8.90	9.1
Preliminaries	6.12	5.88	6.28	6.73
Consultancy fee	8.2	7.7		
Fluctuations	9.4	8.8		
Insurance	2.6	1.8		

**DISCUSSION**

**Direct costs (measured works) drivers in new building projects**

It is worth reiterating that in preliminary estimating, the unit rate adopted represents the direct cost of materials, labour, plant, and subcontractors, as well as their associated on-costs. This is known as measured work. In terms of the measured works, Table 7a shows that, based on both mean and median values, the five key cost drivers in a typical SMM5 work section bill of quantities, in decreasing order of (approximate) magnitude are: substructure (24%), finishing (13%), concrete works (11%), roofing (10.5%) and blockwork (10%). In the SMM7 bill of



quantities, this order is slightly different and consists of groundworks (24.5%), finishing (15%), masonry (11.2%), cladding and covering (10.99%) followed by in situ concrete (10.45%). Thus, for both SMM5 and SMM7 bills of quantities, the substructure/groundworks and finishing (or surface finishes) constitute the two key cost drivers in new building works. Finishing seems particularly significant, as corroborated by Ji et al. (2008), who developed a cost database for finish work to enhance the efficiency and productivity of cost estimation in Korea, utilising building cost data from 90 public apartment buildings. In both SMM5 and SMM7, surface finishes cover the range of subsequent work carried out after ground and structural construction and include finishing to walls, floors, and ceiling.

### **Project allowances**

In preliminary estimating, the unit rates exclude the main contractor's preliminaries and other allowances, such as professional/consultancy fees, contingency allowances, and escalation/fluctuations. These items are assessed separately and added to the estimate. Table 7b above shows that for public building projects based on SMM5, the mean and median provisional sums may hover around 11%, with contingency and preliminaries at approximately 9% and 6%, respectively. Consultancy or professional fees, on the other hand, may be at 8% even though this can reach a maximum of 16% in SMM5 projects, where these were observed as project allowances. It is worth noting from Table 7b that, unlike in SMM5, consultancy fees, fluctuations, and insurance are not observed in SMM7, presumably due to differences in the classification and organisation of work sections.

Hoboabu and Nani (2018) observe that SMM5 and SMM7 are both applied at the discretion of users, resulting in wide variations in the provisions of bills of quantities across the nation. This is particularly so for SMM5 (Adjei-Kumi & Nani, 2006) and the revealing of changing practices due to improvements in the standard classification of works. For example, in SMM7, the consultancy fee is incorporated into the mark-up percentage applied to measured works. At the same time, fluctuations and insurance are covered through various provisions in the Conditions of Contract. Improved measurement of works may also explain the relatively low percentage of provisional sum in the SMM7-based bills of quantities of approximately 2%. This is because defined professional sums are billed under the appropriate work section, which represents the nature of work to be executed. An undefined provisional sum is given in the summary at the end of the bill of quantities (Hoboabu & Nani, 2018). It is also admissible that in SMM7, some provisional sums are included as contingency sums. According to Ross and Williams (2013), provisional sums can also be included in the contract as contingency for the unexpected works. Preliminaries are, however, approximately equal 6% for projects based on both SMM5 and SMM7.



## CONCLUSION

Traditionally, quantity surveyors and construction cost experts leverage their experience of similar past projects in preparing preliminary cost estimates to determine unit cost data over which project allowances are applied. Even though the practice is often based on intuitive judgment, as a form of *a priori* knowledge, it is helpful as a form of case-based reasoning. This study grounds the practice in theory and the case-based reasoning methodological framework. Given that the effectiveness of case-based reasoning depends on the quality of case knowledge (or the databases of cases), the study sought to provide, through a cost analysis of historical bill of quantities data for new public building projects in Ghana, case knowledge for case-based reasoning. Within an accuracy range of  $\pm 40\%$  (typically at the feasibility stage) to a margin of error between  $-15\%$  and  $+25\%$  when sketch designs are available, the study's results are consistent with the existing literature and serve as a valuable case for knowledge-based reasoning in preliminary cost estimating. In terms of measured works (direct costs), substructure works and finishing works (including walls, floors, and ceilings) are the two critical drivers of cost, in order of significance. While concreterwork and roofing follow in order in the SMM5 bill of quantities, masonry and cladding and covering take third and fourth place, respectively, in the SMM7 bill of quantities. The differences can be attributed essentially to modifications in the organisation of the work sections in the two standards.

The paper grounds an otherwise useful but intuitive practice in theory and empirical evidence, thereby providing an empirical basis for effective case-based reasoning in preliminary cost estimating. Practically, the paper provides insight into the cost profile of new building projects based on lump sum contracts and hence, the identification of cost centres or cost-significant items by work sections (or elements). This serves as a benchmark for quick evaluation of priced tenders, particularly for project allowances. Given the multiplicity of factors that affect the cost of buildings, the conclusions of this study are limited to building projects with characteristics similar to those of this study. Further analysis of the data, using predictive analytics for example, within and between different categories of building types, can provide greater insights as case bases for more effective case-based reasoning. Given the cost significance of work sections (elements) such as finishes, specific cost models can be developed for these elements and compared against building types, including schools, health facilities, residential units, offices, and sanitary facilities.

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