Journal of Engineering, Project, and Production Management
2021, 11(1), 52-60

Bill of Material and Labour Template for Construction Information Management

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Project Management
Received April 29, 2020; revised June 14, 2020; June 19, 2020; accepted July 3, 2020
Available online August 23, 2020

Abstract: Information and Communication Technology advancement has made the method of practice across different industries and businesses record fundamental changes in various dimensions and levels. The construction industry is determined to measure up with other industries in this and has since embraced the use of computer software to perform most, if not all of its activities. It is generally known that this software is not cheap and they require special skill to use. This research study is aimed at developing a computerised template for material and labour schedules for some selected items of work in construction using Microsoft Excel. This is an inexpensive way of estimating to save cost while eliminating the traditional method. The study adopted a mixed research method that involved observation of labourers on-site and validation through a questionnaire survey. The personal observation was carried out and labour outputs were recorded which was used together with material constants in developing the bill of material and labour template. The template was validated by practising Quantity Surveyors for ongoing projects and an average of 92% accuracy was recorded. It was concluded that the template can enhance the accuracy of Quantity Surveyors' estimate of materials and labour for construction projects.

Keywords: Construction works, labour schedule, information and communication technology, material schedule, Microsoft Excel.

DOI 10.2478/jeppm-2021-0006

1. Introduction

It has been generally acknowledged that the Information and Communication Technology (ICT) has a great potential to improve professional services quality in the construction industry. Different reports have been carried out on the adoption of ICT in developed countries construction industries like Canada (Rivard, 2000; Rivard et al., 2004); Sweden, Denmark and Finland (Samuelson, 2002); the USA (Issa et al., 2003; Toole, 2003); New Zealand (Doherty, 1997), among others. The same cannot be said for developing countries (Oladapo, 2006; Alhasan et al., 2017). According to Rivard et al. (2004) and Usman et al. (2012) information play two vital roles in all construction projects: "…as the specification of the resulting product (design information) and the initiation and control of the activities required for constructing the facility (management information)." Oyewobi et al., (2015) are of the opinion that traditional means of communication is in use in the construction industry which include the exchange of documents (such as technical drawings, site instructions, specifications, etc) in paper form as well as face-to-face meetings. Today, various software packages developed commercially for the use of Quantity Surveyors (QS) exist among which are QSCad, MasterBill Elite, CATO Enterprise, Conquest, Valesco Estimating, Build Soft, RIPAC Estimating, WinQS, Snape, Workmate etc. This software is targeted at helping the quantity surveyor in preparation of bills, final accounts, valuations, cost planning, cost modelling, cost and tender analysis among others. Although, Ibironke et al. (2011) submitted that almost all professionals in the construction sector are of the opinion that ICT adoption in the work process can have a major impact on service delivery. It was also opined that it can improve the productivity of the professionals while enhancing the efficiency of work. It is generally known that this software is not cheap and easy to come by and also it requires special skills to use them (Agyekum et al., 2015). Mutesi and Kyakula (2011) stated that practising QSs in a reasonable number possess adequate computer literacy and have knowledge about the relevance of technology in the construction industry. However, they are not exploiting its usage to full capacity due to the cost of acquiring the technological systems needed (financial barrier).

In Nigeria today, preparation of the bill of material and labour (BOML) is still done traditionally and this practice is faced with many setbacks. This can be attributed to the high cost of procuring quantity surveying software. The bill of material and labour is an important part of contract documents in the construction industry. It is needed for proper procurement, monitoring and management of materials in any building project. It has been observed that preparing material and labour schedule involves calculations and a lot of paper works thereby giving room for the mistake of omission, errors as well as corrupt practices amongst many other problems. To this end, the set research question is "*Can an in-house template using Microsoft Excel be developed and adjusted for different jobs*". This will be an inexpensive way of estimating to save costs while eliminating the traditional method. This research work, therefore, intends to develop a template for BOML which will assist QSs to keep abreast of the trend in relevant technology that could improve service delivery. The electronic platform will make materials and labour easily quantified and priced within a little time frame and also ameliorate the errors often encountered during the traditional approach. This study will be beneficial to Quantity Surveyors by enabling the preparation of BOML with more accuracy thereby arriving at a precise estimated cost. The development of a BOML template will be of great help to clients as well given that it will ensure value for money is achieved while contractors and sub-contractors will be able to plan for a particular project to be carried out adequately. This is due to the fact that the materials needed can be procured on time while the required manpower can be forecasted.

2. ICT in the Construction Industry

ICT sudden acceleration has had important effects on market structures and procedures, while mainstream recognition and universal use of ICT has increased the dimensions of competitiveness not just within companies internationally but among local firms (Oyediran and Odusami, 2005). Across different sectors and markets, albeit at various stages, developments across ICT have rendered necessary profound improvements in the system of operations (Li et al., 2000; Agyekum et al., 2015). According to Betts (1999) and supported by Oyewobi et al., (2015), ICT also referred to as Information Technology (IT) is defined as "…a collection reference to the integration of computing technology and information processing." To level with their counterparts in other fields, the construction industry has adopted ICT usages such as the internet, networking, telephoning, satellite communication and online mailing to do the majority, if not all, of its operations (Ibidapo, 2000; Chan, 2013). The construction industry globally started utilizing computer and networking technologies during the 1990s. Ever since, it has been seen to be a critical resource in helping the industry deal with the growing complexities of its goods and the increasing demands of its clients and regulators (Betts, 1999; Oyewobi et al., 2015). It has also experienced an improvement in the competitiveness of building project execution and delivery (Liston et al., 2000; Agyekum et al., 2015).

The construction industry is currently undergoing a paradigm shift from conventional paper-based knowledge exchange to digital information exchange, which other sectors such as aircraft production and banking have followed and gained from long ago (Rivard et al., 2004). The ability of the Quantity Surveyors (QS) to take advantage of these changing possibilities provided by the introduction of IT depends on the implementation of modern technology (Castle, 2002; Ikediashi and Ogwueleka, 2016). Over the last decade, the QS profession has experienced major changes in the nature and form of services offered inside and beyond the construction industry (Smith, 2006; Oyewobi et al., 2015). These developments in the qualified QS came in because of the needs of both the design sector and the building customers. Fast track procurement which necessitates faster bill of quantities (BOQ) production as well as cost planning, value management, risk management, commercial management etc. are some of the QSs evolving positions needing ICT to be implemented (Cartlidge, 2006; Agyekum et al., 2015). With the alarming increase/rise in the use of ICT presently in the construction industry, QS has a vital role to play. This is because the QS deals with a lot of information from Architects, engineers and other members of the construction team. So, without a substantial level of knowledge in ICT, the QS would not be able to cope with the demands of these professional colleagues (Chan, 2013). Ikediashi and Ogwueleka, (2016) reported that there is a low level of computer literacy recorded among QSs in the construction industry. They further noted that there is a lack of comprehensive information technology usage by management and QS professionals alike. This, therefore, affects the services provided in the industry by QSs. According to Musa et al., (2010), the unavailability of infrastructural facilities is one of the major factors contributing to the low usage of ICT by QSs in the construction industry.

General features of quantity surveying software

In as much as the developers of quantity surveying software varies, some basic features are common to them since they are designed basically for the same purpose. Oluwakayode (2014) reported some of the aspects of quantity surveying activities aided by software which includes:

Cost planning

Most quantity surveying software allows the user to prepare automatic cost planning using various methods of cost planning available i.e. unit method, cubic method, superficial method, elemental method, approximate estimating method and analytical method, etc (Oyediran and Odusami, 2004; Ikediashi and Ogwueleka, 2016).

Estimating

Almost all the QS software developers have estimating modules in their packages either separately or as a package on its own and this makes estimating faster and easy.

Preparation of bills of quantities

These packages allow direct taking off into the computer. This reduces or eliminates the use of taking off a sheet or other taking off materials. In some programs, digitisers are used (Oladapo, 2006; Aiyetan, 2015).

Automatic squaring and working up

The computer does the squaring up of values and other working up activities automatically. With this, errors and unnecessary time-wasting activities are avoided (Musa et al., 2010).

Automatic bill drafting

Due to the use of the library for description and in some cases, old bill draft being available in the computer for use to prepare new ones, bill drafting becomes easier and less cumbersome and can be done alongside taking off so that as soon as taking off is completed, the BOQ is ready (Peansupap and Walker, 2005; Ikediashi and Ogwueleka, 2016).

Reporting in a different format of bill of quantities

Users can produce their BOQ in different formats as desired by the QS according to the dictate of the project, lines or other factors (Aiyetan, 2015; Oyewobi et al., 2015).

Valuation

As an extension of the BOQ programme, automated valuation is built into some packages since executed work items can be marked in the BOQ and computed by computer to monthly valuation using a specially designed valuation format (Oladapo, 2006; Ikediashi and Ogwueleka, 2016).

Final account

With the valuation reports being stored on the computer memory, the final account can be prepared easily having computed various data that needs to be added. While some developers create separate software for the final account, some include it as a module in the global package (Peansupap and Walker, 2005; Aiyetan, 2015).

3. Structure of a Bill of Materials and Labour

According to Technopedia (2020), the structure of a BOML can be single-level or multi-level. A single level BOML can be easily understood. However, it is not suitable for complex construction projects. In a single level BOML, an item of work in superstructure and substructure can be grouped together e.g. concrete works. This type of BOML, therefore, becomes unsuitable for large construction projects since there is no room for differentiating items of works that belongs to different elements of the construction project. This will make the BOML prone to errors of omission and miscalculation of values. A multi-level BOML is far more suited for medium and larger construction. It gives room for breaking the construction works into smaller units and each smaller unit into elements. This makes it possible for errors to be prevented and the tracking of elements becomes accurate. A single level BOML can be extracted from a multi-level BOML, but a multi-level BOML cannot be generated from a single level BOML (ROBO Design Solutions, 2020).

4. Research Method

Research design is a means of structuring investigations aimed at identifying variables and their relationship to one another. The mixed-methods, i.e., quantitative and qualitative methods, were used for this research work. According to Creswell and Creswell (2017), observations and document studies are the common methods that are used for collecting qualitative data. The population for this research was skilled and unskilled labourers who were observed as regards their labour outputs. Also, registered quantity surveyors were employed for the validation of the developed BOML. The BOML template to be developed was limited to concrete works, blockwork, reinforcement, roof timbers, painting, plastering and rendering. Therefore, three labourers for each of the selected items of work were observed as a case study for this research. These labourers were observed on three different construction projects which are a 5-bedroom duplex, a two-storey office block and a 1500-seater auditorium. Ten (10) practising quantity surveyors with a minimum of 10years of experience in the construction industry were employed in the validation of the template. A stratified and purposive sampling technique was used in selecting the labourers, this is because this sampling technique satisfies the principle of statistical regularity such that if on average the sample chosen from each stratum is picked systematically, then it would have the same composition and characteristics as of the universe. Labourers observed were selected systematically at the different construction sites as there is no actual designated location to reach them. Quantity surveyors, on the other hand, were purposely selected to ensure the validation is carried out by professionals with adequate practical knowledge as well as years of experience. The primary instrument used for data collection in this research was controlled observation. Controlled observation allows flexibility in probing insights and provides the observer with opportunities to make constant clarification. The observations were recorded. The recorded data were used for analysis using descriptive statistics. Confidentiality was assured to the labourers i.e. the personal information of the observed labourers did not exist in the report. The analysed data were used in developing the application server of the template. This information assists the template in carrying out the basic calculations needed to generate the values the users will work at the front end of the template.

System architecture

According to Technopedia (2020), this refers to "…the structures of the system which comprise software components, the externally visible properties of those components and the relationships among them." The template developed comprises of three components which are:

Front end

This is the interface between the user and the software. This is what the user sees when working with the software application. For this research, Microsoft excel is the front end.

Application server

This is the medium that provides the calculation processes logic and data access. The data obtained from observing the skilled and unskilled labourers were used in the calculation process for the template.

Back end

This is the database where all the data pertaining to the software are stored and, in this case, the system hard drive served as the back end.

Template structure

This section describes the overall structure of the template to be developed. For the template developed, Microsoft Excel (a user-friendly software) was used which made the template very easy to use and easy to access. It is required that a new copy of the template be created for each project for record purposes. Fig. 1 shows the template building process in which the empirical observations were carried out on-site physically to get labour outputs of the labourers while the theory was used to get the material constants to be used for the material labour schedule template. The empirical observations and theories were compiled together to arrive at the preliminary conclusion. The preliminary conclusion was used to develop a premise and the relationship between the variables was specified from which the outcomes were anticipated and then the final template was developed.

5. Result

Table 1 shows the data gotten from the observation computed based on one skilled labourer and a gang consisting of one mason and one labourer where applicable. The averaged values for each item of works were used for the development of the BOML.

For the material schedule computation, constants given in published books were compared and calculations from the first principle were made to arrive at the values shown in Tables 2, 3, and 4.

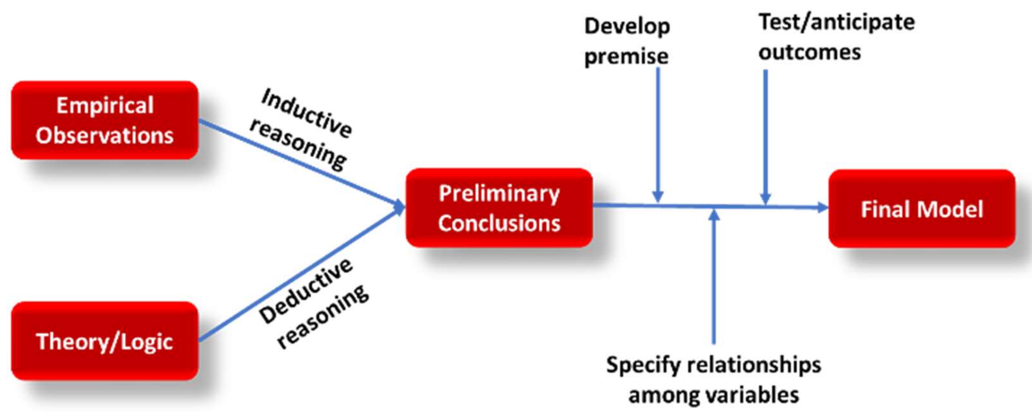

Fig. 1. The template-building process

Table 1. Labour outputs

S/N	Items of works	Labour outputs at each site	Average	S/N	Items of works	Labour outputs at each site	Average
1	Concrete in foundations and beds	3.7hrs/m^3 per gang 4.25hrs/m^3 per gang 3.73hrs/m^3 per gang	3.89 hrs/m^3	**6**	Formwork to sides of foundation and bed	0.35hr/m per tradesman 0.26hr/m per tradesman 0.37hr/m per tradesman	0.33 hrs/m
2	Concrete in slab	7.2hrs/m^3 per gang 7.95hrs/m^3 per gang 8.4hrs/m^3 per gang	7.85 hrs/m^3	**7**	Formwork to sides and soffit of slab	4hrs/m^2 per tradesman 3.6hrs/m^2 per tradesman 3.6hrs/m^2 per tradesman	3.73 hrs/m^2
3	Concrete in columns	13.58hrs/m^3 per gang 13.83hrs/m^3 per gang 13.16hrs/m^3 per gang	13.52 hrs/m^3	**8**	Formwork to columns	5.4hrs/m^2 per tradesman 5.74hrs/m^2 per tradesman 5.79hrs/m^2 per tradesman	5.64 hrs/m^2
4	Concrete in beams	13.70hrs/m^3 per gang 13.10hrs/m^3 per gang 13.55hrs/m^3 per gang	13.45 hrs/m^3	**9**	Formwork to sides and soffit of beams	6.45hrs/m^2 per tradesman 6.04hrs/m^2 per tradesman 6.15hrs/m^2 per tradesman	6.21 hrs/m^2
5	Concrete in staircases	12.95hrs/m^3 per gang 13.80hrs/m^3 per gang 13.97hrs/m^3 per gang	13.57 hrs/m^3	**10**	Formwork to sides and soffit of staircases	7.95hrs/m^2 per tradesman 7.4hrs/m^2 per tradesman 7.4hrs/m^2 per tradesman	7.58 hrs/m^2

Table 1. Labour outputs (continued)

S/N	Items of works	Labour outputs at each site	Average	S/N	Items of works	Labour outputs at each site	Average
11	Reinforcement in foundation and bed	42hrs/tonne per tradesman 41.5hrs/tonne per tradesman 41.24hrs/tonne per tradesman	41.58 hrs/tonne	**17**	19mm thick plastering and rendering for width not exceeding 300mm	6.35hrs/m per gang 6.40hrs/m per gang 6.25hrs/m per gang	6.33 hrs/m
12	Reinforcement in slabs	53.31hrs/tonne per tradesman 52.45hrs/tonne per tradesman 53.80hrs/tonne per tradesman	53.19 hrs/tonne	**18**	35mm thick floor screeding	4.5hrs/m^2 per gang 4.5hrs/m^2 per gang 4.42hrs/m^2 per gang	4.47 hrs/m^2
13	Reinforcement in beams, columns and staircases	59hrs/tonne per tradesman 61.2hrs/tonne per tradesman 58.8hrs/tonne per tradesman	59.67 hrs/tonne	**19**	35mm thick floor screeding for width not exceeding 300mm	5.38hrs/m per gang 5.40hrs/m per gang 5.35hrs/m per gang	5.38 hrs/m
14	Reinforcement in links and stirrups	77hrs/tonne per tradesman 77.7hrs/tonne per tradesman 76.55hrs/tonne per tradesman	77.08 hrs/tonne	**20**	Painting	0.15hr/m^2 per tradesman 0.14hr/m^2 per tradesman 0.14hr/m^2 per tradesman	0.14 hrs/m^2
15	Blockwork	1.2hrs/m^2 per gang 1.0hrs/m^2 per gang 1.08hrs/m^2 per gang	1.09 hrs/m^2	**21**	Painting to width not exceeding 300mm	0.21hr/m per tradesman 0.23hr/m per tradesman 0.27hr/m per tradesman	0.24 hrs/m
16	19mm thick plastering and rendering	5.5hrs/m^2 per gang 5.75hrs/m^2 per gang 5.1hrs/m^2 per gang	5.45 hrs/m^2	**22**	Roof carcassing	0.17hr/m per tradesman 0.25hr/m per tradesman 0.18hr/m per tradesman	0.20 hrs/m

Source: Author's compilation

Table 2. Concrete material analysis constants

Ratio	Cement		Fine aggregate		Coarse aggregate	
	(m^3)	(bags)	(m^3)	(tonnes)	(m^3)	(tonnes)
1:2:4	0.214	6.16	0.428	0.560	0.856	1.121
1:3:6	0.150	4.32	0.450	0.589	0.900	1.179
1:4:8	0.115	3.32	0.461	0.604	0.923	1.209

Source: Author's compilation

Table 3. Cement and sand mortar material analysis constants

S/N	Ratio	Cement		Dry sand	
		(m^3)	(bags)	(m^3)	(tonnes)
1	1:3	0.38	10.94	1.13	1.48
2	1:4	0.30	8.64	1.20	1.57
3	1:6	0.21	6.05	1.29	1.69

Source: Author's compilation

Table 4. Material Constants

S/N	Material quantities	Constants
1	Sandcrete blocks	10 blocks/m^2
2	Mortar for bedding and jointing @ 25mm thick for 225mm block	0.027m^3/m^2
3	Mortar for bedding and jointing @ 25mm thick for 150mm block	0.018m^3/m^2
4	Three coats of emulsion paint (1 undercoat and 2 finishing coats)	0.20 litres/m^2
5	Three coats of texcote (1 undercoat and 2 finishing coats)	0.25 litres/m^2
6	Timber (25x300mm, 50x50mm, 50x75mm, 50x100mm, 50x150mm)	3.60m/length
7	25x300x3600mm plank	1.08m^2
8	50x75x3600mm prop	4no/m^2

Source: Author's compilation

6. Template Development and Documentation

The Microsoft Excel document was formatted to accommodate the material and labour constants such that the quantity of materials needed for each item of works are generated automatically once the quantity of items of works is inputted into the space provided. The user needs to open the BOML template from its location on the system. It is expected that users open a new copy of the BOML template for every new project to be estimated for. This will help users avoid overwriting a previous project which might be useful for record purposes. This can be done by right-clicking on the file icon for BOML and clicking on "New" as shown in Fig. 2.

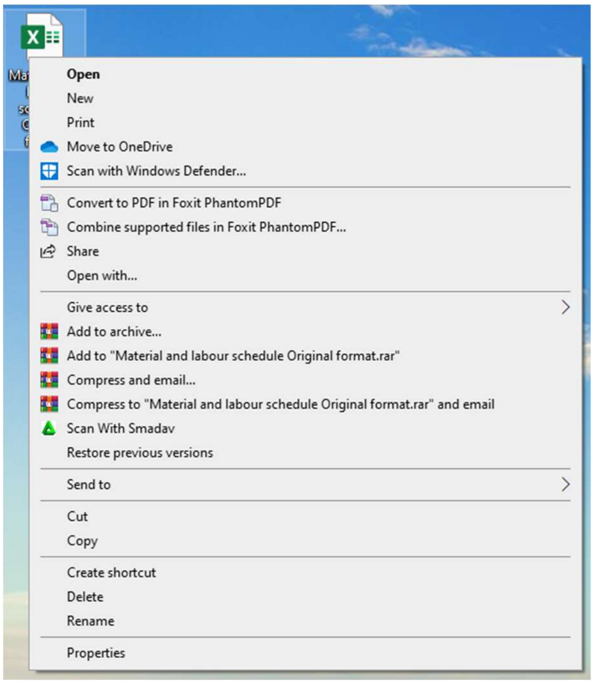

Fig. 2. Opening a new copy of the BOML

The BOML follows the interface pattern of every other Microsoft excel spreadsheet and its usage is similar to Microsoft Excel. The material and labour schedules were separated to treat some items of work that have the same material content but different labour outputs.

The title of the project at hand is to be entered in the space provided above the template sheet named "DOUBLE-CLICK HERE TO TYPE THE PROJECT TITLE" as shown in Fig. 3. Once this is entered in the material schedule, it displays automatically in the labour schedule. The quantity of the item of work for which the material schedule is to be gotten is to be entered by the user under the "QTY" column represented with the colour yellow in the template. The required quantity for each of the items of work will then be shown in the "TOTAL QTY OF MATERIAL" column represented in colour green while the material cost will be displayed in the column named "COST OF MATERIAL". The unit cost for each of the materials is entered and displayed under the column named "MATERIAL UNIT PRICE". The unit prices can be updated regularly as market prices changes. For the labour schedule, the quantity of the item of work for which the labour schedule is to be gotten is also entered by the user under the "QTY" column represented with the colour yellow in the template as shown in Fig. 4. The unit cost for each of the labours is entered and displayed under the column named "LABOUR UNIT PRICE". The unit prices can also be updated regularly based on market conditions. The number of labourers required for the work cannot be accurately estimated since the number of labourers for each work differs based on the volume of work to be done and the time available to complete the job. However, the total cost for the labour required can be estimated and from this, the number of labourers to be employed for the item of work can be derived.

After the development of the template, it was subjected to a validation process by practising Quantity Surveyors to calculate the material and labour content needed for ongoing projects. An average of 92% accuracy was achieved on the BOML done for the 10 projects used for validation by the professional quantity surveyors as shown in Table 5. This shows that the use of a BOML for construction projects will enhance accuracy and promote cost control to ensure the menace of waste and cost overrun on construction projects in reduced.

Fig. 3. Material schedule template sheet

Fig. 4. Labour schedule template sheet

Table 5. Validation of the developed template

Validators	Type of construction project	Accuracy observed (%)	Remark
1	Residential building	98	Excellent
2	Church auditorium	90	Very good
3	Residential building	94	Very good
4	Residential building	88	Very good
5	Office complex	95	Excellent
6	Office complex	89	Very Good
7	School building	88	Very good
8	Shopping complex	96	Excellent
9	Residential building	92	Very good
10	Town hall	90	Very good
Average accuracy		92	

7. Conclusion and Recommendation

The template for material and labour schedules was designed using Microsoft Excel, in which data was retrieved through observation of skilled and unskilled labourers on three different sites. This research work will enhance BOML preparation with the introduction of a standard template for some items of work in construction such as concrete works, blockwork, reinforcement, roof timbers, mortar for plastering and rendering as well as painting. This will not only speed up the preparation of these schedules but also enhance the accuracy of quantity surveying activities from approximate estimating to cost planning and control. The template was validated by professional quantity surveyors using ongoing projects and a 92% accuracy was achieved on average. This is an indication that computerised BOML will be very useful in ameliorating the challenges facing the construction industry in terms of material wastage, inaccurate estimates, cost and time overrun. However, for this electronic template to be efficient, computer literacy is required and a computer system either desktop, laptop or palmtop is necessary. It is therefore recommended that users should familiarise themselves with the use of Microsoft Excel. This can be achieved through video tutorial or written instructions that are readily available online. A major limitation of the template can be attributed to the unstable market situation globally, therefore, a fixed price for materials and labour cannot be adopted. It is recommended that the prices of materials and labour be updated regularly to get up-to-date estimates anytime the template is to be used. The study was limited to selected construction items which are only applicable to building works. Further research can be focused on the development of a BOML template for mechanical and electrical components in a building construction project as well as civil engineering construction projects.

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