Journal of Construction in Developing Countries, Vol. 16(2), 69–90, 2011

Urban Self-Building Labour Cost Modelling in Cameroon

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Abstract: The critical housing shortage in some cities of developing countries such as Cameroon generates an ever-growing desire to increase the housing supply. Due to the complex legislature system of Cameroon, housing policies and high costs associated with the acquisition of housing from the formal sector, the majority of urban residents are resorting to what are termed "informal practices", such as self-construction. This mode of housing provision, although difficult, has become the dominant mode of housing provision within the construction sector of most developing countries. As an informal sector, practices are characterised by unclear accounting methods, including labour costing and by often-present sub-par management techniques, which lead to delays in the completion of some projects. To address these issues, a method of estimating labour cost based on a developed matrix model is presented in this paper. Through the introduction of a finite dimensional vector space composed of standard tasks, the model presented directly relates the quantity of work to the labour cost. Application of this new approach to a case study in Cameroon shows how labour costs could be reduced by 37% compared to the simple matrix method examined by other researchers.

Keywords: Developing countries, Housing, Labour cost, Matrix, Self-construction

INTRODUCTION

In recent years, the population of urban cities in most developing countries, including Cameroon, has surged (Nyambod, 2010). One of the main reasons for the flow of population to cities is the search for jobs and improved living standards. However, in Cameroon, this flow of population is not catered for by an increase in social infrastructure, particularly housing, of which there is an acute shortage (Nyambod, 2010). According to the state-owned real estate corporation, Société Immobilière du Cameroun (SIC), nearly one million homes are needed, of which at least 300 000 are needed in major cities such as Douala and Yaoundé (SIC, 2010). The growing problem of housing scarcity demonstrates that orthodox development strategies, which require financial support from the Cameroon government and the SIC in particular, are failing. This failure is further exacerbated by the fact that current land and housing

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policies, including tenure arrangements, are still colonial in context and are outdated; too restrictive and un-reformed; these policies render the acquisition and provision of affordable housing complex, especially to the urban poor (Pettang et al., 1995). Consequently, the informal sector, although unacknowledged and illegal, has emerged and plays a leading role in the provision of affordable housing (Pettang et al., 1995).

The informal sector is dominated by individuals often called "self-constructors" who execute housing projects without pursuing any formal, legal or regulatory procedures. As the key players in the informal sector, self-constructors dictate the labour cost for most construction projects. In the formal sector, the productivity of material and equipment used in construction projects, is well defined and can be determined at the early design stage. However, the productivity of labour cannot be easily determined in the informal sector. This is partly because human productivity (which defines labour productivity) is constrained by working conditions. Inaccurate assessment of the cost of labour can lead to significant errors in the overall cost of a construction project, disputes with labourers and delays. This has often led to housing of poor quality and endless construction disputes. Given that the informal sector is likely to remain in place in developing countries, including Cameroon, at least for now, it is important to investigate labour cost estimation.

The importance of labour control in the production in self-construction housing has prompted many researchers to search for suitable tools and strategies that can help self-builders in cost optimisation and effective management of housing projects. Based on the weaknesses of existing labour cost estimation models in developing countries, this paper presents a Developed Matrix Approach (AMADEV), which can be used to estimate labour costs more efficiently and accurately than existing models. The accuracy and ease of use of AMADEV make it useful for decision-makers in housing development projects. The use of AMADEV, however, is challenging because self-constructors are the majority of the informal sector and are not adequately skilled to comfortably manipulate matrices. To demonstrate how this difficulty has been minimised, a case study has been used to show how AMADEV can easily be implemented. The implementation format was carefully chosen to conform to the cost estimation format in Cameroon. This format, which is principally made up of cost-quantity tables (Tables 1 and 2) is already commonly used by key stakeholders in the informal sector. This is easy because the table can be used with simple multiplication and addition.

The paper is divided into four main sections. The first section describes the complexities in estimating labour costs and a few commonly used estimation approaches. Based on the shortcomings of the models reviewed in section one, section two presents the methodological framework of the proposed AMADEV method. In section three, we present a case study of the implementation of this new approach. The paper concludes by presenting recommendation(s) for future research in terms of filling gaps within the designed and proposed approach.

LABOUR COST ESTIMATION TECHNIQUES: AN OVERVIEW

In developed countries, most housing development activities and policies are formally well established. However, in Cameroon, housing production is dominated by the informal sector. The sector is characterised by a wide range of non-regulatory mechanisms that are used in undertaking housing construction. These characteristics are quite visible in the following housing development activities: housing surveys, supply chain management, employment and the remuneration of labour, project financing and procurement processes (Pettang et al., 1995). The set of non-regulatory activities being undertaken by construction professionals, termed "self-construction", predominates the informal sector. However, some disadvantages are associated with self-construction; these include unstable financial standing, a lack of monitoring and control of work, lack of skilled labour and instability of the labour/manpower used, a prevalence of odd jobs executed by piece-workers, the use of materials and equipment acquired dubiously (Pettang et al., 1995) and the lack of clear rules in computing labour cost. The labour used in this sector is quite disparate and is often categorised into two groups: family members or friends and professionals (piece-workers, qualified technicians and on-the-job, trained workmen). Previous studies indicate that self-construction could be promoted by optimising labour, building materials and task planning, supported by financial and material credit facilities (Pettang, 1998). Many researchers have sought to develop direct aid to self-constructors, and several studies have proposed facilitating the process of obtaining planning permission, providing efficient financial saving methods for managing housing development projects (Pettang, 1998), and controlling scientific and technical parameters (cost, time and quality) of self-construction projects (Louzolo and Pettang, 2006a).

Based on the discussion above, the essential parameters of a construction project (usually measured with respect to cost, time and quality) are materials, labour and management costs. These variables can be modelled as:

$$C_T = C_{Ma} + C_{MO} + C_{MG} \qquad (1)$$

where C_T is the total construction cost, C_{Ma} is the cost of materials, C_{MO} is the labour cost, and C_{MG} is the cost of management or other costs (such as overheads, insurances, rents, security, vehicles, drivers).

In brief, many estimation techniques have been developed previously to control the scientific and technical cost parameters of a construction project. These techniques include, for example, simplified matrix methods based on summary information relating to the project (i.e., the unit method and the covered area method), more detailed methods (such as analytical methods and statistical-matrix methods) and automatic methods such as UNIFORMAT II (Charrette and Marshall, 1999). These methods will be reviewed in the ensuing sections with the aim of identifying their weaknesses.

In the simple matrix approach, based on the product tables, the effect of the cost of materials (CMa) was calculated for most current construction types, namely masonry bricks, stabilised ground blocks, wood and mud mortar or construction waste mortar (Pettang et al., 1997). C_{Ma} is expressed as follows:

$$C_{Ma} = \sum_{j=1}^{p} Q_j P_j \tag{2}$$

where p is the number of types of material, Q_j is the quantity of material j required, and P_j is the unit price of material j.

The same approach can be and was extended to labour cost evaluation (Pettang, 1998) using manpower required by trade, the daily income of a workman or labourer, and the duration or time required to realise each building element. Thus, the labour cost in equation (1) above is given by the following expression:

$$C_{MO} = (N \times R) \times D = (L_{ij}) = (n_{ij} R_{ij} d_{ij}), \text{ where } 1 \le i \le n; 1 \le j \le n \tag{3}$$

N is the number of different trades required for a given construction activity, R is the daily wage requirement, and D is the duration of the construction activity.

Based on the analytical method developed by Rigo (2002), the term C_{MO} of equation (3) can be expressed as follows:

$$C_{MO} = \sum_{i=1}^{NT} T_i M_i S_i \tag{4}$$

Here, NT is the number of different tasks, and T_i is the workload necessary to carry out task i.

M_i is the number of times that task i will have to be repeated, and S_i is the unit labour cost per hour per worker carrying out task i.

The statistical-matrix approach (Louzolo and Pettang, 2006a; 2006b) combines a simple matrix approach and multiple linear regressions to generate the total construction cost *K* based on *r* independent variables:

$$K = A_0 + \sum_{j=1}^{r} A_j c_j + \in \quad (5)$$

where K is the exogenous variable; C_j with $j = 1, 2..., r$ are endogenous variables; A_0 represents a constant term; $j = 1, 2..., r$ are regression coefficients (parameters); and εi represents the random error (based on an individual worker's behaviour). Based on historical data regarding the observation of an *N*-size statistical sample and the expression for $i = 1, 2..., N$, the total cost for housing *i* is as follows:

$$K_i = A_0 + \sum_{j=1}^{p} A_j c_{ij} + \sum_{j=p+1}^{q} A_j c_{ij} + \sum_{j=q+1}^{r} A_j c_{ij} + \in_i \quad (6)$$

where c_{ij}, $j = 1, 2..., p$, relates to the cost of materials; c_j , $j = p+1,..., q$, relates to the cost of the labour; and c_j, $j = q+1..., r$, relates to the cost of the overheads. The quantity c_{ij} is the value of the variable c_j ($j = 1..., r$) for housing *i*.

This approach demonstrates that the total construction cost K_T can be estimated using five parameters, one relating to labour cost ([*labmtfs*]) and four relating to material costs (roofing and sealing, masonry, carpentry and joinery, and plumbing represented by *matrose*, *matmas*, *matcajo*, and *matplu*, respectively. A margin of tolerance M characterised by confidence intervals of the regression coefficients is also included. Thus:

$$K_T = A_0 + A_1 \times [latmfs] + A_2 \times [matrose] + A_3 \times [matmas] + A_4 \times [matcajo] + A_3 \times [matplu] \pm M \quad (7)$$

The values of the constants, which are equal to the values of the regression coefficients, were determined statistically to fall in the intervals $A_0 \in [-1.2\times10^6; 2.3\times10^5]$, $A_1 \in [3.7; 6.2]$, $A_2 \in [2.1; 4.0]$, $A_3 \in [0.5; 0.9]$, $A_4 \in [0.3; 0.9]$, and $A_5 \in [0.7; 3.5]$. In this study, we have chosen the constant values of $A_0 = 5*10^5$, $A_1 = 5$, $A_2 = 3$, $A_3 = 0.7$, $A_4 = 0.6$, and $A_5 = 2$.

$M = (K_{T_{\sup}} - K_{T_{\inf}})/2$ represents the tolerance margin, and and represent the maximum and minimum estimates of the construction costs obtained from the maximum and minimum values of A_j ($j = 1, 2,..., r$), respectively.

Charrette and Marshall (1999) have analysed the UNIFORMAT II approach well. This method codifies building elements into three to four categories.

The codification and categorisation make it possible to deconstruct all the elements of a construction project that can be used in designing a cost table for subsequent use in calculating the total cost of the project.

The above cost-estimation models have advantages and disadvantages. The UNIFORMAT II approach is quite accurate and makes it possible to directly calculate the construction total cost, including overheads. However, because of a lack of effective means of auto- or self-control, the approach cannot always be adapted to self-construction projects. The simple matrix approach is easy and practical for costing materials (equation 2), but with regard to labour costing (equation 3), it does not appear to improve the precision of worker productivity evaluation in the realisation of a given task. Because this method lacks external checking and supervision, the value of Rij does not accurately represent the quantity of work actually performed during the average official daily duration of work in Cameroon (eight hours). Indeed, for a given task, this approach does not establish a direct relation between the worker's daily income and the quantity of work effectively performed. Equation (4) presents the labour component of the construction cost rather accurately. Nonetheless, at a given stage of the project, this formula does not sufficiently establish the economic weight of each constituent element. Indeed, the difficulty or relative disadvantage of this formula depends on the level of inventory and the subdivision of the tasks. Furthermore, in self-construction, the prevalence of piece-workers makes the measurement of Si rather difficult. In the same way, the determination of Ti as the labour time necessary to realise task i can depend on certain external factors that are difficult to manage (such as materials, site characteristics and behaviour of the workmen).

The statistical-matrix approach is a parametric estimation technique that makes it possible to rapidly calculate project costs from a reduced number of variables. However, any estimate, regardless of its precision, can only lead to a determination of the construction cost (Louzolo, 2006a). This constitutes only one of the aspects of project cost control, and the realisation stage is subject to various disturbances and can exceed the initial budget; this complication cannot be captured using this method. Frequently, it has been noted that self-constructors face many difficulties in executing construction projects, even when financial resources are available. The nature of those difficulties could therefore depend on labour management. Indeed, the labour factor is significant during cost estimation and even during project execution. In addition, any inadequacy in workmen's skill levels in relation to the task can have serious consequences such as abandonment of work, never-ending execution, excessive construction costs, poor security and poor building durability.

Our objective is to propose a cost evaluation method that can help the self-constructor to understand the specifics of labour in the unregulated construction informal sector. In the following section, we present a method for evaluating labour costs in self-construction projects based on developed matrix algebra.

A DEVELOPED MATRIX APPROACH (AMADEV) FOR LABOUR COST ESTIMATION IN URBAN SELF-CONSTRUCTION

The method that we intend to use is deterministically and hypothetical deductive, and based on developed matrix algebra. We assume that the cost of labour can be expressed in *a vector space* with finite dimension. Therefore, regarding building elements, the labour cost would be *a linear combination of vectors* whose components depend on building elements and the task to be executed. For building element SO_i (*i* is fixed, and a ceiling is an example of a building element), the labour cost can be expressed as follows:

$$\overrightarrow{MO_i} = \sum_{j=1}^{t} \mu_{ij} \overrightarrow{m_j} \tag{8}$$

where $\overrightarrow{m_j}$ is the vector space related to the standard task *j*, μ_{ij} represents the correspondent scalar and *t* is the number of standard tasks.

The specific objectives of this approach target the decomposition of the variables likely to influence the cost of labour in self-construction, the choice of a basis for the vector space and the determination of the cost matrices. Figure 1 is a diagram of our method.

Thus,

$$C_T = \sum_{i=1}^{s} (C_{MOi} + C_{Ma,i} + C_{MG,i}) \tag{9}$$

To account for unpredictable price variation (disturbance) and overtime, we introduce an error function ΔT. Therefore, the total cost becomes:

$$C_T = \sum_{i=1}^{s} (C_{MOi} + C_{Ma,i} + C_{MG,i}) + \Delta_T \tag{10}$$

The error Δ_T is obtained from the contract revised price formula:

$$\begin{cases} \Delta_T = \left| C_{Tr} - C_{Ta} \right| \\ C_{Ta} = C_{Tr} \left(\dfrac{I_a}{I_r} \right) \end{cases}$$

C_{Ta} is the current price, C_{Tr} is the future price or price with respect to a particular reference period, I_a is the

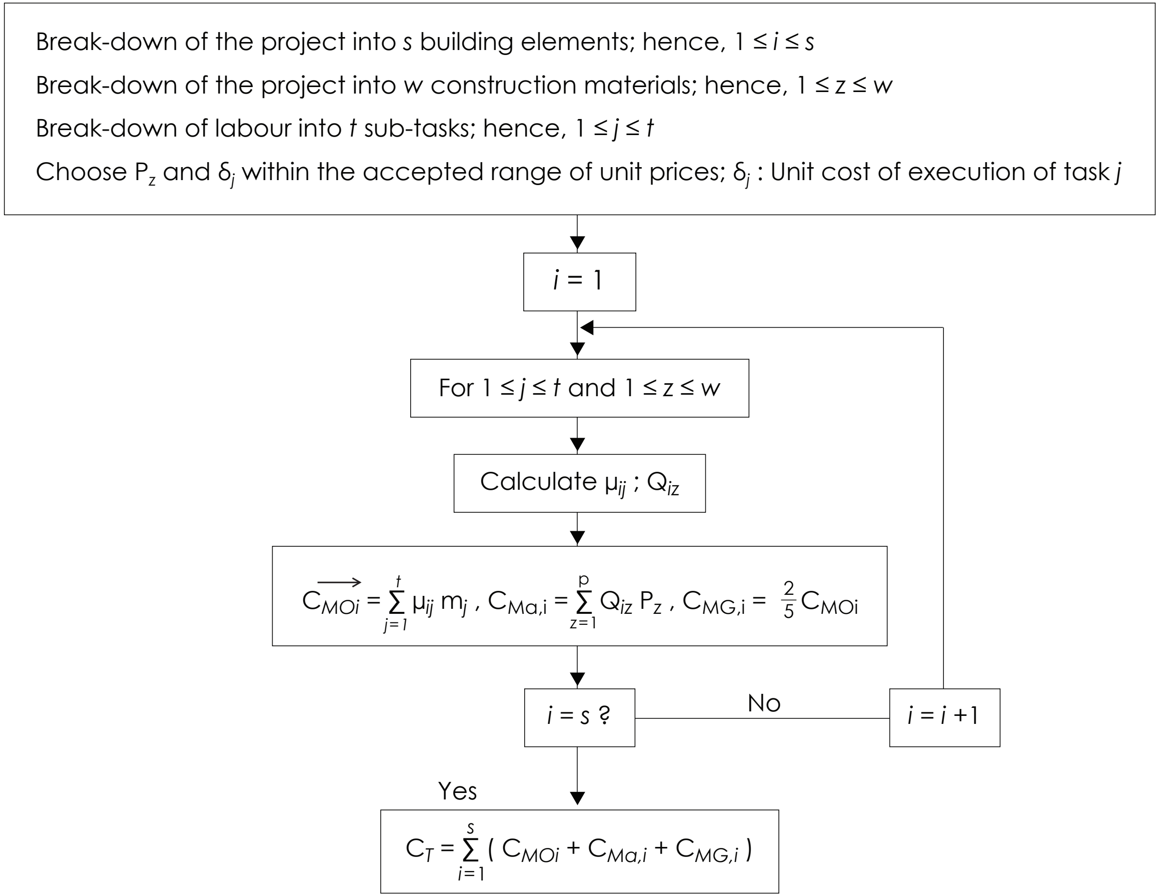

Figure 1. Diagram of the Method

current price index, and I_r is the future price index. The values of I_a and I_r are published by specialised technical departments in the Ministry of Public Works of Cameroon.

Labour Composition and the Choice of the Basis of the Standard Tasks

For a given self-constructed project presented in Table 1, the inventory of the standard tasks to be executed is presented. In the following section, ξ indicates the set of all expenditure relating to labour for a self-construction project. The nonempty set ξ will be provided subject to the usual laws of vector addition and scalar multiplication in the real number field *IR*. Then, (ξ, +, x) is a finite-dimensional vector space over the field *IR* made up of the basis $\{\vec{m}_j\}$. For each standard task *j*, we map a correspondence finite subset of *t* vectors in the following way:

$$\vec{m}_1=(\delta_1,0,0,\ldots,0,0);\ \vec{m}_2=(\delta_2,0,0,\ldots,0,0);\ldots;\\ \vec{m}_j=(0,0,\ldots,\delta_j,\ldots,0,0);\ \vec{m}_t=(0,0,\ldots,0,\delta_t) \quad (11)$$

δ_j is the labour unit cost relating to standard task *j*. The values taken by δ_j are the average values of the unit cost values obtained statistically from several self-construction building sites managed and executed in the Yaoundé urban area. The values μ_{ij} are related to the project type under construction. We obtain the following configuration:

$$\xi \xrightarrow{f} E = \left(IR^t,+,\times\right)\\ d \rightarrow \left(d_1,d_2,\ldots,d_t\right) \quad (12)$$

We assume that the correspondence *f* is injective. This leads us to the determination of the matrices relating to the various components of construction cost in the following sections. These matrices, termed construction cost matrices, include the work quantity matrix, the unit cost matrix, and the cost matrix arranged by task and by building element.

In the following section, $[M_{l,c}]$ indicates an *l* by c matrix with elements M_{nm}, $n = 1\ldots, l$; $m = 1\ldots, c$. The diagonal matrix resulting from $[M_{l,c}]$ is denoted as $[M'_{c,c}]$ and the transpose of the matrix of $[M_{l,c}]$ is denoted as ${}^T[M_{l,c}]$. The product of two matrices $[M_{l,c}]\times[N_{c,k}]=[A_{l,k}]$ is well defined by their units in the real numbers field *IR*. From data relating to a given construction project, we define the matrices $[Q_{s,t}]$ and $[U_{3,t}]$ relating to the quantity of work to be performed and the unit prices, respectively.

The work quantity matrix $[Q_{s,t}]$ represents the volume of work to be performed for each building element. The index *s* indicates the total number of building elements, and *t* represents the total number of standard tasks constituting the construction project. Thus, we can write:

$$[Q_{s,t}] = \begin{bmatrix} \mu_{1,1} & \mu_{1,2} & \cdots & \mu_{1,t} \\ \mu_{2,1} & \mu_{2,2} & \cdots & \mu_{2,t} \\ \cdots & \cdots & \cdots & \cdots \\ \mu_{s,1} & \mu_{s,2} & \cdots & \mu_{s,t} \end{bmatrix} \tag{13}$$

i ∈ {1,..., s} and j ∈ {1,..., t}, μ_{ij} indicates the quantity of work necessary for the realisation of building element SO_i and relative to the standard task j. The elements of $[Q_{s,t}]$ depend on the structural plan.

The unit cost matrix $[U_{3,t}]$ represents the unit price by task and the three components: labour, materials and management.

$$[U_{3,t}] = \begin{bmatrix} u_{1,1} & u_{1,2} & \cdots & u_{1,t} \\ u_{2,1} & u_{2,2} & \cdots & u_{2,t} \\ u_{3,1} & u_{3,2} & \cdots & u_{3,t} \end{bmatrix} \tag{14}$$

j ∈ {1,..., t}, $u_{1,j}$ indicates the labour unit price for the execution of task j, $u_{2,j}$ indicates the cost of materials related to task j and $u_{3,j}$ indicates the management cost related to task j. From the two matrices $[Q_{s,t}]$ and $[U_{3,t}]$, several other matrices are defined as follows:

Therefore, the work quantity matrix per standard task can be defined as

$$[Q_{1,t}] = {}^{T}[I_{s,1}] \times [Q_{s,t}] = [I_{1,s}] \times [Q_{s,t}] \tag{15}$$

$[I_{s,1}]$ is a column vector whose s elements have the unit value 1.

Thus:

$$[Q_{1,t}] = [1; \quad 1; \quad \ldots; \quad 1] \times \begin{bmatrix} \mu_{1,1} & \mu_{1,2} & \cdots & \mu_{1,t} \\ \mu_{2,1} & \mu_{2,2} & \cdots & \mu_{2,t} \\ \cdots & \cdots & \cdots & \cdots \\ \mu_{s,1} & \mu_{s,2} & \cdots & \mu_{s,t} \end{bmatrix} \tag{16}$$

The elements of the row vector $[Q_{1,t}]$ have the general form:

$$\mu_j = \sum_{i=1}^{s} \mu_{i,j}; \quad j = 1, 2\ldots t \tag{17}$$

Therefore the unit cost matrix by standard task can be defined as a row vector as shown in equation 18.

$$[U_{1,t}] = {}^{T}[I_{3,1}] \times [U_{3,t}] = [I_{1,3}] \times [U_{3,t}] \tag{18}$$

$$[U_{1,t}] = [1; \quad 1; \quad 1] \times \begin{bmatrix} u_{1,1} & u_{1,2} & \dots & u_{1,t} \\ u_{2,1} & u_{2,2} & \dots & u_{2,t} \\ u_{3,1} & u_{3,2} & \dots & u_{3,t} \end{bmatrix} \qquad (19)$$

The row vector has *t* elements, whose general form is:

$$u_j = \sum_{k=1}^{3} u_{k,j}; \quad j = 1, 2 \dots t \qquad (20)$$

The index *k* refers to each of the three components of construction cost: *k* = 1 indicates the labour cost, *k* = 2 indicate the materials cost, and *k* = 3 indicates the management cost. In the following section, the matrices resulting from the project data are used to determine the cost matrices.

The cost matrix arranged by task and by building element $[C_{s,t}]$ calculates the total cost of realisation per task for each building element. If $[U'_{t,t}]$ indicates the diagonal resultant matrix, then we obtain the following:

$$[C_{s,t}] = [Q_{s,t}] \times [U'_{t,t}] \qquad (21)$$

Thus,

$$[C_{s,t}] = \begin{bmatrix} \mu_{1,1} & \mu_{1,2} & \dots & \mu_{1,t} \\ \mu_{2,1} & \mu_{2,2} & \dots & \mu_{2,t} \\ \dots & \dots & \dots & \dots \\ \mu_{s,1} & \mu_{s,2} & \dots & \mu_{s,t} \end{bmatrix} \times \begin{bmatrix} u'_{1,1} & 0 & \dots & 0 \\ 0 & u'_{2,2} & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & u'_{t,t} \end{bmatrix} \qquad (22)$$

$$u'_{j,j} = \sum_{k=1}^{3} u_{k,j}; \quad j = 1, 2, \dots, t \qquad (23)$$

The elements of the matrix have the following general form:

$$c_{i,j} = \mu_{i,j} \times u'_{j,j} \qquad (24)$$

The construction cost matrix arranged by building element $[C_{1,s}]$ is defined by

$$[C_{1,s}] = [I_{1,t}] \times {}^{T}[C_{s,t}] = [I_{1,t}] \times [C_{t,s}] \qquad (25)$$

where $[I_{1,t}]$ is a unit linear row vector whose t elements have the unit value 1; then, we obtain

$$[C_{1,s}] = [1;\ \ 1;\ \ \ldots\ \ 1] \times \begin{bmatrix} c_{1,1} & c_{2,1} & \ldots & c_{s,1} \\ c_{1,2} & c_{2,2} & \ldots & c_{s,2} \\ \ldots & \ldots & \ldots & \ldots \\ c_{1,t} & c_{2,t} & \ldots & c_{s,t} \end{bmatrix} \tag{26}$$

The elements of the matrix $[C_{1,s}]$ have the general form

$$c_i = \sum_{j=1}^{t} c_{i,j}\ ;\quad i = 1, 2\ldots s;\quad j = 1, 2\ldots t \tag{27}$$

The above matrix calculates the total cost of construction arranged by building element.

Therefore, the matrix cost arranged by component is a matrix determining the cost of construction based on the three components: labour, materials and management. This matrix is defined by

$$[C_{3,t}] = [U_{3,t}] \times [Q'_{t,t}] \tag{28}$$

where $[Q'_{t,t}]$ is the diagonal matrix resulting from $[Q_{1,t}]$. We define

$$[C_{3,t}] = \begin{bmatrix} u_{1,1} & u_{1,2} & \ldots & u_{1,t} \\ u_{2,1} & u_{2,2} & \ldots & u_{2,t} \\ u_{3,1} & u_{3,2} & \ldots & u_{3,t} \end{bmatrix} \times \begin{bmatrix} \mu'_{1,1} & 0 & \ldots & 0 \\ 0 & \mu'_{2,2} & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & \ldots & \mu'_{t,t} \end{bmatrix} \tag{29}$$

where

$$\mu'_{j,j} = \sum_{i=1}^{s} \mu_{i,j} \tag{30}$$

The elements of the matrix $[C_{3,t}]$ are written as follows:

$$c_{k,j} = u_{k,j} \times \mu'_{j,j}\ ;\ \text{with } k = 1, 2, 3 \text{ and } j = 1, 2\ldots t \tag{31}$$

Here, k = 1 indicates the labour cost, k = 2 indicates the materials cost and k = 3 indicates the management cost. The labour cost results from the matrix $[C_{3,t}]$ by

$$C_{MO} = \sum_{j=1}^{t} c_{1,j} = \sum_{j=1}^{t} u_{1,j} \times \mu'_{j,j} \tag{32}$$

It is important to note that equation (32) is the basis of this study.

Therefore, the construction matrix cost arranged by task $[C_{1,t}]$, which gives the total construction cost for each task, can be defined as

$$[C_{1,t}] = [I_{1,3}] \times [C_{3,t}] \quad (33)$$

Thus,

$$[C_{1,t}] = [1; \ 1; \ 1] \times \begin{bmatrix} c_{1,1} & c_{1,2} & \ldots & c_{1,t} \\ c_{2,1} & c_{2,2} & \ldots & c_{2,t} \\ c_{3,1} & c_{3,2} & \ldots & c_{3,t} \end{bmatrix} \quad (34)$$

The total construction cost C_T in Figure 1 is obtained by summing the elements of each matrix $[C_{1,t}]$, $[C_{3,t}]$ or $[C_{1,s}]$.

For example, $C_T = \left|[C_{1,t}]\right| \pm \Delta_T$ (the variables are the same as those previously defined).

CASE STUDY: APPLICATION OF THE MATRIX APPROACH USING STANDARD TASKS

The Choice of an Urban Building Plan

To validate the AMADEV, a hypothetical urban building case study was employed. The building size was assumed to be 120m^2. There are two main reasons for this choice. First, this choice conforms to the results of surveys performed in 1993 in the Yaoundé urban area by the Yaoundé Urban Council (Mogue, 1993), in which 43% of housing had useful areas that were used in the study of between 100m^2 and 150m^2. Furthermore, previous studies have shown that modest urban buildings in Cameroon contain, on average, approximately six people (Nguindjel, 2000). Second, to verify, compare and analyse the results from AMADEV, this paper explores an existing case study used in previous research. A labour cost estimation model developed by Louzolo and Pettang (2006a; 2006b) was validated using an urban building with specifications defined by Mogue (1993) and Nguindjel (2000). By using the same case study, we can reasonably compare the results between the different models. In accordance with architectural standards regarding minimal useful areas, this urban household model contains seven areas: a sitting room, a kitchen, two bathrooms and four bedrooms. This provides a useful surface area of 120m^2 (Figure 2).

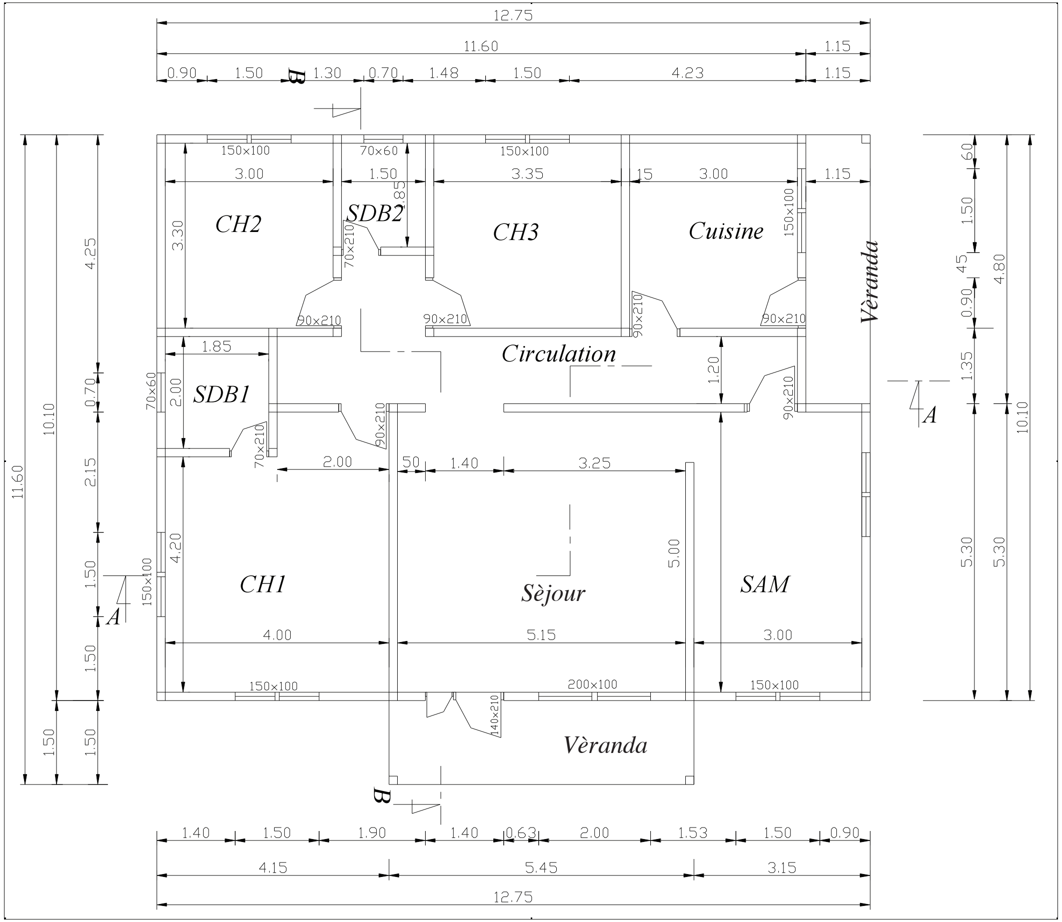

Figure 2. Standard Plan of an Urban Building with a Floor Area of 120 m²

Table 1. Decomposition of the Labour into Standards Tasks

Vector Code	Standard Task Denomination	Unit Price FCFA	Vector Code	Standard Task Denomination	Unit Price FCFA
m_1	Drain excavation	800/linear metre	m_{14}	Roofing	500/m^2
m_2	Well excavation	3 500/m^3	m_{15}	Joisting out of slats	50 000/m^3
m_3	First concrete 150 kg/m^3	7 000/m^3	m_{16}	Ceiling work	1 000/m^2
m_4	Steel bending	300/kg	m_{17}	Door/window installation	6 000/u
m_5	Formwork	1 500/m^2	m_{18}	Plumbing	50 000/lumpsum
m_6	Reinforced Concrete 350 kg/m^3	7 500/m^3	m_{19}	Electrical installation	50 000/lumpsum
m_7	Fills rolled under pavement	1500/m^3	m_{20}	Installation of other apparatus	4 000/u
m_8	Ordinary Concrete 300 kg/m^3	7 000/m^3	m_{21}	Surfacing with a trowel	500/m^2
m_9	20-cm-wide Masonry brick	1000/m^2	m_{22}	Tiling	1 300/m^2
m_{10}	15-cm-wide Masonry brick	700/m^2	m_{23}	Coating and connections masonry	1 000/m^2
m_{11}	Framework	75 000/m^3	m_{24}	Whitewashing	150/m^2
m_{12}	Installation of rafters	75 000/m^3	m_{25}	Painting of two layers of Pantex on walls	400/m^2
m_{13}	Installation of purlins	60 000/m^3			

The useful areas are Sejour (Parlour), 25.75m^2; CH1 (Room 1), 15.40m^2; CH2 (Room 2), 10.10m^2; CH3 (Room 3), 11.15m^2; SDB 1 (Bathroom 1), 3.70 m^2; SDB 2 (Bathroom 2), 3m^2; SAM (Dining Room), 15m^2; Cuisine (Kitchen), 9.90 m2; and Circulation (Corridor), 26m^2.

For building element SO_1, application of equation (8) yields the following vector:

Table 2. Cost of Labour Arranged by Building Element

Sub-structure	Denomination	Labour Cost (FCFA)
SO_1	Foundation + pavement + first chaining	456 250
SO_2	Wall elevation with masonry bricks	220 100
SO_3	Columns + lintels + second chaining	137 985
SO_4	Frame and cover	371 513
SO_5	Ceiling	121 000
SO_6	Joinery	120 000
SO_7	Plumbing	45 000
SO_8	Electrical installation	17 500
SO_9	Interior and exterior coatings	589 800
SO_{10}	Sealed coatings	39 520
SO_{11}	Internal and external painting	546 345
	Total	2 665 013

$$\overrightarrow{MO}_1 = \sum_{j=1}^{25} \mu_{i,j} \vec{m}_j = 111\vec{m}_1 + 7.36\vec{m}_2 + 2.57\vec{m}_3 + 66.16\vec{m}_4$$

$$+242\vec{m}_5 + 27.57\vec{m}_6 + 6.05\vec{m}_7 + 9\vec{m}_8 + 8.53\vec{m}_9 + 0.5\vec{m}_{18}$$

Thus, the labour cost of the building element SO_i is equal to:

C_{MO1} = 111 x 800 + 7.36 x 3500 + 2.57 x 7000 + 66.16 x 1000 + 242 x 300 + 27.57 x 1500 + 6.05 x 7500 + 9 x 7000 + 8.53 x 700 + 0.5 x 50000 = 456 250 FCFA.

The total labour cost is expressed as follows:

$$C_{\overrightarrow{MO}} = \sum_{i=1}^{11} \overrightarrow{MO}_i = \sum_{i=1}^{11}\sum_{j=1}^{25} \mu_{i,j} \vec{m}_j = \sum_{j=1}^{25} \eta_j \vec{m}_j \quad = 2\,665\,013 \text{ F CFA}$$

The details of the labour cost per building element are listed in Table 2.

Assuming that C_T is being determined for current projects, P = P_o, hence, Δ_T=/P-P_o/=0.

The execution of matrix algebra using MATLAB.6 software in calculating C_T as stated in Figure 1 gives the results presented in Appendices A, B and C. The total cost of construction for this example is equal to:

$$C_T = \left|\left[C_{1,t}\right]\right| = \left|\left[C_{3,t}\right]\right| = \left|\left[C_{1,s}\right]\right| = 10\ 327\ 094 \text{ F CFA}$$

The labour cost is $C_{MO} = \sum_{1}^{25} C_{1m}$ = 2 665 013 F CFA, which represents 26% of the total construction cost; this amount agrees with that found in the literature (Louzolo and Pettang, 2006a; 2006b).

Analysis of Results from the Implementation of AMADEV on a Case Study

To establish the degree of validity of AMADEV, the results noted were compared with results from an existing model in two ways. First, the author explored using the model developed by Louzolo and Pettang (2006a; 2006b) to compute the labour cost of the case study in this paper and compared the results with those obtained here. This comparison was not pursued, as the technique developed by Louzolo and Pettang (2006a; 2006b) was simpler and did not break down the building components into detailed building elements; it was therefore difficult to draw comparisons based on the building elements considered in this case study. For instance, in this paper, "foundation + pavement + first chaining" means that the foundation, pavement and first floor chaining are considered as different elements, and the unit cost is calculated as that of the block "foundation + pavement + first chaining". In Louzolo and Pettang (2006a; 2006b), this block is simply described as the foundation, making it difficult to establish what the constituent standard tasks required in constructing the foundation are. Second, to overcome this difficulty, we used a second approach to compare the results based on proportionality by finding the ratio of the total cost of a building to its surface area.

This is logical in the sense that both models adopted case studies with the same specifications, although their surface areas were slightly different. To validate the calculations, we used the same unit labour cost as that used by Louzolo and Pettang (2006a; 2006b) without including the error term due to price increases since 2006. For this reason, the values from this study are very conservative and are thus reasonable in making comparisons. Louzolo and Pettang (2006b) found that the labour cost for a similar building (110m^2) was 3 343 000 F CFA (i.e., 30 391 F CFA/m^2). Similarly, AMADEV yields 2 665 013 F CFA /120 m^2 (i.e. 22 208 F CFA/m^2). Thus, AMADEV reveals a gain of 37%, i.e. a reduction in labour cost compared to the simple matrix approach. This disparity verifies the advantageousness of the proposed approach. Furthermore, other methods, such as the simple matrix approach, use the number of workers and the time taken for task execution as data. These data are not readily available during the design stage and are likely to generate additional expenditure during construction when they are not defined with sufficient precision.

CONCLUSION

The proposed model has made it possible to establish a relationship between the cost of labour and the quantity of work performed at each stage of construction projects. Moreover, the relation obtained between task and building elements would permit the self-constructor to plan expenditure as the project and availability of financial resources evolve. Admittedly, the observance of deadlines or schedules is one of the major objectives of any construction project. However, this is not always an absolute priority for the self-constructor in practice because the pace of work depends on the cash flow available. Although a time factor is not directly implied, this method of evaluating labour cost is likely to create a positive and personal motivation towards observing the planned work schedule. Indeed, in the informal sector, where self-construction dominates, time management is solely dependent on decisions made by the pieceworker. Thus, by taking this new approach to standard tasks, the overhead costs related to management, particularly in the choice of labour, are attenuated. The case study demonstrates that it is possible to obtain a profit of 37% on labour cost, i.e. a reduction in labour cost compared to the traditional matrix approach. In this study, we focused on the labour cost of a construction project. However, for total control of the labour employed in self-construction, we expect to integrate the time component in a future study with the particular aim of optimising the workers' productivity by task.

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APPENDICES

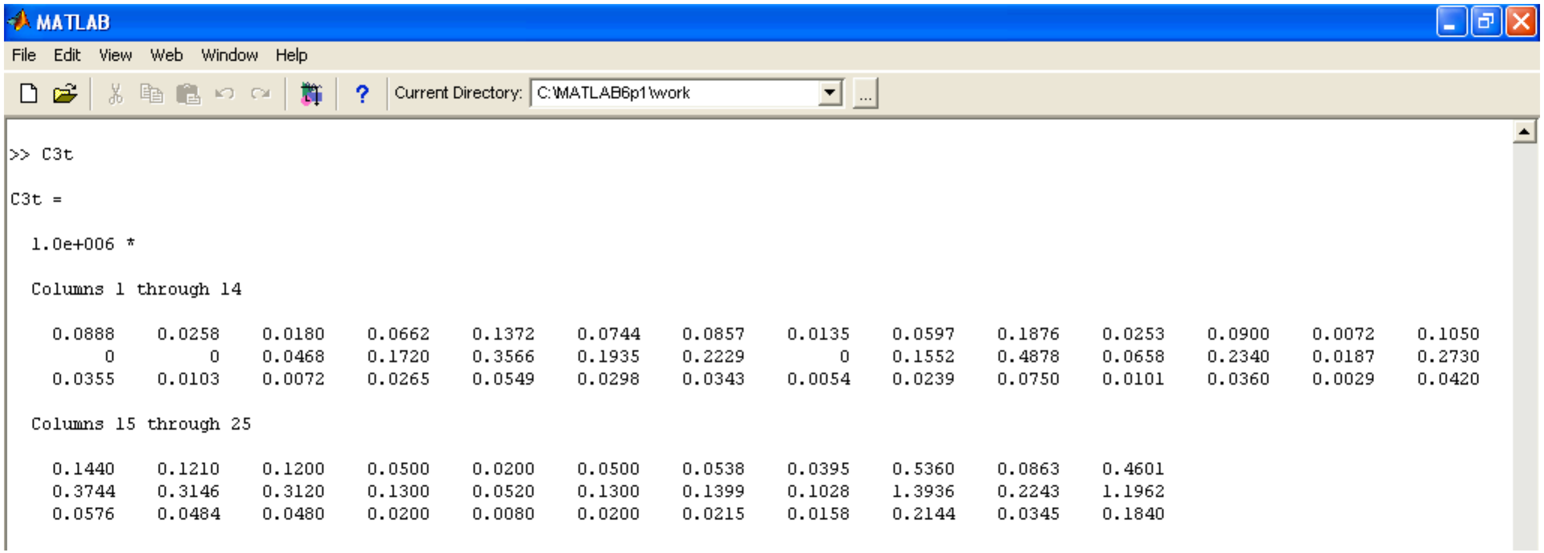
Appendix A

Task and building elements cost matrix, expressed in thousands of Francs CFA $[C_{s,t}] = [Q_{s,t}] \times [U'_{t,t}]$

```
MATLAB
File  Edit  View  Web  Window  Help
Current Directory: C:\MATLAB6p1\work

>> Cst

Cst =

  1.0e+006 *

  Columns 1 through 14

    0.1243    0.0361    0.0720    0.2646    0.2904    0.1654    0.1815    0.0189    0.2388         0         0         0         0         0
         0         0         0         0         0         0         0         0         0    0.7504         0         0         0         0
         0         0         0         0    0.2582    0.1323    0.1614         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0    0.1013    0.3600    0.0288    0.4200
         0         0         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0         0         0         0

  Columns 15 through 25

         0         0         0    0.1000         0         0         0         0         0         0         0
         0         0         0         0         0         0    0.0013         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0
    0.5760         0         0         0         0         0         0         0         0         0         0
         0    4.8400         0         0         0         0         0         0         0         0         0
         0         0    0.4800         0         0         0         0         0         0         0         0
         0         0         0    0.1000    0.0800         0         0         0         0         0         0
         0         0         0         0    0.0056         0         0         0         0         0         0
         0         0         0         0         0         0    0.2152         0    2.1440         0         0
         0         0         0         0         0         0         0    0.1581         0         0         0
         0         0         0         0         0         0         0         0         0    0.3451    1.8403
```

Appendix B

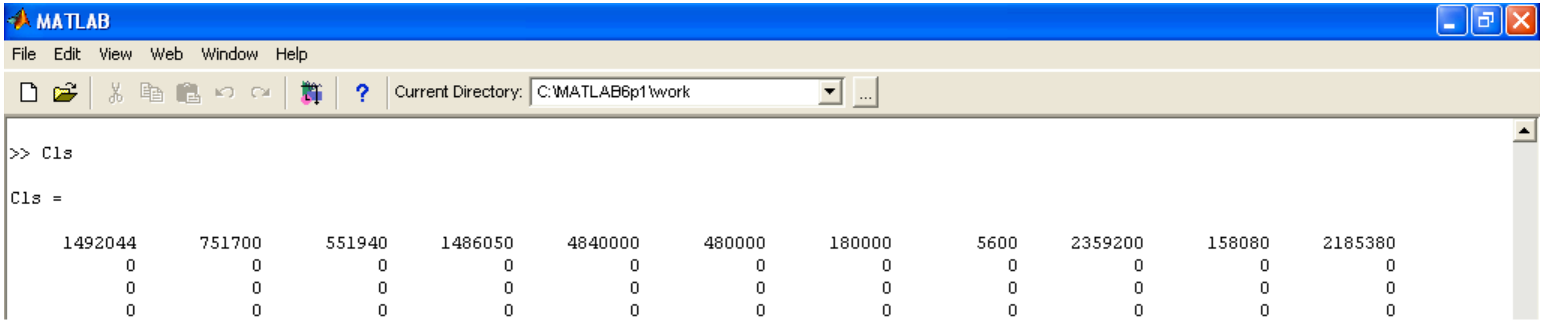
Global cost matrix, expressed in thousands of Francs CFA arranged by construction component $\left[C_{3,t}\right]=\left[U_{3,t}\right]\times\left[Q'_{1,t}\right]=\left(C_{nm}\right)_{n=1,2,3;\quad m=1,2,\ldots,t}$




```
>> C3t

C3t =

  1.0e+006 *

  Columns 1 through 14

    0.0888    0.0258    0.0180    0.0662    0.1372    0.0744    0.0857    0.0135    0.0597    0.1876    0.0253    0.0900    0.0072    0.1050
         0         0    0.0468    0.1720    0.3566    0.1935    0.2229         0    0.1552    0.4878    0.0658    0.2340    0.0187    0.2730
    0.0355    0.0103    0.0072    0.0265    0.0549    0.0298    0.0343    0.0054    0.0239    0.0750    0.0101    0.0360    0.0029    0.0420

  Columns 15 through 25

    0.1440    0.1210    0.1200    0.0500    0.0200    0.0500    0.0538    0.0395    0.5360    0.0863    0.4601
    0.3744    0.3146    0.3120    0.1300    0.0520    0.1300    0.1399    0.1028    1.3936    0.2243    1.1962
    0.0576    0.0484    0.0480    0.0200    0.0080    0.0200    0.0215    0.0158    0.2144    0.0345    0.1840
```

Appendix C

Construction cost matrix, expressed in thousands of Francs CFA arranged by building element $\left[C_{1,s}\right] = \left[I_{1,t}\right] \times^{T} \left[C_{s,t}\right]$



1492044	751700	551940	1486050	4840000	480000	180000	5600	2359200	158080	2185380
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0