

## Optimization of productivity in the rehabilitation of building linked to BIM

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**Abstract.** In this paper, building information modelling (BIM) associated to the principle of significant items emerged at quantities and costs in the optimization of productivity related to the rehabilitation of the building where proposed and discussed. A quantitative and qualitative study related to the field of application based on some parameters such as pathology diagnosis, projects documents and bills of quantities were used for model development at the preliminary stage of this work. The study identified 14 quantities significant items specified to cost value based on the use of the 80/20 Pareto rule, through the integration of building information modelling (BIM) in the optimisation of labour productivity for rehabilitation of buildings. The results of this study reveal the reliability and the improvement of labour productivity using building information modelling process integrating quantities and cost significant items.

**Keywords:** building information modelling; mathematical model; optimization; productivity; significant items; statistical analysis; the 80/20 Pareto-rule

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### 1. Introduction

The construction industry is one of the main sectors important for the development of any country by the socio-economic promotion which is a major contributor to the economy of the country. Productivity is mainly one of the most important factor that has a direct impact on labour performance which mainly coupled to delay, cost and time delivery of the project building information modelling (BIM) associated to the principle of significant items emerged at quantities and costs in the optimization of productivity related to the rehabilitation of the building where proposed and discussed. A quantitative and qualitative study related to the field of application based on some parameters such as pathology diagnosis, projects documents and bills of quantities were used to the development of a data base at any intervention stage of work. It is important to determine the effect and factors affecting the time delay and cost expenditure. Quantities significant items specified to cost value through the integration of building information modelling (BIM) in the optimisation of productivity for rehabilitation of buildings were studied.

For this purpose of this piece of research, labour productivity, building Information modelling, quantity significant items, delay and cost were investigated and used as a mean to build a model by

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emerging characteristics, parameters and all detailed data of the project in package containing the all history of the project, that serves as a data base for present and future intervention at any time of the life cycle of the project for best and rigorous decision making.

### 1.1 Productivity

Labor productivity in construction has been widely discussed by many researchers to find solutions to improve productivity. It is among the most important factors affecting the physical progresses of all construction projects as defined by many researchers (Durdyev and Mbachu 2011, Enshassi *et al.* 2007, Jarkas and Bitar 2012, Lim and Alum 1995, Abdel-Wahab and Vogl 2011, Chigara and Moyo 2014, Hafez *et al.* 2014). Productivity can be the assessment of the work efficiency, and can be measured, in a real and concrete way, by means of a set of indicators whereat relating the produced quantity and the consumed quantity is the common point as defined by Stankiewicz (2002). Productivity represents a major concern in the views of decision-makers, directors or managers to the economy in the building industry. Further, the cost of labor comprises, in most countries, 30 to 50% of the overall project cost as defined by Jarkas *et al.* (2012). In addition, the study of labor productivity in the construction industry arouses incremental attention in which; the construction industry is faced with multiple problems related to its manpower as argued by Horner *et al.* (1989). Rojas and Aramvareekul (2003) argued that labor productivity is considered as one of the best indicators of the production efficiency. Research conducted by Boughaba and Bouabaz (2020) on the identification and risk management related to construction project, they argued that the success or failure of any projects depends on the pace of labour productivity. A research conducted by Horner *et al.* (1989) on labour productivity with the economical side and reported that an increase of 10% in construction labor productivity has resulted in savings of a billion to the UK economy. Moreover, Jarkas and Horner (2015) concluded that productivity in construction fields depends for the most part, on human effort and performance and productivity is the ability to produce more without any additional effort. On the other hand, Handa and Abdalla (2013), defines productivity as the ratio of the production of goods and/or services to basic resource inputs. Many researchers (Al aghbari *et al.* 2017, Arditi and Mochtar 1996, Vogl *et al.* 2015, David Krishna 2000) considered that productivity as a quantity produced per input unit as the ratio between the total outputs and the total inputs, in which is expressed as a rate in %. Therefore, the objective of this section is to identify the factors influencing the productivity to develop a solution t to the case study.

### 1.2 Building information modeling (BIM)

The Building Information Modeling (BIM) is a collaborative process around a digital model, as an integrated way of working based on specific business tools that allow the execution and management of a building throughout its life cycle. Several searchers studied the applicability of building information modeling in field of the construction industry (Zheng *et al.* 2019, Eastman 1995, Zhang *et al.* 2013, DeMaestri 2017, Joffroy 1999, Joblot *et al.* 2016, Morledge and Smith 2013, Stefan *et al.* 2015, Boton *et al.* 2015, Mahamadu *et al.* 2019, Succar *et al.* 2012), by the adoption of BIM for professional activities based on computer tools with application capable of creating and modifying models in a three-dimensional system of a project to be implemented. Eastman (1995), defines building information modeling as a computational environment to support design and construction. According to Joblot *et al.* (2018), building information modeling

Table 1 Primary parameters and dimensions

N°	Agent	Role
1	The owner (private or public, individual or collective)	Financing of the works
2	Architect and/or engineer	Directs and ensure the rehabilitation management
3	The constructor	Execution of the works (in some areas, the know-how has completely disappeared; while in others, it is still possible to build as previously carried out.

represents the virtual construction of a facility that containing smart objects in a unique source file which, is shared among members of the project team, in the aim to increase the volume of communication and collaboration. They define building information modeling as a digital representation of a construction process intended to facilitate the exchange and interpretability of information in digital format. Celni *et al.* (2017) define building information modeling as a process for exchange of information relating to a building for decision making for renovation or new built and support that the digital model information is one of the main tools. Bryde *et al.* (2013) studied the project benefits of building information modeling (BIM) and argued that several benefits have been brought by BIM such as significant project cost and time savings through the project life cycle.

The objective of this section is to synthesize the literature dealing with the integration of BIM into labor productivity in the rehabilitation of buildings, through studies carried out using data files based on building design, planning and bills of quantities, relating to the projects concerned, to meet this objective.

### 1.3 Rehabilitation process and rehabimed

The old buildings become the subjects to an intervention at any time of the life cycle of the project. Most constructions require regular maintenance and periodical rehabilitation. However, the intervention operations on such building differ according to the measures and the actions to be taken. Moreover, the choice to proceed with one of the approaches is based on many factors, such as historical, social, technical, economic and aesthetic factors. RehabiMed method as defined by Casanovas (2007), is a method for the rehabilitation of Mediterranean traditional architecture that requires continued action and evaluation in line with the evolution of the area and inhabitants. The rehabiMed method proposes a four steps process as summarized in Table 1.

## 2. Methodology

Research on optimization of labour productivity by integrating building information modelling (BIM) into the rehabilitation of buildings based quantities significant items is relatively new.

A spreadsheet simulation in Microsoft Excel was used, using a computer for processing the data and the results. Statistical analysis of the results is proposed and developed as a method to optimize labor productivity. An overview of the mathematical and statistical methods applied according to the objectives is presented in the following sections.



Fig. 1 Site map of the rehabilitation project



Fig. 2 Samples of some pathologies detected (BIM)

### 3. Model development

#### 3.1 Diagnosis and rehabilitation study

The study concerns a rehabilitation project of old residential buildings, shown schematically according to the site map Fig. 1 using building information modelling (BIM) with some samples of pathologies detected related to the projects shown in Fig. 2.

#### 3.2 Application of the 80/20 rule to quantities significant

The hypothesis that 80% of the value of a project is contained in only 20% of the bill items is referred to significant items. Many researchers (Horner and Zakieh 1996, Wang and Horner 2007) show that 80% of the value of the measured work in a bill of quantities is contained in 20% of the items. The significant items (SI) method is a way to develop a simple model by using historical bills of quantities from the construction industry.

Table 2 Quantities significant work packages items

N°	Significant work packages	Unit	N°	Significant work packages	Unit
1	Preparation of construction site	u	10	Laminated timber beam 200 x250mm	ml
2	Demolition of false ceiling	m <sup>2</sup>	11	Wooden floor demolishing	M <sup>2</sup>
3	Standardized structural steel profile	kg	12	Plastering with cement mortar	ml
4	Anchor with 12 mm expansion	u	13	Reinforced concrete for raft of 15 cm	m <sup>3</sup>
5	Brick load-bearing wall 14 cm	m <sup>3</sup>	14	Door and window to housing	u
6	Sloped roof Flat	ml	15	Plasterboard false plasterboard	ml
7	Waterproof paint and Potion finish	ml	16	UPN 160 For Bearing	kg
8	Lime plaster	ml	17	Concrete for Unidirectional Flooring	m <sup>3</sup>
9	Sealing and bathroom finishing	ml	18	Retouching of plaster vertical siding	ml

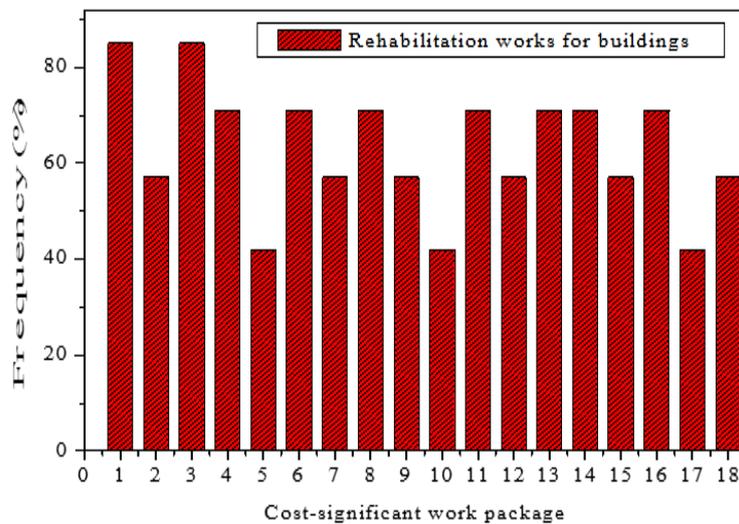


Fig. 3 Histogram showing the frequency quantities significant work packages items

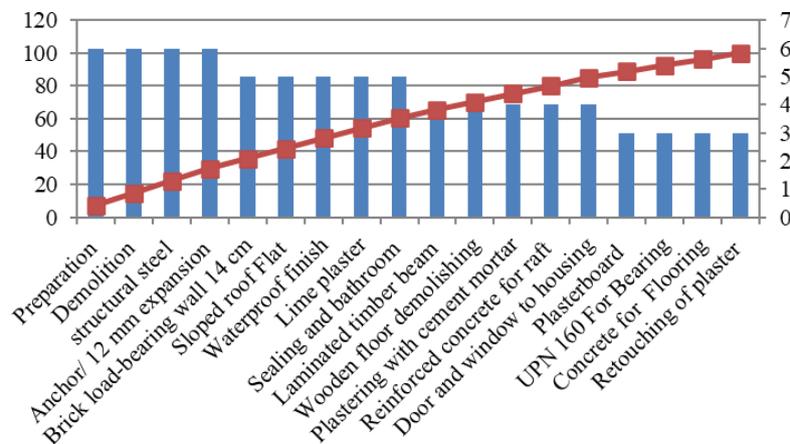


Fig. 4 The 80/20 Pareto-rule

Table 3 Individual frequency and cumulative frequencies for each project

N°	Significant work packages model	Items							Total items	Frequency %	Cumulative Frequencies
		1	2	3	4	5	6	7			
1	Preparation of construction site	x	x		x	x	x	x	6	7.40740	7.407
2	Demolition of false ceiling in reeds	x	x	x		x	x	x	6	7.40740	14.815
3	Standardized structural steel	x		x	x	x		x	6	7.40740	22.222
4	Anchor/ 12 mm expansion connector	x		x		x	x	x	6	7.40740	29.630
5	Brick load-bearing wall 14 cm		x	x	x		x	x	5	6.17284	35.802
6	Sloped roof Flat roof tile or channel	x	x		x	x	x		5	6.17284	41.975
7	Waterproof paint and Potion finish	x		x	x	x	x		5	6.17284	48.148
8	Lime plaster		x	x	x		x	x	5	6.17284	54.321
9	Sealing and bathroom finishing	x	x		x	x		x	5	6.17284	60.494
10	Laminated timber beam 200x250mm	x		x		x		x	4	4.93827	65.432
11	Wooden floor demolishing	x	x			x	x		4	4.93827	70.370
12	Plastering with cement mortar		x		x		x	x	4	4.93827	75.309
13	Reinforced concrete for raft of 15cm	X		x		x		x	4	4.93827	80.247
14	Door and window to housing		x		x		x	x	4	4.93827	85.185
15	Plasterboard false plasterboard	x		x	x			x	3	3.70370	88.889
16	UPN 160 For Bearing		x			x	x		3	3.70370	92.593
17	Concrete for Unidirectional Flooring			x			x	x	3	3.70370	96.296
18	Retouching of plaster vertical siding			x	x			x	3	3.70370	100.00
Total									81		

### 3.3 The concept of work packages

The work packaging concepts involves combining similar items into work packages that are similar in nature and correspond more closely to site operations than to the individual item (Bouabaz and Horner 1990, Otmani *et al.* 2020), The quantities significant work packages proved to be recurrent in every project's bill and the combination of identified potentials quantities significance items between quantities and life-cycle cost were made. Significance of items based quantities results of the Quantities significant work packages items model is presented in Table 2.

The histogram drawn as a bar chart in Fig. 3 show the repetition of items that occur in every project as described in Table 3 to form the packages model.

### 3.4 The Use of 80:20 Pareto Rule

The main objective of this section is to test the 80/20 Pareto -Rule on the adopted quantities significant work packages items model to confirm the most significant items that represent 80% of the total value as shown in Table 3.

Pareto rule were used by many researchers (Asif 1988, Bouabaz *et al.* 2012, Adegoke *et al.* 2017), in the field of estimating and controlling projects. However, Asif (1988) used Pareto law and concluded in his work that the exponential distribution model fits the 80/20 rule and can be used for predicting at least 80% of the project value.

Table 4 Results of estimated values based quantities for each category of cost significant items

N	Bill value	Value of Cswp at 20% (DA)	Estimated value at 20% (DA) cmf = 0.77	Error at 20% (%)	Value of Cswp at 15.5% (DA)	Estimated Value at 15.5% (DA) cmf = 0.78	Error at 15.5% (%)
1	14058033.1	11556792.3	15008821.2	-6.763	10567295.58	13547814.85	-3.629
2	12262602.2	8892353.72	11700465.4	4.584	9965679.68	12776512.41	4.191
3	24059989.7	19478952.5	25630200.6	-6.526	19940016.53	25564123.75	6.251
4	39208112.7	32058794.6	42182624.5	-7.586	29966909.33	38419114.52	-2.012
5	42263000.4	32935872.3	43336674.2	-2.540	33731578.30	43245613.20	2.325
6	59211112.4	40995637.2	53941627.8	8.899	46887403.10	60112055.25	1.521
7	71101854.5	57658153.4	75865991.3	-6.701	55257262.83	70842644.65	-0.364

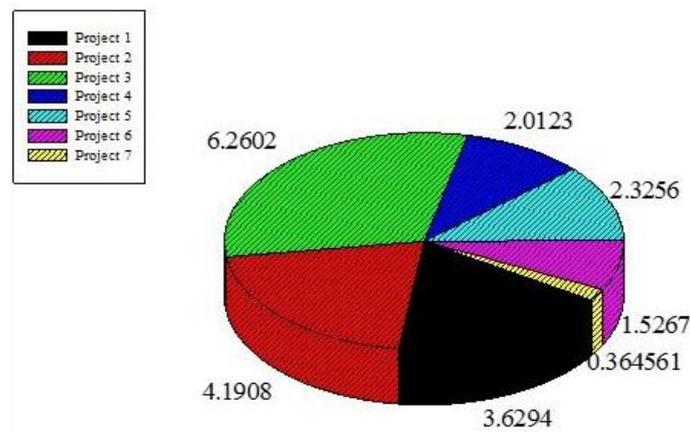


Fig. 5 Error distribution as a total percentage of estimates

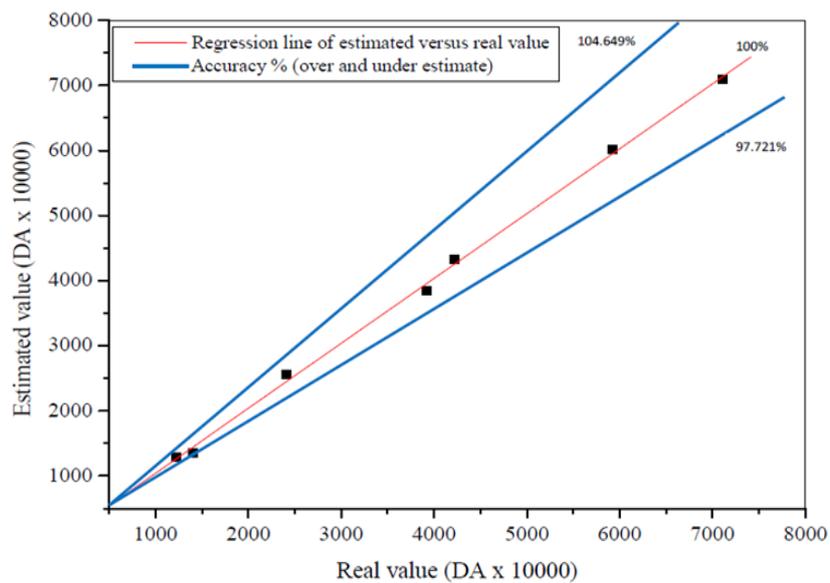


Fig. 6 Regression line of upper and lower limit of estimated versus real value

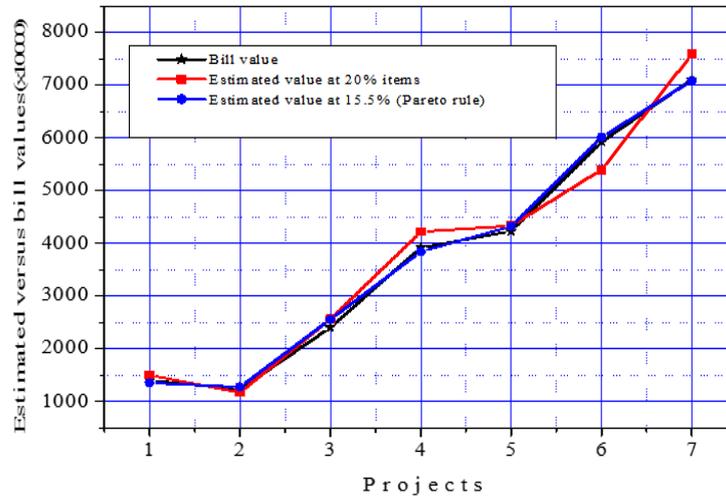


Fig. 7 Linearly plot of bill value versus estimated

### 3.4.1 Pareto analysis

For the purpose of this study Pareto analysis was used as one of the techniques for data analysis and this was achieved by analyzing the quantities significant work packages model for rehabilitation of buildings in order to identify the most significant items that could estimate projects at 80%. The study consists in confirming the 80/20 Pareto rule on rehabilitation projects on a lot of residential buildings composed of set projects as described in Table 3 according to the model developed in order to identify the significant elements that represent 80% of the value of the project.

The results obtained according to the diagram in Fig. 4 shows that activities 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 are responsible for 80% of the cost of the project, which confirms that the said activities are most significant. The study concluded that 80% of the value could be estimated within 14 significant items that represent 15.5% of the items that seems to be the most important.

## 4. Results

### 4.1 Quantities estimation

The results on the testing phase of the model as shown in Table 4 can be interpreted, that at 20% of cost significant items the error is highly observed, while at Pareto's analysis the error is relatively small within 15.5% in which the model could be estimated only by 14 items that represent 80% of the bill value. The final estimated value is determined by the cost model factor.

The error distribution over each project as shown in Fig. 5 is defined as the percentage difference between the estimated and real value extracted from the bill.

### 4.2 Statistical analysis

The model validation based statistical methods and testing stages is shown in Fig. 6. The slope is close to 1 and the intercept is close to 0. In addition, regression analysis can provide the value of

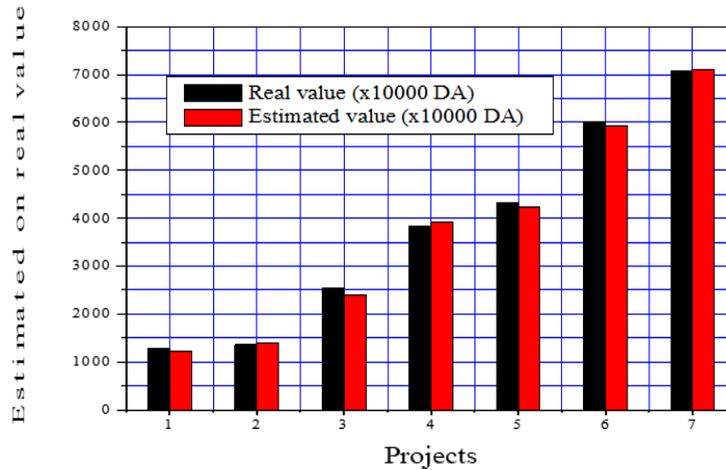


Fig. 8 Histogram of bill value versus estimated at 15.5% (Pareto diagram)

the correlation coefficient ( $R^2$ ) between the actual value and the estimated value that confirms the accuracy and the efficiency of the results. This variable measures the variation between the actual value and the estimated result by the  $R^2$  in which is close to 1, indicating a good fit and linear. The statistical analysis of the model at testing phase is presented graphically on the Fig. 6. The trends lines show the medium, the over and the under estimate at testing phase according to the calculation of the accuracy, where the accuracy oscillates between 104.65% this can be interpreted that an over estimate of 4.65% could be resulted. The under estimate is about 97.72%, this can be a save of 2.28% to the owner. Statistically the residuals demonstrates higher accuracy at higher costs where the quantities are very significant.

#### 4.3 Performance comparison of the model

The comparison of all the set of projects at testing phase along with the real values versus estimated values in terms of accuracy and statistical analysis can be better visualised through the Linearly plot and the histogram bar chart as shown in Figs. 7 and 8.

## 5. Conclusions

This study has demonstrated the use of a mixed applications approach to the optimization of labour productivity in the rehabilitation of building by link to building information modelling (BIM) associated to the principle of significant items emerged at quantities and costs. However, it is a success and a step forward in the field of research in general and construction management in particular to link building information modelling technology and the integration of the principle of significant items that make a huge data base for the whole life cycle of the case study and we conclude that:

- The model developed may be of the form cost equals the sum of Quantities by the unit rate of each packages unit rates divided by the model factor. The results from the plot of the estimated on the real values are almost identical as shown in Fig. 6.

- The results obtained have revealed that the model established has given better results using quantities and cost significant work packages methods. A low MSE (Mean Squared Error) values at development and testing phases confirm the results accuracy.

- The results from Pareto rule concluded that the cost of quantities significant items is within 15.5% that represents 14 quantity significant items that represent 80% of the total cost.

Therefore, this study expected to be a means for future research via the application and integrating building information modelling for civil engineering and construction management projects. However, the adoption of this development will promotes the field of construction management for better decision-making by the professionals in the construction industry. The results of this study reveal the reliability and the improvement of labour productivity following the building information modelling process adapted in this study to the rehabilitation of building project.

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