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Simple Method Proposal for Cost Estimation from Work Breakdown Structure

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Abstract

Regardless the extensive literature in project management, the model for cost estimation remains unclear and unexploited mainly in terms of simple methods. Accuracy effort and schedule estimation is still a challenge. This paper introduces stream lining procedures from project work breakdown structure (WBS) evaluating the duration processes and either the input cost hour or the fixed costs. The measures are made via hypothesis testing over the responsibility assignment matrix (RAM). We propose a method for project cost construction using a spreadsheet to create an early-stage budget allocation. In this paper we argue that the simulated cost results present superior accuracy while establishing the applicability of the proposed simulation procedure. Generally, the precision is related with the WBS detailed design. The cost methodology approach offers a simplified decision tool for assessing the construction cost on the project managers' decision.

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Keywords: Project Cost Estimation; Project Management; WBS and Responsibility Assignment Matrix.

1. Introduction

Project management literature refers cost estimation which is essentially performed using two methodologies: probabilistic and deterministic [1, 2, 3, 11]. Probabilistic estimation is used when there isn't much information

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available, when uncertainties exist in early estimates of the project or to simplify the probability of cost overruns of the project the management reserve funds. The estimation procedure includes simulation processes from data collection, model formulation analysis, and for example Monte Carlo simulation [4, 5, 6]. The deterministic approach is generally used for detailed estimation when specific data permits realistic accurateness. Estimation procedures normally implement value estimation established on historical data or personnel professional experience. Associated approach techniques applying, linear programming, and optimization [7, 8, 9]. However, in practice detailed information generally cannot be accessed in time for use in budget proposals during initial stages. In situations involving inadequate information during the initial stages of the project, project management typically uses subjective experience judgments or draws analogies with similar projects to perform deterministic cost value estimates [10, 11]. The methodology proposed in this paper is suggested by the authors to carry out this work using the WBS combined with RAM variants, both of which are also a project executing judgment. This paper is organized as follows: next section describes cost assessment methods where a brief explanation is given. Next, the proposed methodology is examined, starting with brief WBS considerations. Then follows an explanation of the RAM and how it relates with WBS. The next phase of the proposed method describes the RAM transformation into duration Resources Assignment Matrix (RAM_d). Then it is shown the conversion of the RAM into a cost estimation Resources Assignment Matrix for the project (RAM_s). Finally, in the last section, the conclusions are presented along with some suggestions for improving the approach and future research steps.

2. Cost assessment methods

Cost assessment practices may be categorized into qualitative and quantitative procedures [1, 2, 3, 11, 12]. Qualitative cost estimation procedures employ historical data and with expertise experience is drawn an estimate project costs [13, 14, 15]. Since relevant historical data shares features with the current project, it is possible to infer estimation in terms of design, process, data, and knowledge and forecasting project costs. Nevertheless, this approach suffers some problems: the likeness is problematic to extent and deeply influenced by subjectivity and the influence on project costs processes may not be effectively measured [2, 16, 17]. Even though these inadequacies, qualitative calculations may offer a reference for experienced project managers.

In another way, quantitative procedures rely on historical data and professional understanding to analyze project designs, processes, and unique features. Systematic methods are used to discover cost tasks and resources used in project activities to define project costs [1, 14, 15, 16, 17, 21]. During these practices, a project manager may get assessments for project costs and they also need time to collect enough information during the initial project. Linking ideas, the probabilistic valuation technique fits to the quantitative group [8, 9, 15], and moreover accomplishes approximations with probability data on event under repetitive simulation realizations [1, 2, 15, 16]. In the case of software development projects, over the last fifteen years software cost estimation research has shown a growing interest in the use of combinations of statistical prediction and machine learning techniques as these were proved able to detect composite relationships. Classic approaches like algorithmic models [4, 5, 6, 7] involve analytical or statistical equations relating the software project costs to a number of input parameters called cost drivers. The procedures change lately, because of the agile movement, however historical data are still necessary to an effective cost estimation [24, 25]. In order to acquire relevant knowledge to make a good estimate of project costs, we need to make an approach which integrates the organizational component, that is the project team [8, 17, 18, 19]. The authors believe that to include this organizational approach, we need a good project design which shall include the WBS [10, 13, 15] and the RAM [10, 13, 15, 20, 21, 22, 23].

3. Methodology and approach

As stated previously, the proposed methodology aligns the project WBS with RAM. These design elements are the key to the whole process, since they offer a good view of project details, providing the basis for the calculation of estimated costs, even in a pre-project phase. The process uses a spreadsheet containing a representation of WBS and also RAM as shown in Figures 1 and 2 respectively. The method proposes upgrading WBS in RAM, which is then, modified RAM_d, which contains time duration estimates. This is a modified RAM, where now each assigned

responsibility is replaced by an estimate of the duration of the activity. Then, a new line is added representing an estimated cost / charge per unit time of work activities, resulting in RAMs. From this last, it is easy to determine the project cost estimate. The entire process is explained in detail in the remainder of this paper.

3.1. Project Plan and WBS Design

The project scope of work is an iterative process that is commonly complete by the project team with the use of a Work Breakdown Structure (WBS), letting the team capture and then decomposes all of the effort of the project. All of the defined work must be planned, assessed and approved with the use of combined management control plans [10, 13, 20, 23]. Consequently the project team should organize and present the project plan, which includes the following items:

- Project Charter;
- Summary project management strategy;
- Scope statement, e.g. objectives and deliveries;
- WBS to the level of which control may be exercised;
- *Cost estimates with schedules start and finish dates*;
- Responsibility assignments for each deliverable within WBS;
- Major milestones;
- Risk management;
- Other management plans.

So, we have all the necessary to implement the methodology, allowing an integrated item that justify “*Cost estimates with schedules start and finish dates*”. The Figure 1 shows a WBS sample, which will be used to explain the methodology.

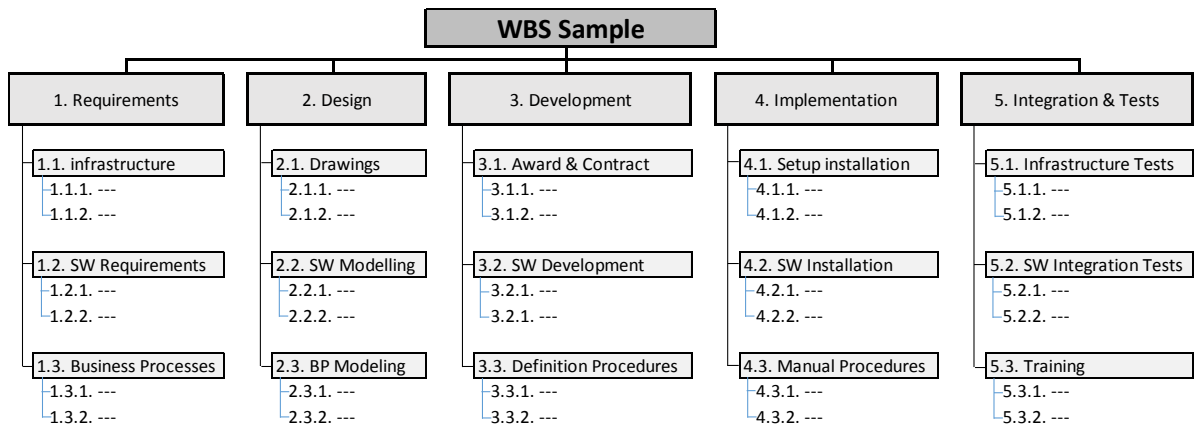


Fig. 1. WBS Sample to explain the methodology.

The WBS sample follows the Rolling Wave Project Planning (RWPP) since this approach to project development, is a phased iterative applicable to new product development, information systems and other technical development environments. It is an excellent formal project development approach for creative work [26]. When done well, it balances structured process with flexibility as shown. Another observation from Figure 1 is that the WBS is divided into three layers, as the authors believe that most of the designs involve an infrastructure that will have a particular contract, a software development and application of technology and finally both must be integrated

with the human component of the organization. These three layers develop a good design WBS, since a well-designed WBS is crucial to the success of cost estimation methodology proposed.

3.2. Responsibility Assignment Matrix

Project responsibilities roles must be assigned to project participants. In practice, participants can vary over time; however the authors recommend that the strategic level should be used against the operational level, where this variation occurs more frequently. Thus, it is also recommended, in other author's assignment of responsibilities roles to participants who are involved in the project's success. In addition to, its functions and project manager's responsibilities are generally more critical; however they may vary according to the application area of the project [10, 13, 15, 20, 21, 23]. In conclusion, the Responsibility Assignment Matrix (RAM) should be strategic, and is used to ensure that each project management component is assigned to a responsible staff. The following Figure 2 shows a generic RAM, which will be used to explain the methodology.

WBS Item \ Role	Owner Work	Functional Manager A	Functional Manager B	...	Functional Manager K	Project Manager	Business Analyst	Programmer	Security Expert	Web Designer	Back Office	Contractor 1	Contractor 2	...	Contractor i
1. Requirements	S				I	R			A						
1.1. Infrastructure		P	I		S	P	R								
1.1.1. ---		A	A		S	R									
1.1.2. ---		A	A		S	R									
1.2. SW Requirements		S	P	P	P	P	R		A		I				
1.2.1. ---			P		S		R				I				
1.2.2. ---		S	P	P	P		R		A						
1.3. Business Processes	S	P	A	P	P	P	R				I				
1.3.1. ---			S	P	I		R				I				
1.3.2. ---		P	A	P	S		R				I				
2. Design						R									
2.1. Drawings					S					I	R				
2.1.1. ---	S	P	A			P	I			R					
2.1.2. ---					S		I			A	R				
2.2. SW Modelling		S	P			P	R	I	I	I	I				
2.2.1. ---			S				R		I						
2.2.2. ---		S					R	I		I	I				
2.3. BP Modeling	S	P	P	P	P	P	R				I				
2.3.1. ---			P		P		R								
2.3.2. ---			P		P		R	I							
3. Development			S	P		P	I	R	I	I	I				
....															
5.3. Training	S	P	P	P	P	P	R								
5.3.1. ---			P				R								P
5.3.2. ---		P			P		R			I		I			

P = Participant A = Accountable R = Review Required I = Input Required S = Sign-Off Required

Fig. 2. RAM sample to explain the methodology.

3.3. Time Duration Estimation

By assigning responsibilities in the project, the project manager is now able to make a length of time estimate for each item in the WBS. In case of difficulty in estimating, they could refer the matter or even historical data of similar projects in order to better consolidate the estimate. The authors suggest that in a first iteration, it is not necessary to use the complete RAM, as it has being used to work in a strategic level. A simpler version is sufficient, as Figure 3 shows.

WBS Item \ Role	Owner Work	Functional Manager A	Functional Manager B	...	Functional Manager K	Project Manager	Business Analyst	Programmer	Security Expert	Web Designer	Back Office	Contractor 1	Contractor 2	...	Contractor i
1. Requirements	S				I	R			A						
1.1. Infrastructure		P	I		S	P	R								
1.2. SW Requirements		S	P	P	P	P	R		A		I				
1.3. Business Processes	S	P	A	P	P	P	R				I				
2. Design						R									
2.1. Drawings					S					I	R				
2.2. SW Modelling		S	P			P	R	I	I	I	I				
2.3. BP Modeling	S	P	P	P	P	P	R				I				
3. Development			S	P		P	I	R	I	I	I				
....															
5.3. Training	S	P	P	P	P	P	R								

Fig. 3. Strategic Responsibility Assignment Matrix.

This reduction simplifies the work, since only responsible for the strategic work package is included. Then each row of the RAM is changed by the length of time estimated as Figure 3 shows. It is assumed that each role (letter), for example in the design task responsibility is changed by a number corresponding to a length of time in accordance with the rules as shown in Table 1.

Table 1. Corresponding function to RAM letter: standard PMI [13].

RAM letter abbreviation	Function	Meaning
P	Participant	Usually a meeting
A	Accountable	Must be consulted
R	Review Required	Responsible for the Execution
I	Input Required	Must provide Information
S	Sign-off Required	Approval Responsible

In terms of run or execution time, “R” is the overall implementation. Other letters usually designate a meeting, or someone to be heard or an approval, which means, once the rule is assimilated to meetings, communication channels or the like. In this article, the authors used the nomenclature indicated by the PMI [13]. Other forms may be more useful to the project manager, according to their experience. For example, the Cleland & King [20] nomenclature, as indicated in Table 2 is another possible form, which may seem more appealing.

Table 2. Alternative standard: Cleland & King [20].

RAM letter abbreviation	Function	Meaning
X	<u>e</u> Xecute work	Responsibility for Implementation
D	<u>D</u> ecide	Responsibility for Management
d	<u>d</u> ecide jointly or in part	Responsibility for Management
T	<u>T</u> ask tutor (define rules and regulations)	Responsibility for Management
P	controls <u>P</u> rogress	Responsibility for Management
C	must be <u>C</u> onsulted	Communication Channel
I	must be <u>I</u> nformed	Communication Channel
A	available to <u>A</u> dvice	Communication Channel

WBS Item \ Role	Owner Work	Functional Manager A	Functional Manager B	...	Functional Manager K	Project Manager	Business Analyst	Programmer	Security Expert	Web Designer	Back Office	Contractor 1	Contractor 2	...	Contractor i
1. Requirements	1h				0.5h	4h			2h						
1.1. infrastructure		0.5h	0.5h		1h	1h	2d					10.000€	2.500€		5.000€
1.2. SW Requirements		0.5h	1h	0.5h	1.5h	1h	2d		1h		1h				
1.3. Business Processes	1h	0.5h	1h	0.5h	1h	4h	4d				1d				
2. Design						2h									
2.1. Drawings					2h					2d	2d				
2.2. SW Modelling		1h	1h			1h	3d	4h	1h	2h	1d				
2.3. BP Modeling	1h	1h	1h	1h	1h	1h	1w				3h				
3. Development			1h	0.5h		1h	4h	3w	1d	2h	2d				
....															
5.3. Training	1h	1h	1h	1h	2h	1h	2d								
Duration Time	4h	3.5h		3.5h	9h	16h	22d	15.5d	1.5d	2.5d	6.5d	10.000€	2.500€		5.000€

Fig. 4. RAM changed to Duration Time Estimation – RAM_t.

In RAM_i which Figure 4 shows, the contractors are inserted with fixed costs, since it is a contract it does not need to include an estimative of time, after all the goal is an estimate of the project cost. Other ways to estimate are possible, for example rentals with a fixed cost, this situation would have to include the time of rental. The authors believe that the use of a spreadsheet, as described in the methodology allows a great versatility to handle with new situations. Another example is to include the five PMI processes [13], which add more rows and execution time for project.

This altered RAM_i as shown in Figure 4, includes project participants (left side of the project manager), on the ground that some projects need to have a project cost estimate that the company will have to ensure in its successful implementation. This serves the purpose for example; in projects co-financed the company needs to put part of the project budget. If this is not the case, the RAM_i amended may include only the right side of the project manager.

3.4. Rate Estimation for each Activity

Each activity is performed by some specialized area. The project participant responsible may provide an estimative cost per hour. Usually this is based on previous experience or eventually on historical data. With this estimative number, RAM_i is changed as shown in Figure 5 into RAM_s . The process may be easily performed if used a spreadsheet. As shown in Figure 5, the Estimation Cost it obtained per each column as Equation 1 shows:

$$Cost\ Estimation_i = Hour\ Estimation\ Cost_i \times Duration\ Time_i \quad (1)$$

WBS Item \ Role	Owner Work	Functional Manager A	Functional Manager B	...	Functional Manager K	Project Manager	Business Analyst	Programmer	Security Expert	Web Designer	Back Office	Contractor 1	Contractor 2	...	Contractor I
Hour Estimation Cost	60 €	25 €	25 €	15 €	15 €	75 €	60 €	25 €	75 €	40 €	40 €	10.000€	2.500€		5.000€
1. Requirements	1h				0.5h	4h	0:00		2h			10.000€	2.500€		5.000€
1.1. Infrastructure		0.5h	0.5h		1h	1h	2d								
1.2. SW Requirements		0.5h	1h	0.5h	1.5h	1h	2d		1h		1h				
1.3. Business Processes	1h	0.5h	1h	0.5h	1h	4h	4d				1d				
2. Design						2h									
2.1. Drawings					2h					2d	2d				
2.2. SW Modelling		1h	1h			1h	3d	4h	1h	2h	1d				
2.3. BP Modeling	1h	1h	1h	1h	1h	1h	1w				3h				
3. Development			1h	0.5h		1h	4h	3w	1d	2h	2d				
....															
5.3. Training	1h	1h	1h	1h	2h	1h	2d								
Duration Time	4h	3.5h	6.5h	3.5h	9h	16h	22d	15.5d	1.5d	2.5d	6.5d	10.000€	2.500€		5.000€
Estimation Cost	240,00 €	87,50 €	162,50 €	52,50 €	135,00 €	1 200,00 €	10 560,00 €	3 100,00 €	900,00 €	800,00 €	2 080,00 €	10.000€	2.500€		5.000€

Fig. 5. RAM used to calculate an Estimation Cost – RAM_s .

3.5. Project Cost Estimation

Now the final project estimation cost, based in Equation 1 it is the sum of all columns, Equation 2 shows:

$$Cost\ Estimation = \sum Hour\ Estimation\ Cost_i \times Duration\ Time_i \quad (2)$$

For the example, the value must also add the fixed cost from the contractors. Figure 6 shows the procedure:

WBS Item \ Role	Owner Work	Functional Manager A	Functional Manager B	...	Functional Manager K	Project Manager	Business Analyst	Programmer	Security Expert	Web Designer	Back Office	Contractor 1	Contractor 2	...	Contractor I	Total
Hour Estimation Cost	60 €	25 €	25 €	15 €	15 €	75 €	60 €	25 €	75 €	40 €	40 €	10.000€	2.500€		5.000€	
Duration Time	4h	3.5h	6.5h	3.5h	9h	16h	22d	15.5d	1.5d	2.5d	6.5d	10.000€	2.500€		5.000€	
Estimation Cost	240,00 €	87,50 €	162,50 €	52,50 €	135,00 €	1 200,00 €	10 560,00 €	3 100,00 €	900,00 €	800,00 €	2 080,00 €	10 000,00 €	2 500,00 €		5 000,00 €	36 817,50 €

Fig. 6. Project Estimation Cost

In summary, the methodology can be represented as Figure 7 shows. In conclusion the start is marked from WBS, which has set them the responsibility by creating the RAM. To create the RAMs the roles of the participants in RAM should be replaced for time estimates. In continuity, are inserted costs estimates, contracts and other values by creating a RAM_{ζ} . From this last overall project cost estimation results in the sum of the products as indicated in Equation 2.

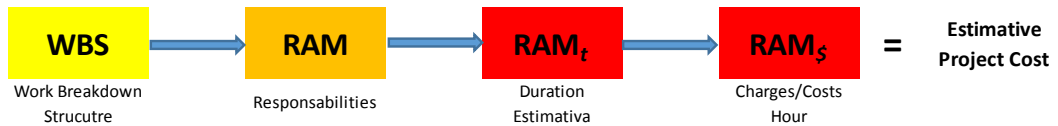


Fig. 7. Methodology synthesis proposal.

4. Discussion

This approach is a Simple Method for Cost Estimation from Work Breakdown Structure. As exposed, provisional cost estimation is easily obtained. The results indicated the applicability of the approach and suggested that the generation of the cost estimation may be conceived as a fairly good solution starting from the WBS and RAM, associating time and charges according to the nature of the project environment. The overall estimation project cost, may be complemented within the methodology including other project features, such as: projects meetings and PMI processes. All the detail stands in the WBS, and using a spreadsheet, any WBS change, is easily accommodated through all the steps: Responsibility Assignment Matrix, Time Estimation, Charges/Contractors cost estimation and finally the sum of all costs.

The authors believe that the outcome of the current research adds a contribution to the current body of knowledge in the cost management practice; however the method is not exempted from shortcomings as expected. Among the shortcomings, firstly, the method required further validation with practices projects. Secondly, based on the concept model developed, all the underlying factors needed to be tested or hypothesized in order for the evaluation of the quantitative impacts of each step on the overall cost estimation of the project.

5. Conclusion

Accurately and proficient estimating construction costs during the pre-conceptual stage can determine project viability. However, generating accurate estimates is typically a difficult task as reliable information is generally not available during this phase. This paper shows a simple method that reduces uncertainty in cost estimates during the pre-conceptual stage via WBS and correlated with the responsibility assignment matrix projects.

Overall, the main contributions of this paper are: Firstly, the authors developed and showed an appropriate method for the initial phase cost estimation of a project that attempts to overcome the limitations oriented metrics estimation on existing approaches, in general complex. Secondly, the proposed methodology allows project managers to make quantitative estimates of costs with a qualitative approach using the RAM project environment. This approach also helps to improve the learning of organizational management. Finally, the use of responsibility matrix where the roles of functions are changed to an estimate of time and subsequently cost estimation / contracts provides a simple method to estimate all costs where other design characteristics are also easily accommodated.

Future work should be focused on the application of the proposed methodology to identify opportunities for improvement as well as detect their weaknesses, which certainly exist. The use of information systems for the historical project data management can and should also be studied, as will facilitate the collection of elements such as duration estimates and average costs.

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