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Dr. Euysup Shim and Dr. Seong-Jin Kim

ABSTRACT

In construction projects, overall markup amount needs to be distributed to each activity. Therefore, a unit price for each activity in unit price bid should be submitted including markup and a value of each activity including cost and markup is required by project owners in lump-sum contract. Since distribution of markup can affect a contractor's cash flow, a contractor's profit markup distribution has been of interest to contractors and researchers. Two existing methods for markup distribution are proportional distribution and front-loaded unbalanced distribution. While the proportional markup distribution approach is simple and straightforward, it does not relieve the contractor's financial burden which is transferred from the project owner. While the front-loaded unbalanced markup distribution approach can improve the contractor's cash flow, this approach is regarded as an unethical strategy due to potential additional cost to project owners. Furthermore, a front-loaded unbalanced markup distribution may not be accepted by project owners. This paper presents a new approach to markup distribution which is based on different markup rates among different cost items. A framework for the new approach was developed using an Excel spreadsheet and the Excel solver add-in. The framework is to find the optimal markup rates for cost items, and the optimization problem can be solved by the Excel solver. The framework, furthermore, can enhance understanding and control of the problem solving procedure through visual presentation of variables in the Excel spreadsheet. The proposed framework would be helpful to contractors as an alternative tool for markup distribution in construction projects.

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Introduction

In construction projects, the contractor's general overhead cost and profit are components of the total construction project price in addition to estimated construction cost (both direct and indirect costs). While construction cost for a project can be estimated accurately according to project documents, such as drawings and specifications, general overhead cost and profit are more difficult to estimate accurately and can be affected by many factors, such as market conditions, or contractors' need for the job (Peterson, 2009). Many contractors may determine the amount of general overhead cost and profit in terms of markup as a percentage of total construction cost: for example, 15% of total construction cost (Peterson, 2009).

The amount of markup determined by the contractor needs to be distributed among construction activities in a project. Under a unit-price type contract, contractors (or bidders) need to determine the unit-price of each activity by distributing overall project markup amount among each activity. Under a lump-sum type contract, contractors (or general contractor) are required to submit a schedule of values (SoV) to the project owner which shows the value of each activity. The value of each activity includes not only costs to the contractors, but also a portion of the overall markup amount.

While the markup amount allocated to each activity can indicate amounts of profit and general overhead costs which are proportionally distributed, distribution of overall markup amount in each activity can affect cash-flow to the contractors (Mincks & Johnston, 2011). For example, by inflating the markup amount for early activities and deflating the markup amount for late activities, contractors can improve their cash-flow and reduce interest costs (Peterson, 2009). Furthermore, the contractor's profit can be increased by manipulating the markup distribution in case of expected errors in quantity of work provided by the owner's representative (Cattell, 2012). Due to the impacts of markup distribution on the contractor's cash-flow and profitability, how to distribute the markup to construction activities has been of interest to both construction practitioners and researchers.

This paper presents a new approach to the distribution of overall markup to each activity through cost item-based distribution of the markup. This paper is composed in the following sequence. First, existing methods for markup distribution are reviewed, and their advantages and shortcomings are discussed. Next, the problem statement for this research and objective of this research are discussed. Then, a new framework for markup distribution based on cost items is presented with a hypothetical project. Its effectiveness is determined by comparing the results from the proposed framework to existing methods. Lastly, discussions on the proposed approach and conclusions are presented.

Existing Methods for Markup Distribution in Construction Projects

Markup distribution to each construction activity is required for unit price bidding and for lump-sum contracts. Bidders are required to determine the unit price for each activity based on quantity of work provided by the engineer (or project owner's representative) under unit-price bidding. Amounts of markups distributed to activities are considered to determine the winner of the bid (Cattell, Bowen, & Kaka, 2007). In the case of lump-sum type contracts, project owners require contractors to submit a schedule of values prior to the start of construction, and each activity's value should include cost to the contractor (direct cost and indirect cost) for the activity and a portion of markup (Peterson, 2009). The schedule of values submitted by the contractor is used as a basis for progress payments. While the purpose and usage of markup distribution in unit price bidding and schedule of values are different from each other, the basic idea of distributing overall markup to activities is similar. Therefore, in this paper, no distinction in markup distribution between unit-price bidding and schedule of values is made.

One of the methods to distribute overall markup is to allocate markup amounts proportionally to the cost of each activity. As briefly explained by Mincks and Johnston (2011), the markup amount to one activity is determined by the percentage of the activity's cost to total cost. This method leads to 'balanced' markup in each activity and is simple to calculate. However, due to 'balanced' distribution of markup, it is less likely that cash flow is improved by this method and 'unbalanced' markup distribution method is used by some contractors (Cattell, Bowen, & Kaka, 2010).

Another method for distribution of markup is to allocate overall markup non-proportionally to each activity or uneven distribution. This method has three different approaches as classified by Cattell (2012):

- *Front-end loading*: a higher markup rate is used for distribution to early activities and a lower markup rate is used for late activities. While the total project cost (or bid price) is not changed by *front-end loading*, contractors can receive larger amounts of cash (progress payment) early on. This can improve the cash-flow to contractors.

- *Back-end loading*: if high inflation is expected, contractors increase the markup (or unit price) for late activities which have a high expected escalation. Contractors can get additional escalation in compensation for inflation.

- *Quantity error exploitation*: if contractors expect change (increase) in one activity's quantity, the activity's unit price is increased along with reduced unit price for other activities at no change in total bid price. When the quantity increases, contractors can get increased benefit from inflated unit price.

Out of these three unbalancing approaches, the second approach, *back-end loading*, is not considered in this paper as it is not common in construction projects under relatively short duration with low inflation rate as in the United States (Arditi & Chotibhongs, 2009). Also, the third method, *quantity error exploitation loading*, is regarded as illegal by U.S. Department of Transportation Federal Highway Administration (Arditi & Chotibhongs, 2009) and, therefore, not considered in this paper.

Due to the possibility of improvement in the contractor's cash-flow and profit, unbalanced distribution of markup by front-end loading has been of interest to many researchers and several different unbalanced bidding models have been proposed (Stark, 1974; Ashley & Teicholz, 1977; Diekmann, Mayer, & Stark, 1982; Nassar, 2004; Cattell et al., 2007; Cattell, Bowen, & Kaka, 2008). In general, two different approaches to unbalanced markup distribution by front-end loading exist: 1) to optimize markup values for activities by mathematical model, and 2) to distribute markup manually.

The existing mathematical models to optimize markup values have different objectives: A) maximized present value of benefits to the contractor (Cattell, 2013), B) maximized profit to the contractor along with each activity's degree of contribution to profit (Cattell et al., 2007), and C) minimized risk to the contractor (Christodoulou, 2008; Afshar & Amiri, 2010; Cattell et al., 2010). The mathematical models under this category can provide optimal solutions, but the solutions are related to either the upper limit or lower limit of the markup rate (Cattell, 2013). While the results lead to maximized benefit to the contractor, markup distribution is extremely unbalanced. Therefore, it is more likely that an extremely unbalanced bid or schedule of values under this approach may be rejected by project owner (Cattell et al., 2010).

Mincks and Johnston (2011) explain a manual distribution of markup. Based on timing of activities scheduled, early activities and late activities are selected. Then, the markup rate for early activities is inflated and that for late activities is deflated so that there is no change to the overall project price. While this approach is very simple and straightforward, it takes more time than a mathematical model and the results may not be optimal.

The existing markup distribution methods by front-end loading find a markup rate for each activity and the critical factor is timing of each activity: the earlier an activity is scheduled, the higher markup rate is allocated (Shrestha, Shrestha, & Joshi, 2012). However, this approach may not be preferred by the project owner: the amount of markup required for each activity is not directly related to timing of the activity. Also, this approach may increase profit to the contractor and cost to the project owner. Therefore, unbalanced markup distribution through *front-end loading* is regarded as unethical by project owners and many contractors (Arditi & Chotibhongs, 2009).

Another pitfall of unbalanced markup distribution through front-end loading is considering only the activity's timing for markup distribution (Cattell, 2013). The order or timing of activities is not directly related to the amount of markup for each activity. Instead, contractors may need different markup amounts among different cost items: material costs, labor costs, equipment costs, and subcontract costs. For example, higher markup rate may be needed for labor costs than subcontract costs because contractors need more effort for labor supervision and administration.

The last disadvantage of existing approaches to unbalanced markup distribution through front-end loading is 'unrealistically' simplifying cash-flows (Peterson, 2009). Cash-flows which are to be optimized in the existing mathematical models are represented by the present value of cash-inflows to the contractor or the present value of net cash-flows in each construction activity: *price (cash-inflow) less cost (cash-outflow)*. This simple representation does not reflect the cumulative interaction of cash-outflows (labor, material, equipment, and subcontract cost) and cash-inflows (progress payment less retainage): different timing of cash-inflows and cash-outflows makes the contractor's balance different from net cash-flow (difference between total cash-inflows and total cash-outflows) (Lucko, 2011).

Problem Statement and Objective

The existing methods to markup distribution in construction projects have been shown to have the following shortcomings: 1) potential to be regarded as unethical, 2) irrelevant consideration for markup distribution (no consideration of different cost items and unnecessary consideration of activity's timing), and 3) usage of assumptions which are too simple to be realistic (no reflection of cumulative interaction between cash-inflows and cash-outflows). Therefore, the objective of this research is to develop a new approach to markup distribution which can overcome the shortcomings of the existing methods.

Framework for Cost Item-based Markup Distribution

This section is to present a new framework for markup distribution based on different cost items for more detailed and realistic solutions.

Cash Inflow to Contractors

Contractors in construction projects typically receive monthly progress payments depending on the amount of work finished. Actual amounts of cash inflow to contractors are affected by the following two factors: 1) delay in progress payment and 2) owner's retainage (Peterson, 2009).

The process of progress payment is initiated by submitting a pay request to the project owner's representative. Then, the pay request is reviewed by the owner's representative and submitted to the project owner. After the project owner's review and approval, the contractor receives progress payments. A typical pay cycle is 30 days but may be extended to 45 to 60 days due to poor economic situations in the industry (Setzer, 2009). Project owners withhold a portion of every billed amount until completion (or substantial completion) of the project to ensure the project is performed according to construction documents. Both delay in progress payments and owner's retainage cause contractors to use their own cash (or to borrow cash, if not available) to support construction operations.

Cash Outflow to Contractors

Cash outflow to contractors includes payment for different cost items: material costs, labor costs, equipment costs, subcontract costs, and other costs. The amount of cash-outflows and their timing vary depending on the type of cost item and are affected by: 1) contractor's retainage, and 2) 'pay-when-paid' clause.

As the project owner withholds a portion of every billed amount, the general contractor withholds the same portion of the billed amount from subcontractors (Peterson, 2009). One of the common payment terms in contracts between the general contractor and subcontractors (or material suppliers) is the delay in payments to subcontractors or suppliers until the general contractor receives a progress payment from the project owner (Peterson, 2009).

Contractor's retainage and 'pay-when-paid' clause may be applied to cost items differently. Thus, the amount of cash-outflow to contractors can be determined for each of the cost items as followings:

- Labor costs: contractors are required to make payments for labor costs either weekly or bi-weekly by law. Therefore, labor costs must be paid irrespective of receipt of progress payment from the project owner.

- Material costs: typically material costs are paid by the contractor in full, but 'pay-when-paid' clause is applied.

- Subcontract costs: both contractor's retainage and 'pay-when-paid' clause are applied to subcontract costs. Thus, no financial burden is on the contractors: the financial burden is transferred to the subcontractors (Peterson, 2009).

Different Markup Rates among Cost Items

As discussed by Mincks and Johnston (2011), contractors may need different markup rates among cost items. For example, if a general contractor hires a subcontractor (or specialty contractor) in a lump-sum contract, the subcontractor takes responsibility for the cost and duration of that portion of the project. Therefore, the general contractor's markup to cover job-site indirect costs may decrease. Another example is markup amounts for material costs. As suggested by Cui, Hastak, and Halpin (2010), if the project owner allows inclusion of costs of the material, which was delivered and stored at the jobsite but not installed, in monthly progress pay requests, the contractor may need less markup amount for material cost.

Distribution of markup is not directly related to timing of activities, and markup distribution with regard to activity timing may not make sense to the project owner. Therefore, the framework for markup distribution presented in this paper adopts consideration of different cost items rather than timing of activities.

Problem Formulation: Optimized Distribution of Markup among Cost Items

The problem to be solved is to find optimized markup rates for cost items to maximize contractor's benefit. The contractor's benefit is represented by present value of net cash-flow after receiving progress payments from the owner. Mathematically the problem is expressed by the following equation.

$$Maximize \sum_{i=0}^{T} PV(CF(i)) = \sum_{i=0}^{T} [\frac{1}{(1+r)^i} \times (CI(i) - CO(i))] \quad (1)$$

Where, i is i^{th} month

T is total number of months for the overall duration of the project

PV is Present Value

r is monthly interest rate

$CF(i)$ is net cash-flow amount at the end of i^{th} month

$CI(i)$ is cash-inflow amount at the end of i^{th} month

$CO(i)$ is cash-outflow amount at the end of i^{th} month

The markup rate for each cost item is assumed to be constrained by an upper limit and a lower limit. This is expressed as shown in Equation (2).

$$L_j \leq mr_j \leq U_j \quad (2)$$

Where, j is cost item index number: j=1 for material cost, j=2 for labor cost,

j=3 for subcontract cost, j=4 for equipment cost, j=5 for other cost

mr_j is markup % of the j^{th} cost item

L_j is lower bound of markup % of the j^{th} cost item

U_j is upper bound of markup % of the j^{th} cost item

$mr_4 = mr_1$ (markup rate for equipment cost is same as that for material cost)

$mr_5 = mr_2$ (markup rate for other cost is same as that for labor cost)

In addition, the sum of markup amounts distributed into each cost item for each activity should be same as total markup amount. This can be expressed as shown in Equation (3).

$$\sum_{j=1}^{5}\sum_{k=1}^{n}(C_{k,j}\times mr_j) = M_{Total} \quad (3)$$

Where, n is total number of construction activities

C_{kj} is estimated cost of the j^{th} cost item in the k^{th} activity

M_{Total} is total amount of markup to be distributed

The Optimization Model in Excel Spreadsheet

The linear problem shown in Equation (1) cannot be solved manually because calculation of cash-inflow amount *(CI(i))* and cash-outflow amount *(CO(i))* is very complicated with the consideration of payment policies and payment terms such as owner's and contractor's retainage, delayed payment by project owner, and 'pay-when-paid' clause.

Spreadsheet software, such as Excel, can solve complicated problems transparently by visualized framework, and users can get complete understanding and control of the framework (Nassar, 2004). The framework presented in this paper was developed based on an Excel spreadsheet, and the Solver, an add-in program available in Excel, to solve the optimization problem without additional advanced computer software. The proposed framework does not require mathematical calculations by hand or additional computer software for optimization. This framework can be used and performed by contractors who have Excel software.

A hypothetical construction project is used to illustrate the proposed framework for markup distribution based on cost items. The hypothetical project is from Mincks and Johnston (2011), and this project includes 29 construction activities. Table 1 shows the estimated costs for cost items in each activity, and the overall markup amount is $106,990 (8%). Schedule of this project is also shown in Table 1. In addition to the estimated costs and schedule, this project is assumed to have the following key input variables: an overall markup rate of 8%, the owner's and the contractor's retainage rate of 10%, and the monthly interest rate of 1.5%.

TABLE (1): ESTIMATED COSTS AND SCHEDULE FOR THE HYPOTHETICAL PROJECT

		Estimated Cost						Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
		Labor	Material	Equipment	Sub-contract	Others	Subtotal	1	2	3	4	5	6	7	8	9	10	11
1	Mobilization	$2,000	$2,000	$5,000	$1,000	$17,200	$27,200	100%										
2	General Conditions	$56,200	$300	$250	$0	$0	$56,750	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	
3	Earthwork	$0	$0	$0	$45,000	$0	$45,000	50%	50%									
4	Site Improvements	$0	$0	$0	$49,600	$0	$49,600										100%	
5	Concrete	$6,000	$32,700	$2,500	$35,500	$0	$76,700		60%	40%								
6	Masonry	$22,800	$40,000	$3,200	$0	$0	$66,000			100%								
7	Structural Steel	$18,000	$155,000	$8,000	$0	$0	$181,000			60%	40%							
8	Carpentry	$24,200	$66,300	$0	$0	$0	$90,500					10%		80%	10%			
9	Dampproofing	$600	$1,000	$0	$0	$0	$1,600			100%								
10	Insulation	$14,200	$24,300	$0	$0	$0	$38,500						100%					
11	Roofing/Flashing	$23,400	$43,300	$3,000	$0	$0	$69,700				20%	80%						
12	Sealants	$3,200	$6,400	$0	$0	$0	$9,600						100%					
13	Doors, Hardware	$10,000	$61,200	$0	$0	$0	$71,200			25%		25%	20%	30%				
14	Windows, Glazing	$8,770	$22,000	$4,100	$0	$0	$34,870						100%					
15	Interior Partitions	$31,400	$74,500	$6,200	$0	$0	$112,100					60%	10%	30%				
16	Acoustical Ceilings	$11,000	$20,000	$4,000	$0	$0	$35,000				20%				80%			
17	Ceramic Tile	$5,000	$11,500	$0	$0	$0	$16,500							100%				
18	Resilient Flooring	$3,200	$18,400	$0	$0	$0	$21,600							50%	50%			
19	Carpet	$5,100	$16,400	$0	$0	$0	$21,500							50%	50%			
20	Painting	$18,000	$27,000	$3,100	$0	$0	$48,100							40%	60%			
21	Wallcovering	$3,200	$5,200	$0	$0	$0	$8,400								100%			
22	Specialties	$7,500	$21,840	$0	$0	$0	$29,340								90%	10%		
23	Plumbing	$0	$0	$0	$49,200	$0	$49,200	20%	20%	10%	10%	5%			35%			
24	HVAC	$0	$0	$0	$55,220	$0	$55,220				30%	10%	20%	10%	10%	10%	10%	
25	Fire Protection	$0	$0	$0	$18,440	$0	$18,440						80%		20%			
26	Electrical Power	$0	$0	$0	$26,000	$0	$26,000						80%	20%				
27	Electrical Circuits	$0	$0	$0	$28,800	$0	$28,800		20%	20%	20%	20%				20%		
28	Lighting Fixtures	$0	$0	$0	$36,400	$0	$36,400								50%	50%		
29	Fire Alarm	$0	$0	$0	$20,800	$0	$20,800									60%	40%	
	Subtotal	$274,770	$648,990	$38,850	$359,100	$17,200	$1,337,770											
	Markup	8%					$106,590											
	Total bid price						$1,444,360											

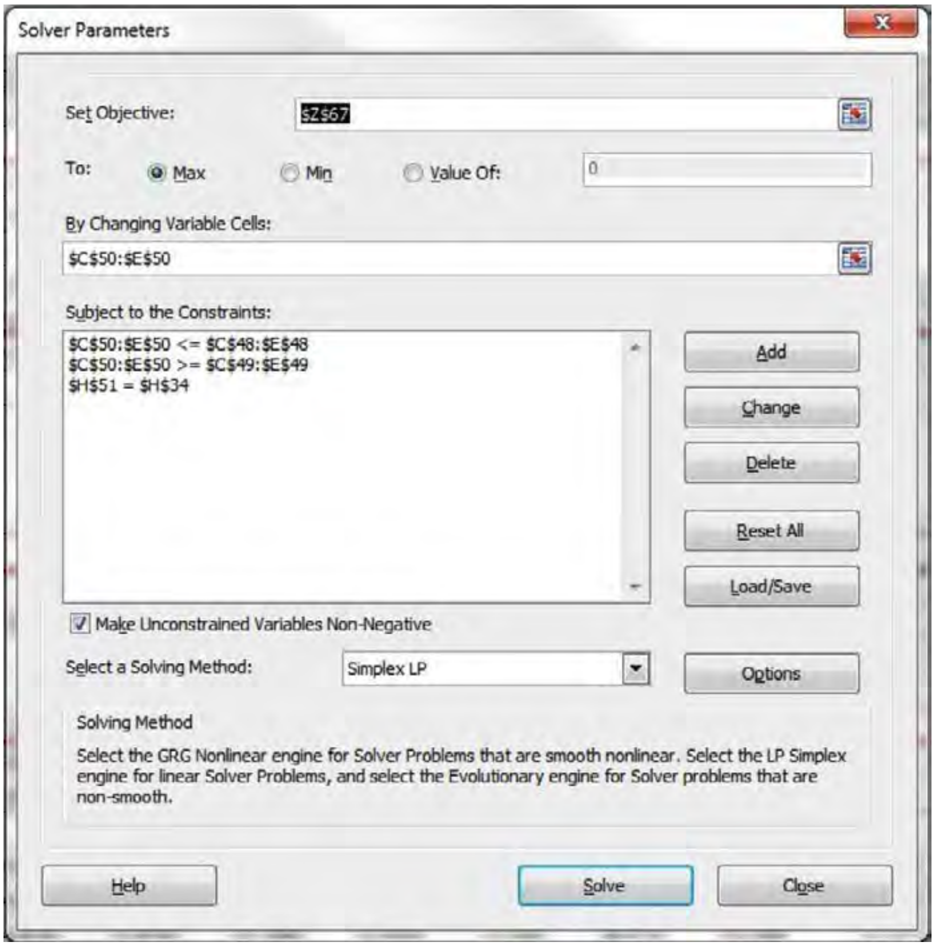
For the hypothetical project, it is assumed that the markup rate for material costs is the same as that for equipment costs. The markup rate for labor costs is assumed to be the same as that for other costs. It should be noticed that the upper bound and lower bound of markup rates for labor costs and other costs are set higher than those for material, equipment, and subcontract costs. The range of markup rates can be selected by the contractors who use this framework. The upper bound and lower bounds of markups rates for the cost items are shown in Figure 1.

FIGURE (1): SETUP OF MARKUP RATES TO BE DETERMINED THROUGH EXCEL SOLVER

	A	B	C	D	E
46					
47			Markup %- Material & Equipment	Markup%- Labor & Others	Markup%- Subcontract
48		Markup Upperbound	10%	20%	10%
49		Markup Lowerbound	0.00%	5.00%	0.00%
50					

In the framework, the Excel solver attempts to find the optimal solution by changing markup rates in the cells C50, D50 and E50 as shown in Figure 1. The objective of the problem is to maximize the present value of the cash-flows after receiving progress payments as expressed in Equation 1. Figure 2 shows the input window for the Excel solver parameters. Also, the optimization problem to find the best set of markup rates for different cost items has constraints as shown in Equation 2 and 3.

FIGURE (2): SETUP OF SOLVER PARAMETERS FOR THE EXAMPLE PROJECT



As one value is selected for markup rate for each cost item, the framework calculates cost-loaded schedules for both cash-inflow and cash-outflow according to the selected values for markup rates as shown in Table 2 and Table 3. The cost-loaded schedules are based on markup rates, estimated costs, and the estimate schedule as shown in Figure 1.

TABLE (2): EXAMPLE COST-LOADED SCHEDULE FOR CASH-INFLOW

	Cash-inflow Labor Cost	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
		1	2	3	4	5	6	7	8	9	10	11
1	Mobilization	$2,262	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	General Conditions	$6,357	$6,357	$6,357	$6,357	$6,357	$6,357	$6,357	$6,357	$6,357	$6,357	$0
3	Earthwork	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	Site Improvements	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	Concrete	$0	$4,072	$2,715	$0	$0	$0	$0	$0	$0	$0	$0
6	Masonry	$0	$0	$25,789	$0	$0	$0	$0	$0	$0	$0	$0
7	Structural Steel	$0	$0	$12,216	$8,144	$0	$0	$0	$0	$0	$0	$0
8	Carpentry	$0	$0	$0	$0	$2,737	$0	$21,898	$2,737	$0	$0	$0
9	Dampproofing	$0	$0	$679	$0	$0	$0	$0	$0	$0	$0	$0
10	Insulation	$0	$0	$0	$0	$0	$16,062	$0	$0	$0	$0	$0
11	Roofing/Flashing	$0	$0	$0	$18,527	$7,940	$0	$0	$0	$0	$0	$0
12	Sealants	$0	$0	$0	$0	$0	$3,619	$0	$0	$0	$0	$0
13	Doors, Hardware	$0	$0	$2,828	$0	$2,828	$2,262	$3,393	$0	$0	$0	$0
14	Windows, Glazing	$0	$0	$0	$0	$0	$9,354	$0	$0	$0	$0	$0
15	Interior Partitions	$0	$0	$0	$0	$17,758	$7,103	$10,655	$0	$0	$0	$0
16	Acoustical Ceilings	$0	$0	$0	$2,488	$0	$0	$0	$9,954	$0	$0	$0
17	Ceramic Tile	$0	$0	$0	$0	$0	$0	$5,655	$0	$0	$0	$0
18	Resilient Flooring	$0	$0	$0	$0	$0	$0	$1,810	$1,810	$0	$0	$0
19	Carpet	$0	$0	$0	$0	$0	$0	$2,884	$2,884	$0	$0	$0
20	Painting	$0	$0	$0	$0	$0	$0	$8,415	$12,623	$0	$0	$0
21	Wallcovering	$0	$0	$0	$0	$0	$0	$0	$3,619	$0	$0	$0
22	Specialties	$0	$0	$0	$0	$0	$0	$0	$8,042	$894	$0	$0
23	Plumbing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	HVAC	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	Fire Protection	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
26	Electrical Power	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
27	Electrical Circuits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	Lighting Fixtures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
29	Fire Alarm	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

TABLE (3): EXAMPLE COST-LOADED SCHEDULE FOR CASH-OUTFLOW

	Cash-outflow Labor Cost	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
		1	2	3	4	5	6	7	8	9	10	11
1	Mobilization	$2,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	General Conditions	$5,620	$5,620	$5,620	$5,620	$5,620	$5,620	$5,620	$5,620	$5,620	$5,620	$0
3	Earthwork	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	Site Improvements	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	Concrete	$0	$3,600	$2,400	$0	$0	$0	$0	$0	$0	$0	$0
6	Masonry	$0	$0	$22,800	$0	$0	$0	$0	$0	$0	$0	$0
7	Structural Steel	$0	$0	$10,800	$7,200	$0	$0	$0	$0	$0	$0	$0
8	Carpentry	$0	$0	$0	$0	$2,420	$0	$19,360	$2,420	$0	$0	$0
9	Dampproofing	$0	$0	$600	$0	$0	$0	$0	$0	$0	$0	$0
10	Insulation	$0	$0	$0	$0	$0	$14,200	$0	$0	$0	$0	$0
11	Roofing/Flashing	$0	$0	$0	$16,380	$7,020	$0	$0	$0	$0	$0	$0
12	Sealants	$0	$0	$0	$0	$0	$3,200	$0	$0	$0	$0	$0
13	Doors, Hardware	$0	$0	$2,500	$0	$2,500	$2,000	$3,000	$0	$0	$0	$0
14	Windows, Glazing	$0	$0	$0	$0	$0	$8,270	$0	$0	$0	$0	$0
15	Interior Partitions	$0	$0	$0	$0	$15,700	$6,280	$9,420	$0	$0	$0	$0
16	Acoustical Ceilings	$0	$0	$0	$2,200	$0	$0	$0	$8,800	$0	$0	$0
17	Ceramic Tile	$0	$0	$0	$0	$0	$0	$5,000	$0	$0	$0	$0
18	Resilient Flooring	$0	$0	$0	$0	$0	$0	$1,600	$1,600	$0	$0	$0
19	Carpet	$0	$0	$0	$0	$0	$0	$2,550	$2,550	$0	$0	$0
20	Painting	$0	$0	$0	$0	$0	$0	$7,440	$11,160	$0	$0	$0
21	Wallcovering	$0	$0	$0	$0	$0	$0	$0	$3,200	$0	$0	$0
22	Specialties	$0	$0	$0	$0	$0	$0	$0	$7,110	$790	$0	$0
23	Plumbing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	HVAC	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	Fire Protection	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
26	Electrical Power	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
27	Electrical Circuits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	Lighting Fixtures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
29	Fire Alarm	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

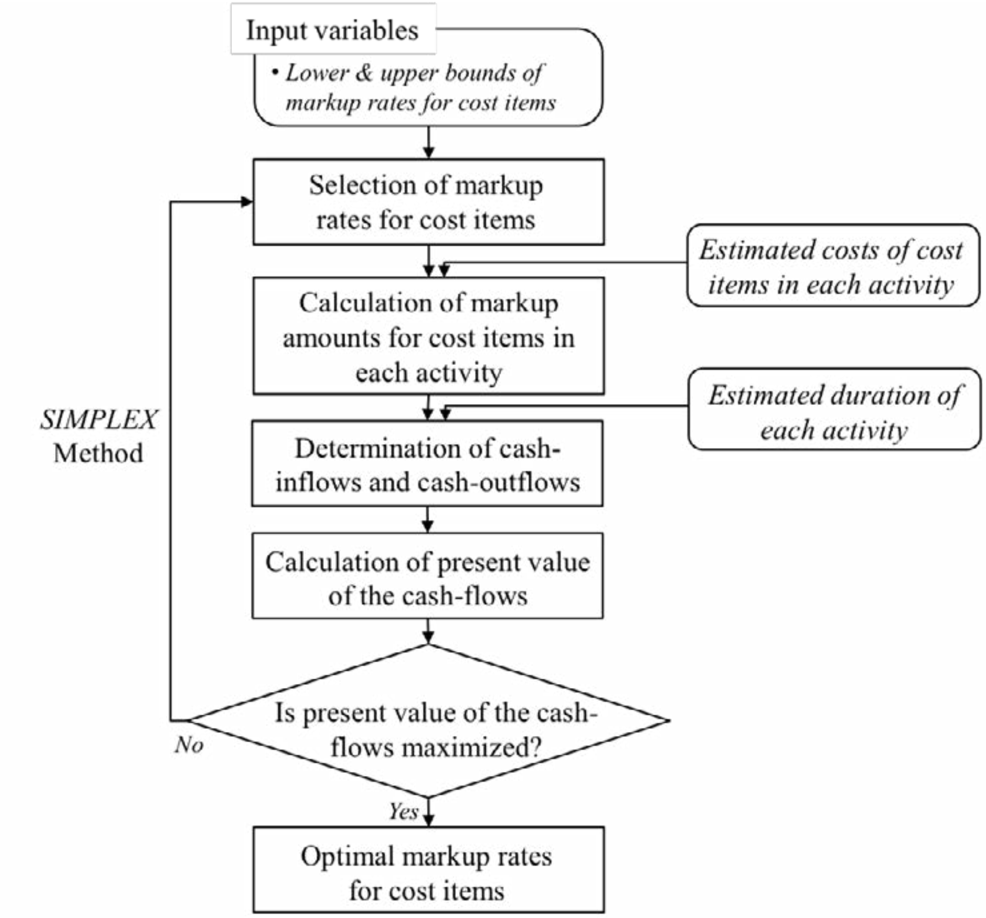
Then, the framework calculates total cash-inflow amount and cash-outflow amount both before and after receipt of progress payments and also calculates total present value (PV) of cash-flow after receipt of progress payments as shown in Table 4.

TABLE (4): CASH-FLOW ANALYSIS TABLE OF THE HYPOTHETICAL PROJECT

	June	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Receipt												
- Materials	-	2,233	21,615	178,679	105,589	79,283	88,319	146,861	88,842	2,393	33	-
- Labor	-	8,619	10,429	50,582	35,516	37,620	44,757	61,068	48,026	7,250	6,357	-
- Equipment	-	5,528	1,678	9,928	6,738	4,428	6,012	3,174	5,198	28	28	-
- Subcontractor	-	33,340	57,800	25,360	25,685	12,155	46,630	10,735	51,925	31,015	63,455	-
- Other		19,455	-	-	-	-	-	-	-	-	-	-
Total Value (Billing Amount)	-	69,174	91,521	64,548	173,528	133,485	185,718	221,837	193,990	40,685	69,872	-
Total receipt amount	-	-	62,257	82,369	238,094	156,175	120,137	167,146	199,653	174,591	36,617	207,321
(Cumulative receipts)	-	-	62,257	144,626	382,719	538,895	659,031	826,177	1,025,831	1,200,422	1,237,039	1,444,360
Payments												
- Materials	-	-	2,030	19,650	162,435	95,990	72,075	80,290	133,510	80,765	2,175	30
- Labor	-	7,620	9,220	44,720	31,400	33,260	39,570	53,990	42,460	6,410	5,620	-
- Equipment	-	-	5,025	1,525	9,025	6,125	4,025	5,465	2,885	4,725	25	25
- Subcontractor	-	-	30,006	52,020	22,824	23,117	10,940	41,967	9,662	46,733	27,914	92,920
- Other	-	17,200	-	-	-	-	-	-	-	-	-	-
Total Payments	-	24,820	46,281	117,915	225,684	158,492	126,610	181,712	188,517	138,633	35,734	92,975
(Cumulative payments)	-	24,820	71,101	189,016	414,700	573,192	699,801	881,513	1,070,030	1,208,662	1,244,396	1,337,370
Cash Flow Projection												
Cash-flow before receipt of progress payment	-	-24,820	-9,220	-44,720	-31,400	-33,260	-39,570	-53,990	-42,460	-6,410	-5,620	0
Cumulative cash-flow before receipt of progress payment	-	-24,820	-34,040	-53,564	-75,790	-65,241	-73,867	-94,760	-97,796	-50,609	-13,860	-7,357
Cash-flow after receipt of progress payment	-	-24,820	15,976	-35,546	12,410	-2,316	-6,473	-14,566	11,137	35,959	883	114,346
Cumulative cash-flow after receipt of progress payment	-	-24,820	-8,844	-44,390	-31,981	-34,297	-40,770	-55,336	-44,199	-8,240	-7,357	106,990
Maximum Cash to be invested by the contractor				**-$97,796**								
PV of net cash-flow after receipt of progress payment	0	-24,453	15,507	-33,993	11,692	-2,150	-5,920	-13,124	9,886	31,449	761	97,073
Total PV of net cash-flows after receipt of progress payment				**$86,728**								

This process in the framework is repeated until the Excel solver finds the optimal solution by the Simplex method, a standard method of maximizing a linear function of multiple variables with multiple constraints (Bazaraa, Jarvis & Sherali, 1990). The repeated process used in the frame is presented in Figure 3.

FIGURE (3): OPTIMIZATION PROCESSES IN THE COST ITEM BASED MARKUP DISTRIBUTION FRAMEWORK

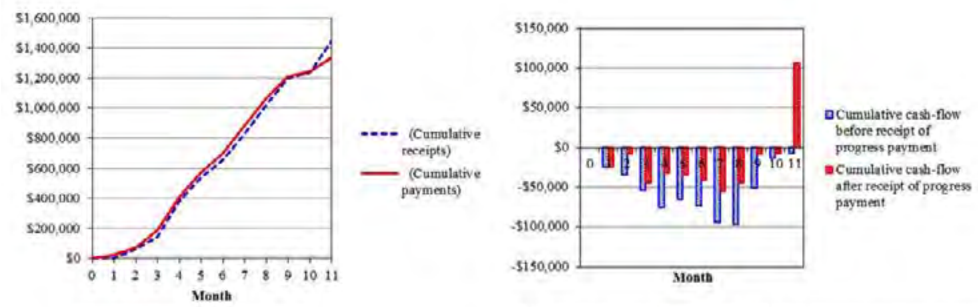


In the hypothetical project, the Solver found the optimal solutions as shown in Table 5. Notice that the optimal solutions for markup rates are affected by several factors, such as estimate costs for each cost item, and timing. Based on the optimal solution found, the framework can prepare plots which show cash-inflow and cash-outflow as shown in Figure 4.

TABLE (5): OPTIMIZED MARKUP RATE

	Markup rate		
	Material & equipment cost	Labor & other cost	Subcontract cost
Lower bound	0%	5%	0%
Upper bound	10%	20%	10%
Optimized markup rate	10.00%	13.11%	0.00%

FIGURE (4): PLOTS OF THE RESULTS FROM THE FRAMEWORK



(a) Cash-inflow and cash-outflow

(b) Cumulative cash-flow before and after progress payment receipt

To validate the proposed framework, sensitivity of the optimal markup rates and/or present value of the cash-flows determined by the framework to upper and lower bounds of markup factors was analyzed. This validation process was based on same upper bounds (and lower bounds) of markup rates among cost items: upper bound (and lower bound) of material & equipment costs markup rate is same as those of labor & other costs and subcontract costs. Figure 5 shows the change in the optimized present value of cash-flows with different upper bound of markup rates. The optimized present value of the hypothetical project increases with higher upper bound of markup rates. It should be noticed that the hypothetical project is based on total markup amount of 8% ($106,990). When the upper bound of markup rates for the cost items is 8%, and the lower bound is 0%, the optimized present value of the project is determined as $86,539. However, as the upper bound increases, the proposed framework could find a better solution (higher present value): for example, the optimized present value of the cash-flows of $86,792 was determined along with upper bound of markup rate of 20%. No higher upper bound of markup rates was helpful to get a better result.

FIGURE (5): CHANGE IN OPTIMIZED PRESENT VALUE OF THE CASH-FLOWS WITH DIFFERENT UPPER BOUND OF MARKUP RATES

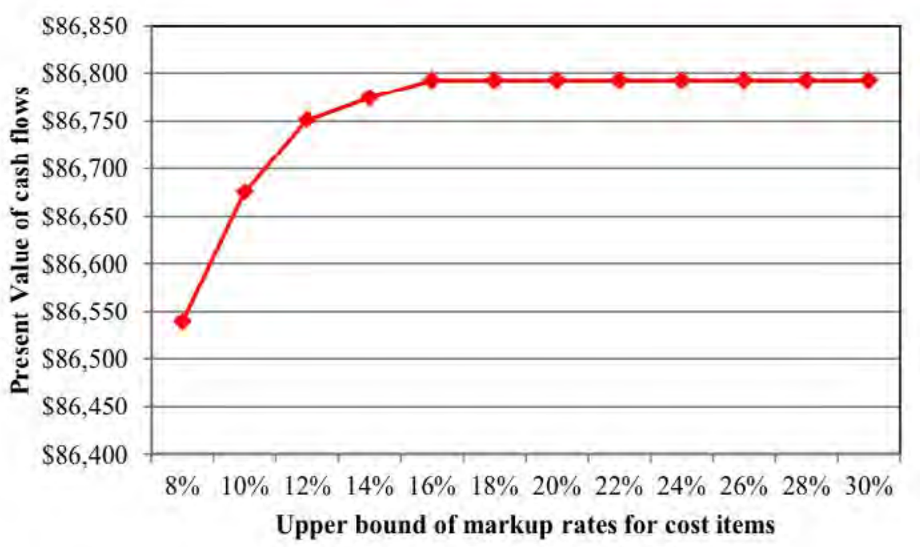
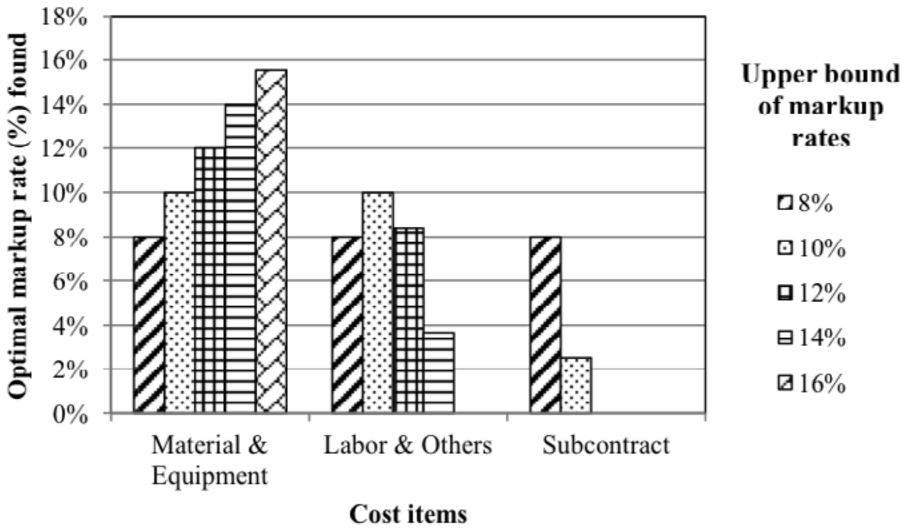


Figure 6 shows the sensitivity of the optimal markup rates for the cost items to different upper bounds. When the upper bound of markup rates is 8% and the lower bound is 0% in the base case, the optimal markup rates for material & equipment costs, labor & other costs, and subcontract costs are same to each other as 8%. However, when the upper bound increases, the proposed framework could find a different optimal markup rates among the cost items. For example, when the upper bound for markup rates is 16%, the optimal markup rates for material & equipment costs, labor & others costs, and subcontract costs are 15.56%, 0%, and 0% respectively. These optimal markup rates lead to the best present value of the cash-flows of $86,792 as discussed in the previous section. It should be noticed that this unequal optimal markup rates is determine both by percentage of each cost item and by timing of activities. The percentage of material & equipment costs in the total estimated cost for the hypothetical project is 51.4% ($687,800 vs. $1,337,370 as shown in Figure 1). The percentages of labor & others costs and subcontract costs are 21.8% ($291,470), and 26.8% ($358,100) respectively.

FIGURE (6): CHANGE IN OPTIMAL MARKUP RATES WITH DIFFERENT UPPER BOUND OF MARKUP RATES



To determine the effectiveness of the solution from the proposed framework, the results are compared to the solutions from two other markup distribution methods: 1) balanced markup distribution, and 2) unbalanced markup distribution through front-loading. Table 6 shows the comparison of results among the three methods. The upper bound of markup rates for the unbalanced markup distribution through front-loading was set as 20% which is same as that of labor & other costs for the cost item based distribution for the purpose of the comparison in similar conditions. The maximized present value of net cash-flows from the proposed framework through cost item based distribution ($86,728) is higher than that from balanced markup distribution ($86,539). While the difference ($189 or 0.22%) is not significant, the proposed framework provides a better solution than the balanced (or equal) markup distribution. This is because the proposed framework tries to find a better solution to how to distribute a fixed amount of total markups into each activity than that from the balanced markup distribution. However, it should be noticed that the amount of enhanced net present value from the proposed framework depends on percentages of cost amounts among cost items and timing of activities.

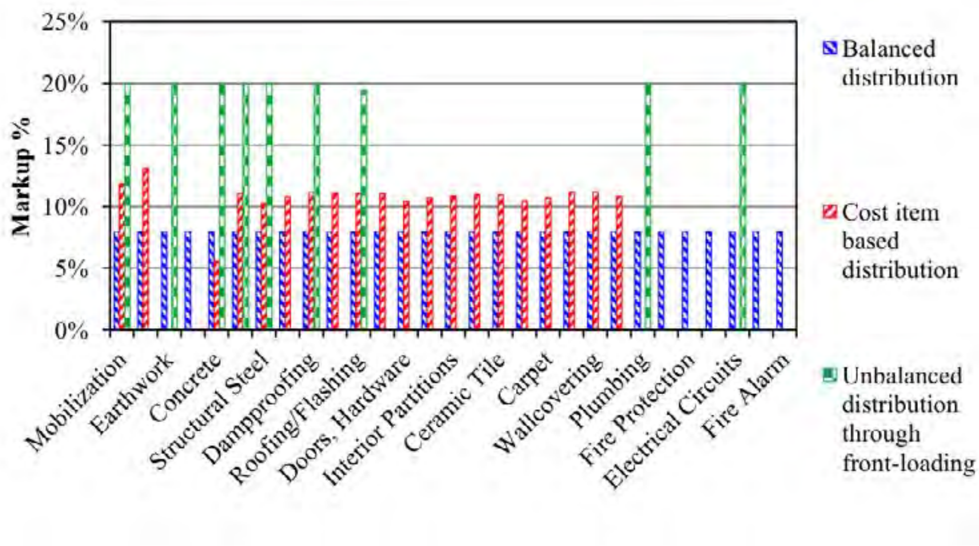
TABLE (6): COMPARISON OF THE RESULTS AMONG THE THREE METHODS

	Balanced distribution	Cost item based distribution	Unbalanced distribution through front-loading
Total PV of net cash-flows	$86,539	$86,728	$89,404

On the other hand, the net present value from the cost item based distribution method is smaller than that from the unbalanced distribution method ($86,728 vs. $89,404). This expected result is due to 'blatantly unbalanced' markup distribution caused by consideration of only timing of activities. The difference may indicate additional cost to the project owner and, thus, the project owner may reject the markup distribution (either a unbalanced bid or a unbalanced schedule of values).

Figure 7 shows the markup rates distributed to each activity among the three methods. It should be noticed that the markup rate for each activity under the cost item based distribution method is represented by average markup rate: average markup rate is calculated 1) by adding the resulted markup amounts for each cost item in each activity, and 2) by dividing the sum by the estimated cost for the activity. The markup rates from front-loading unbalanced distribution which are represented by green histogram are extreme, and only a few activities have non-zero markup rates. However, the proposed framework through markup distribution based on cost item leads to more balanced markup rates than front-loading unbalancing.

FIGURE (7): COMPARISON OF MARKUP RATES DISTRIBUTED TO EACH ACTIVITY AMONG THE THREE METHODS



Discussion

Optimized markup distribution through front-loading leads to extremely unbalanced distribution of markup as criticized by Cattell (2013). While this approach may increase contractor's profit, front-end loaded markup can require additional cost to the project owner. This is why front-loaded markup distribution is regarded as an unethical strategy (Kenley, 2003). If the degree of unbalancing is apparent or blatant, the project owner may not accept the bid proposal or may request modification of the schedule of values. Therefore, front-loaded markup distribution is not recommended, even though some researchers and practitioners advocate front-loaded markup distribution (Cattell et al., 2007; Cattell et al. 2010; Mincks & Johnston, 2011).

On the other hand, 'balanced' or equally distributed markup approach does not provide any tool to relieve the contractor's financial burdens caused by contract terms (owner's retainage and delay in progress payments). That is why a front-loaded markup distribution is still advocated and used by some contractors and researchers.

The '*cost item based distribution*' framework presented in this paper does not distribute markup directly among construction activities. Instead, it finds different markup rates among different cost items. The solution from this framework is affected by several factors, such as composition of cost items in each activity, magnitude of cost items, and time for cost items to be performed. The solution from this framework is not as extremely unbalanced as that from front-loaded markup and can reduce contractor's financial burden.

There is no 100% correct answer for estimation of markup amount for a construction project and distribution of total markup amount into each activity. Specifically, there is no method for markup distribution either for preparation of bids or for development of schedule of values which is specified by project owners. Instead, project owners use non-specific terms to prevent unbalanced distribution of markup: for example, "*the imbalance must not be **detrimental** to the government buyer"* by the Federal Acquisition Regulation (FAR) §52.514-10(e), "*if any unit prices are obviously unbalanced, either in excess of or below the **reasonable** cost analysis values*" in the Minnesota Department of Transportation (MN DOT) Standard Specification §1027 (McGreevy & Landrum, 2014). Therefore, any method for markup distribution discussed in this paper may be accepted. However, what is more important and critical to construction project owners is degree of imbalance in markup distribution. The cost item based markup distribution proposed in this paper is one method for markup distribution for non-blatantly unbalanced markup distribution.

Conclusion

Contractors are required by project owners to distribute overall markup for a construction project to each activity. The existing methods for markup distribution are 1) balanced distribution and 2) unbalanced distribution through front-loading. Both methods have shortcomings and, specifically, the unbalanced markup distribution through front-loading is regarded as unethical and not recommended.

This paper presents a new approach to markup distribution based on cost items: the overall markup amount is not directly distributed to activities but rather distributed through different markup rates among different cost items. Markup rates needed for labor costs may be different from that for material costs in real construction projects. And same markup rates among different cost items may be only for development of a bid price or schedule of values, not for budget preparation. Thus, the proposed framework can provide more accurate markup amounts distributed in activities. The framework for the proposed approach considers detailed policies and procedures related to cash flow and enables contractors to find more realistic solutions. The framework offers to find the optimal markup rates for cost items, and the optimization problem is solved by Excel solver. No additional computer software is needed in this framework. Furthermore, it enhances understanding and control of the calculation procedure through visual presentation of variables.

The proposed framework with markup distribution based on cost items may not be the best or optimal approach for markup distribution. However, this framework allows solutions in between the 'unethical' front-loaded markup distribution and the 'balanced' markup distribution. Also, this framework can be a practical tool to contractors who need to distribute overall markup to activities without complicated mathematical calculation. Furthermore, the proposed framework provides additional solutions to analyze cash flow for a construction project and to forecast the amount of funds to be prepared for the project. Compared to the uniformly balanced markup distribution method, the proposal framework can provide more accurate markup amounts for activities and can enhance contractors' net present value by some degree. Also, this framework can reduce contractors' risk for their bid proposals (or schedule of values) submitted to be rejected from the unbalanced markup distribution method through front-loading.

The solution from the proposed framework may not be the best both for the project owner and the contractor, since there is no detailed description (or requirement) of 'best' solution for markup distribution. The cost item based markup distribution method is proposed as another method for markup distribution in construction projects. It should be noticed that this proposed method may lead to a blatantly unbalanced markup distribution depending on upper & lower bounds of markup rates to be selected by the contractors, composition of activities' cost, and schedule of activities.

Future study of this framework is planned to incorporate schedule as a variable. The framework presented in this paper is based on a pre-planned fixed schedule. However, schedule is another key variable in construction projects and incorporating a schedule variable in this framework can be more helpful to contractors.

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