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Costing of the Production and Delivery of Ready-Mix-Concrete

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Abstract

The paper presents a model for costing production and transportation of ready-mix-concrete (RMC) based on type of the mix and customer site information. The on-floor cost of the mix is based on the type of concrete and is estimated using activity based costing (ABC). The cost of transporting RMC to customer's site is obtained as a function of traveling distance, traffic factor, and demand. Volume-based discounts, penalty for late delivery, and cost of mix spoilage are considered. Moreover, the paper provides a cost ground for improving the RMC production system using activity based management (ABM) to improve the financial performance of the company. The proposed model is applied at a local RMC company where obtained results show differences between the costing system of the company and that using the proposed model.

Keywords: Activity-based costing (ABC); Activity-based management (ABM); Ready mix concrete (RMC)

1. Introduction

Companies sell their products/services to make profit, where profit on a product is the difference between the selling price and the total cost of making that product. To be successful, a product must satisfy design specification within the cost criteria specified at the start of the project. To estimate the cost of a product, traditional cost methodologies were used since 1920s. Theses costing methodologies were appropriate then but not today because of the different financial objectives (pricing and profitability analysis, not inventory valuation) and the different operating situation (labors intensive, overheads, majority of cost is the manufacturing cost, single product company). On the other hand, activity-based costing (ABC) tackles theses issues.

ABC is a costing model that identifies activities in an organization and assigns the cost of each activity resource to products according to the actual consumption by each activity. This helps estimating the actual cost of products for the purpose of discontinuing unprofitable products and lowering prices of overpriced ones. ABC assigns the cost of resource to products through activities. As a result, ABC has predominantly been used to support strategic decisions such as pricing, outsourcing, and identification and measurement of process improvement initiatives. Several researchers discussed costing criteria in the manufacturing and service arenas. In this study, we utilize ABC in leading efforts for managing and improving activities in ready-mixed concrete (RMC) plants.

RMC refers to concrete that is specifically manufactured for delivery to the customer's construction site by truck-mounted transit mixers in a freshly mixed and plastic or unhardened state. The first ready-mix factory was built in the 1930s, but the industry did not begin to expand significantly until the 1960s, and it has continued to grow since then. RMC can be custom-made to suit different applications and is sold by volume usually expressed in cubic meters. It is sometimes preferred over on-site concrete mixing because of the precision of the mixture and reduced worksite confusion. Other advantages of RMC include elimination of storage space for basic materials at site, less labor, and lower levels of pollution at the site. A disadvantage of RMC is the impact of traveling time on properties of concrete. This time is largely influenced by the distance from plant to site, weight limits of roads and bridges, and traffic conditions. Today, modern additives help elongate the time-span of RMC at added expense. To our knowledge, no research exists that utilizes ABC for managing/improving the activities of producing and transporting RMC.

This paper presents a model for costing RMC based on the type of the mix and site information. To this end, the production process is subdivided into its main activities. The cost of each activity is then evaluated utilizing financial records of the company. A cost fraction of that activity is allocated to a product based on the rate of its consumption of that activity [1, 2]. The per-product cost is set constant for a product regardless to the customer information. A further investigation of the value of each activity is used to improve the performance of the production system and hence reduce the cost. The second cost phase deals with transporting products to customer's site. The study employs heuristics for concrete delivery to compute the actual cost of transportation based on site information, the volume of the ordered product, and the state of the traffic to and from the site. Cost information are then used to derive improvement efforts of the various

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activities using lean thinking. Projected results help managers realize cost and efforts associated with production and overhead activities. The rest of the paper is organized as follows. Section 2 provides background and reviews related literature. Section 3 presents the proposed costing model. Section 4 presents a case study and the final section provides concluding remarks.

2. Background and Literature Review

In today's markets, manufacturing companies, especially small ones, struggle to increase their profits because of the high competitiveness and globalization. Therefore, more efforts are directed towards reducing production expenses. To this end, the impact of the various value-added, supporting, and non value-added activities on the cost of the product or service should be investigated.

Today, manufacturing companies are becoming more information intensive, highly flexible, and immediately responsive to the customer expectations [3]. Due to the changing manufacturing environment, traditional cost accounting is rapidly disappearing. Traditional accounting systems were developed at a time when direct labor contributed to a large percentage of the total cost of the product. Changes in manufacturing technologies, such as the just-in-time philosophy, robotics, and flexible manufacturing systems decreased the direct labor component of production and increased overhead cost. In today's manufacturing environment, direct labor accounts for only 10% of the cost, whereas material accounts for 55% and overhead for 35%. As a result, product cost distortion occurs due to allocating overhead cost to the products arbitrarily on the basis of direct labor hours used by each product [4, 5]. Cooper reports several situations that can cause distortions to occur, examples include production volume diversity, complexity diversity, material diversity, and setup diversity [6, 7]. In the literature, several researchers applied ABC in real life. Examples include air conditioning industry [8], land transportation [9], agricultural systems [10], and healthcare [11, 12].

ABC emerged as a logical alternative to traditional cost management systems that tended to produce insufficient results when it came to allocating cost. The concept of ABC came into prominence with the development of ABM by cooper and Kaplan in 1988 [1]. ABC concentrates on the need to make a more realistic allocation of overhead cost to products. It emphasizes the requirement to obtain a better understanding of the behavior of overhead cost, and thus ascertains what causes overhead cost and how they relate to products ABC provides information to identify the components of overhead more precisely, assigns cost of resource to products more accurately, and as a result it acts as a decision support tool for companies [4, 13]. The implementation of ABC is justified if the cost of installing and operating the system are more than offsets by the long term benefits [14]. Several limitations of ABC are presented in [15, 16, 17].

Element of ABC include Activity: Work performed within an organization or the aggregations of action performed within an organization. Activity driver: Associates activates with their respective cost object. Activity drivers' measure the frequency and intensity of the demand placed on activities by cost objects. They are typically a one-to-one relationship with the activity. Activity measures: A measure of the workload involved in the activity. It can be similar to the activity driver. Bill of activity: A listing of the activities required (and optionally, the associated cost of the resources consumed) by a product or other cost object. It should list each activity, activity drivers, number of units, unit cost per driver, and extended cost that, taken together, compose the total for any particular cost object. Cost drivers: Any element that would cause a change in the cost of activity. Cost elements: An amount paid for a resource consumed by an activity and included in activity cost pool. Cost objects: Any customer, product, service, contract, project, or other work unit for that separate cost measurement is desired. Performance measures: Indicators of the work performed and the results achieved in an activity, process, or organizational unit. Performance measures may be financial or operational. Processes: A series of activities linked to perform a specific objective. Resources: An economic element that is applied or used in the performance of activities, salaries and materials are resources used in the performance of activities. They can also include any non-monetary assets that are essential for the completion of the item. Resource drivers: A measurement tool to associate cost with their respective activities or cost object resources drivers measure the quantity of resources consumed by an activity, typically a one-to-one relationship with the resource [1]. Figure 1 illustrates the hierarchical relationship among expense categories, activities, and products.

In [18], the authors proposed efficient and inexpensive steps for implementing ABC in small business. This procedure systematically provides the decision-maker with accurate cost information to establish corporate strategies, determine product cost, and improve the cost structure.

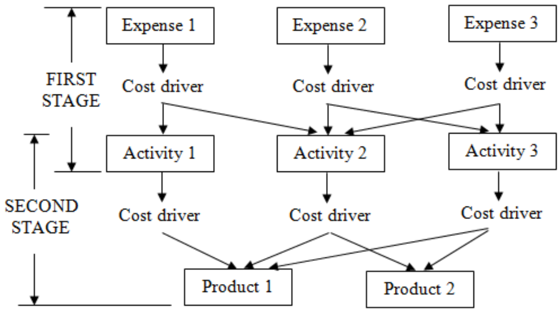

Figure 1: Relationship among expense categories, activities, and products [1].

ABC, by itself, is not enough for continuous improvement of the company. Activity Based Management (ABM) is a management philosophy that focuses on the planning, execution and measurement of activities and helps companies to survive in the competitive world of business. ABM allows leaders to examine non-value-added activities and make rational decisions to eliminate them. ABM relies on the ABC system to specify where non-value-added activities exist and to value the monetary benefits associated with their elimination [19, 20]. Management must institute a conscious process of organizational change and implementation if the organization is to receive benefits from the improved insights resulting from an ABC analysis [2]. Figure 2 illustrates the stages of ABM including monitoring, managing, and improving the performance of process [21].

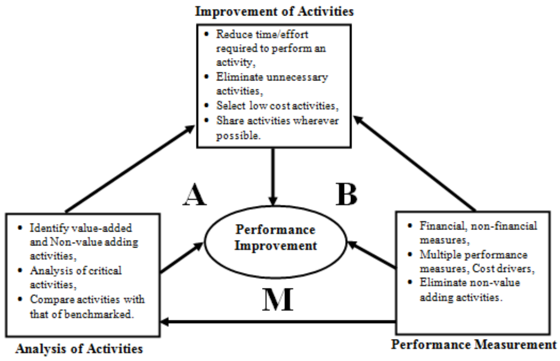

Figure 2: A conceptual framework for activity –based management [21].

Concrete is a primary material used in architecture and public work projects ranging in size from a single house to high-rise buildings. Concrete is a hardened building material created by combining a chemically inert mineral aggregate (usually sand, gravel, or crushed stone), a binder (natural or synthetic cement), chemical additives, and water. As concrete dries, it acquires a stone-like consistency that renders it ideal for constructing roads, bridges, water supply and sewage systems, factories, airports, railroads, waterways, mass transit systems, and other structures. The U.S. RMC industry had over $27 billion in annual sales and 107,000 employed workers in 2005. It has experienced solid growth during the past 15 years: real revenues have grown at an average annual rate of 3.8 percent since 1992 [22].

Concrete manufacturers expect their raw material suppliers to supply a consistent, uniform product. At the cement production factory, the proportions of the various raw materials that go into cement must be checked to achieve a consistent kiln feed, and samples of the mix are frequently examined using X-ray fluorescence analysis [22]. The strength of concrete is probably the most important property that must be tested to comply with specifications. To achieve the desired strength, workers must carefully control the manufacturing process, which they normally do by using statistical process control. The American Standard of Testing Materials and other organizations have developed a variety of methods for testing strength. Quality control charts are widely used by the suppliers of ready-mixed concrete and by the engineer on site to continually assess the strength of concrete. Other properties important for compliance include cement content, water/cement ratio, and workability, and standard test methods have been developed for these as well.

RMC is not only a product, it is a service, and each year about 20 million cubic meters of concrete are delivered in truck-mixers [23]. The truck-mixers have developed since the late 1940s from a mobile site mixer into specialized vehicle capable of mixing, delivering and distributing concrete in a very economic manner. Indeed, in the viability of RMC depends on the efficient utilization of the specialized truck-mixer fleet [24]. Although truck-mixer vehicles available in the range from 2 to 9 cubic meters capacity, the majority in use have a load capacity of 6 cubic meters of concrete. With "shelf life" of only a few hours, RMC is very much a local delivery service with an average distance from the depot to point of delivery of about 8 km.

Delivery cost, including the question of economy of scale, has been of interest to decision makers in different transportation sectors for many years. Managers need to have enough information about their cost to make the right decision about the type of services to provide and the prices to charge [25]. There are many approaches to estimate the cost per km for trucks. Each of them employs a different methodology and models to calculate the variable cost of operating trucks. Fuel, repair and maintenance, tire, depreciation, and labor cost are the most important cost that are considered to estimate operating cost per km. Daniels [26] divided vehicle operating cost into two different categories, running cost and standing cost. Running cost includes fuel consumption, engine oil consumption, tire cost, and maintenance cost. Standing cost includes license, insurance, interest charges. Daniels considered speed as the most important factor in fuel consumption and found maintenance cost rise with increasing speed. If fuel consumption and maintenance cost change, operating cost will change as well. Vehicle size is another factor that affects fuel consumption and it will change operating cost. By using average axle number for each firm we can include vehicle size in our model.

Watanatada and Dhareshwar [27] divided the variables that affect the truck operating cost to the following categories: 1. Truck characteristics e.g., weight, engine power, and maintenance. 2. Local factors e.g., speed limit, fuel price, labor cost, and drivers' attitude. 3. Road characteristics e.g., pavement roughness, and road width. Operating cost is considered a function of road characteristics and so is policy sensitive. Barnes and Langworthy [28] estimated operating cost for commercial trucks based on fuel, repair, maintenance, tires and depreciation cost. The authors also considered adjustment factors for cost, based on pavement roughness, driving conditions and fuel price changes. Moreover, they estimated the average truck operating cost per *km* at $0.27 cents not including labor cost. For a labor cost of around $0.22 per *km*, the total operating cost using Barnes' model adds up to $0.49 per *km*. Hashami [29] developed and tested a linear model in her thesis of Operating Cost for Commercial Vehicle Operators. Details of her contribution are presented in section 3.

3. Cost Model for RMC

To estimate the cost of a demanded volume of RMC, it is necessary to cost required materials, labor involved, fuel and maintenance needed, plant and ancillary equipment hired and depreciated, and delivery of RMC to customer site. The proposed cost model subdivides the cost of RMC into three main cost categories including 1) On-floor cost: the model utilizes a step-by-step ABC procedure from literature, 2) Cost of delivery: a new model for costing the delivery of RMC is proposed, and 3) Cost associated with riding RMC scrap: the model assigns cost to scrap based on the location where RMC got spoiled. To illustrate, if RMC is spoiled in the factory, only on-floor cost will be charged. On the other hand, the sum of on-floor and delivery cost is charged if RMC is spoiled in its way to customer.

3.1. On-floor cost: The ABC model

Figure 3 illustrates the proposed ABC model based on procedures for producing RMC and the related plant processes. A common procedure to identify cost activities is to interview people who work in overhead departments and ask them to describe their major activities. Activity centers are established such that all activities related to accomplishing a particular attribute are grouped. A good rule of thumb is not to have more than 20-25 activity centers for an ABC project [2]. Table 1 presents RMC main in-plant activities and their cost centers.

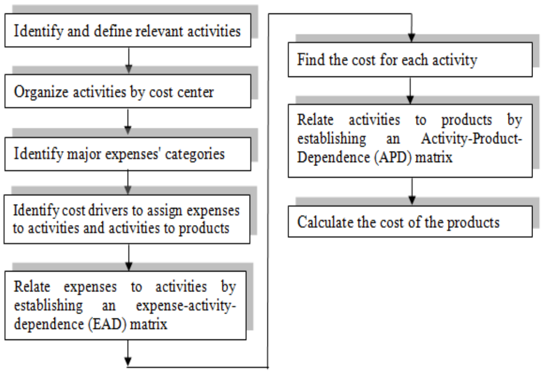

Figure 3: On-floor ABC procedure.

For a typical RMC plant, Table 2 presents expense categories included in the income statement of the company. Moreover, the table presents the cost driver(s) of each category. Once the main expenses have been defined, a total cost of each expense can be found. Sample cost values are shown in Table 2 as obtained from the case study. This helps management and reengineering-teams efforts to minimizing expenses. Notice that equipment complexity is used as a cost driver for maintenance since more complex machines usually require more effort and time. The complexity of the machine may be measured by the number of components of the machine or the amount of technology contained in that machine. Miscellaneous costs (MC) are expenses that cannot be itemized or traced back to specific activities. Hence, miscellaneous cost are estimated or forecasted for the coming year (MC_{t+1}) based on historical data and are divided equally over all overhead activities.

Table 1: Main activities and their cost centers.

Activities	**Cost centers**
1. Electrical maintenance 2. Vehicle maintenance 3. Riding scrap 4. Equipment and plant maintenance	Maintenance center
5. Management 6. Guard work 7. Marketing and advertising	Administration center
8. Purchasing 9. General accounting	Accounting center
10. Material receiving and shipping 11. Employee transportation	Transportation center
12. Weighing 13. Mixing Operation	Preparation of raw material
14. Quality Assurance	Development center

Table 2: Expense categories, their cost drivers and yearly cost

Expense category	**Cost driver**	**Cost** ($/year)
Overhead Expenses		
Salaries	Total labor salary per year	153,672
Overtime	Total labor overtime per year	67,976
Depreciation	550Money use of resources	173,
Office Expense	Level of use of office resources (%)	3,655
Utilities	Total cost per year	1,800
Transport	Distance (km)	10,440
Maintenance	Equipment complexity	49,407
Insurance	Cost of resource used by activity	34,860
Licenses	Type of licenses	4,490
Research and development	Cost of resource used by activity	4,950
Communication	Cost of resource used by activity	10,354
Miscellaneous	Total cost per year	300
	Total	515,454
Materials' Cost		
Portland Cement	Unit mass	1,772,550
Fine Aggregate	Unit mass	264,690
Coarse Aggregate	Unit mass	263,385
Water	Unit mass	38,466
Chemical Component	Unit mass	89,100
	Total	2,428,191

To relate expenses to activities, an Expense-Activity-Dependence (EAD) matrix is established [18]. To illustrate, the activities that contribute to each expense are identified and the EAD matrix is created. The expense categories represent the columns of the EAD matrix, whereas the activities represent the rows. If activity *i* contributes to the expense category *j*, a checkmark"√" is placed in the cell *i*, *j*. Follows, each expense category is traced back to activities and each expense category is divided among activities according to the proportion of contribution. The check marks in the EAD matrix are replaced by the proportions of contribution such that each column of the EAD matrix must add up to 1, implying that the entire expense category is spread across the activities.

Equation 1 presents the total cost *TCA(i)* of activity *i* where, *j* is the number of expense categories and *EAD(i,j)* is the entry *i,j* of the EAD matrix.

$$TCA(i) = \sum_{j=1}^{J} EAD(i, j) \quad (1)$$

To obtain the overhead cost of a unit volume of an RMC product, the activities consumed by the product are identified and the Activity-Product-Dependence (APD) matrix is created. If product *k* (row entry) consumes the activity *i* (column entry), a check-mark is placed on the cell *k,i*. Follows, check marks in the APD matrix are replaced by the estimated proportions of consumption of product *k* from activity *i* such that each column of the APD matrix must add up to 1. These proportions are traced over the demand years and are assumed to be constant over the years. Equation 2 illustrates the overhead cost CO_k of a unit volume of product *k* where, *N* is Number of activities and *APD(k, i)* is the entry *k*, *i* of the APD matrix.

$$CO_k = \sum_{i=1}^{N} TCA(i) \times APD(k,i) \quad (2)$$

On-floor cost (CF_k) of a unit volume of product *k* is then computed by adding the cost of overhead activities to the cost of raw materials as illustrated in equation 3. Where, *M* is the number of materials' types, u_{mk} is the amount of material *m* used to produce a unit volume of product *k*, and c_m is the unit cost of material *m*. To estimate CF_k for the coming year (*t+1*), overhead expenses and materials' volumes and cost are to be foreseen based on expert opinion, regression models or time series analysis.

$$CF_k = CO_k + \sum_{m=1}^{M} u_{mk} c_m \quad (3)$$

3.2. Delivery cost model:

The RMC supply process can be divided into five major components including RMC production, product loading, transporting RMC to site, RMC placement, and truck return. The RMC production and placement activities must be connected by trucks to form an operation cycle. Since RMC is a perishable and un-storable material, it cannot be generated and stored in advance. Hence, time is critical when it comes to the delivery process of RMC because as time passes, the properties of fresh concrete change quickly, causing it to become unusable within few hours. If the truck travel time exceeds the cold-joint time (the time within which the concrete hardens), the concrete is rendered useless and must be dumped, which raises the operating cost. Therefore, to conform to quality and legislation requirements, RMC must be poured within a set time constraint. In practice, truck service is limited to a given region; the trucks must be carefully dispatched in order to prevent the cold joint process. Consequently, RMC production scheduling and truck-dispatching not only affect transshipment efficiency, but also the operating cost. A number of limitations on the RMC must be taken into account before building a model for RMC delivery:

- The materials are batched at a central plant, and the mixing begins at the plant, so the traveling time from the plant to the site is critical over longer distances.
- Access roads and site access have to be able to carry the weight of the truck and load.
- RMC should be placed within 2 hours of batching to avoid cold-joint. Concrete is still useable after this point but may not conform to the relevant specifications.
- A minimum volume of RMC must be available in the truck during each trip.

Hashami [29] developed a general linear model (Equation 4) to obtain the total annual cost of delivery taking into account the correlations among the delivery variables. The model treats all customers equally, which means that near and far customers will pay the same amount of money.

$$C = B\,O + B1\,(K/T) + B2\,T + B3\,P + B4\,O + B5\,H \quad (4)$$

Where: *C*: Total annual cost, *O*: 1 if the firm is the owner/operator, 0 otherwise, *K*: Overall travel distance in kilometers, *T*: Number of truckloads, *P*: 1 if firm is assessed a financial penalty for late delivery, 0 otherwise, *H*: 1 if the firm hauls more than one product, 0 otherwise, and *B*, *B1*, *B2*, *B3*, *B4*, and *B5* are the associated cost.

The paper presents a model for costing the delivery of RMC to the customer as a function of the travel distance and traffic conditions. To this end, the travel distance (l, in kilometers) is penalized by a factor ($w \geq 1$) to account for traffic conditions. Equation 5 illustrates the cost of delivery (CT_k) of a truck load of product *k* where, w_h and w_r are traffic factors for the hauling and return trip respectively, and c_h and c_r are the cost *($/km)* for the hauling and return trip respectively.

$$CT_k = l_h\, w_h\, c_h + l_r\, w_r\, c_r \quad (5)$$

3.3. Cost of riding RMC wastes:

Concrete waste is a material that is no longer valuable in its current state for its intended use and is either discarded or recycled. Reasons for RMC spoilage include failure to confirm to required RMC specifications, or delay during which cold-joint takes place. Such delays are due plant break down, truck break down, or traffic conditions. Potential cost associated with spoilage management include the on-floor cost of wasted concrete (CO_k), and delivery cost to the location where spoilage took place (CT_k); $CT_k = 0$ if spoilage took place at the RMC plant. Equation 6 illustrates the proposed costing model (CS_t) of riding spoiled amounts of all RMC products during year *t*. In this paper, we use forecasting methods to predicate the spoilage amounts (VS_{kt+1}) of product *k* for the coming year (*t+1*) based on historical data. The estimated spoilage cost per year (CS_{t+1}) is then divided over the estimated volume of production for all RMC products (TD_{t+1}) during that year to obtain the spoilage cost per unit volume. TD_{t+1} is estimated using forecasting methods based on demand history.

$$CS_t = \sum_k \left(CF_k + CT_k\right)VS_{kt} \qquad (6)$$

3.4. Penalties for late deliveries and volume discounts:

The cost associated with delayed concrete deliveries (*CP*) cannot be itemized or traced back to specific activities. Hence, *CP* cost are estimated or forecasted for the coming year and are divided over TD_{t+1} to obtain the related cost per unit volume. On the other hand, volume discounts are traceable cost and are part of the marketing policy of the company. Volume discounts may take various formats including fixed discount per order, percentage discounts based on volume, and rough discounts based on negotiations with the customer. To this end, the proposed model does not include volume discounts and leaves the room to company on deciding the amount of discount on an order as a reduction from its profit.

3.5. Total cost of RMC:

Equation 7 presents the total cost (C_{kt+1}) for producing and transporting D_k unit volumes of RMC product *k* for the year *t+1*. Where, *c* is the capacity of the truck, and $\left\lceil \frac{D_k}{c} \right\rceil$, number of required truck loads, is the nearest integer greater than or equal to $\frac{D_k}{c}$.

$$C_{k\,t+1}(D_k) = CF_{k\,t+1}\, D_k + CT_{k\,t+1}\left\lceil \frac{D_k}{c} \right\rceil + \left(CS_{t+1} + CP_{t+1}\right)\frac{D_k}{TD_{t+1}} \qquad (5)$$

Note that real time costing of product k is composed of 1. Estimated overhead cost, 2. Today's cost of materials, 3. Today's cost of delivery, 4. Estimated cost of spoiled RMC, and 5. Estimated cost of penalties. To compute the true cost of a product during a previous year, financial records are consulted to provide true expenses. Moreover, true demands replace estimated ones.

4. Model Verification

To verify the usability of the model, we implement the proposed costing model on a local RMC plant and results are compared to that obtained using the traditional costing model of the company. To identify and classify activities, trace expenses to activities, and trace activities' cost to products, departments in the RMC plant are visited, employees are interviewed, and organization chart is studied. The main identified activities include maintenance (electrical, cars and bulldozer, equipments and plant), management, purchasing, general accounting, receiving, employee transportation, weighing, mixing, quality assurance, waste management (riding scrap), and guard work (plant equipment and inventory). A thorough investigation of related expenses show that expenses of the activities can be categorized into salaries, overtime, office, communication, research and development, insurance, licensing, fuel and oil, raw materials, water and electricity, and miscellanies.

To obtain the on-floor cost of products, we track expenses of the company to products through expense categories and related activities. Table 2 illustrates expense categories and their cost. Expense categories are related to activities as shown in the EAD Matrix, Table 3. Dollar values for activity-expense intersection and total cost per activity are shown in Table 4.

Table 3: Expense-Activity-Dependence (EAD) Matrix.

Activity	**Expense Categories**											
	Salaries	Overtime	Depreciation	Office Expense	Utilities	Transport	Insurance	Communication	Licenses	Maintenance	R&D	Miscellaneous
Electrical Maintenance	0.081	0.114			0.083			0.081		0.248	0.101	0.083
Vehicle Maintenance	0.025	0.038			0.083			0.041		0.029	0.141	0.083
Equipments and plant Maintenance	0.119	0.170			0.083	0.073		0.122		0.711		0.083
Management	0.158		0.005	0.337	0.083	0.181	0.001	0.219	0.022	0.005	0.404	0.083
RM receiving	0.019	0.024			0.083		0.001	0.023				0.083
General accounting	0.081		0.005	0.237	0.083	0.141	0.001	0.077	0.022	0.002	0.091	0.083
Purchasing raw material	0.033		0.004	0.027	0.083	0.141	0.001	0.035	0.022		0.061	0.083
Employee transportation	0.018	0.024	0.004		0.083	0.280	0.001		0.022	0.003		0.083
Weighing	0.018	0.025			0.083							0.083
Mixing	0.388	0.543	0.977		0.083		0.990	0.348	0.880			0.083
Quality assurance	0.041	0.061	0.004	0.399	0.083	0.141	0.001	0.023	0.022	0.002	0.202	0.083
Waste management	0.002	0.001	0.001		0.001	0.010	0.001		0.010			0.002
Guard work	0.017				0.083	0.033		0.031				0.083

Table 4: Dollar values for activity-expense intersections and total activity cost.

Activity	Expense Categories											Cost ($/Year)
	Salaries	Overtime	Depreciation	Office Expense	Utilities	Transport	Insurance	Communication	Licenses	Maintenance	R&D	Miscellaneous	
Electrical Maintenance	12,447.43	7,749.26			149.850			838.674		12,252.94	499.950	24.950	33,963.06
Vehicle Maintenance	3,841.80	2,583.09			149.85			424.51		1,432.80	697.95	24.95	9,154.96
Equipments and plant Maintenance	18,286.97	11,555.92			149.85	762.12		1,263.19		35,128.38		24.95	67,171.37
Management	24,280.18		867.75	1,231.74	149.85	1,889.64	49.80	2,267.53	98.78	247.04	1,999.80	24.95	33,107.04
RM receiving	2,919.77	1,631.42			149.85		49.80	238.14				24.95	5,013.93
General accounting	12,447.43		867.75	866.24	149.85	1,472.04	49.80	797.26	98.78	98.81	450.45	24.95	17,323.36
Purchasing raw material	5,071.18		694.20	98.69	149.85	1,472.04	49.80	362.39	98.78		301.95	24.95	8,323.82
Employee transportation	2,766.10	1,631.42	694.20		149.85	2,923.20	49.80		98.78	148.22		24.95	8,486.52
Weighing	2,766.1	1,699.4			149.85							24.95	4,640.30
Mixing	59,624.74	36,910.97	169,558.35		149.85		34,511.40	3,603.19	3,951.20			24.95	308,334.65
Quality assurance	6,300.55	4,146.54	694.20	1,458.35	149.85	1,472.04	49.80	238.14	98.78	98.81	999.90	24.95	15,731.91
Waste management	307.34	67.98	173.55		1.80	104.40	49.80		44.90			0.60	750.37
Guard work	2,612.42				149.85	344.52		320.97				24.95	3,452.72

To cost the various products, P150, P200, P250, P300, and P350, of the company for 2009, the activities consumed by each product are identified and the Activity-Product Dependence (APD) matrix is created. It is noticed that the only difference between these products is the percentage of raw materials consumed by the product. Hence, the dollar expense of a product type k from a certain activity, excluding materials, equals the relative yearly demand of that product type ($\frac{D_k}{TD}$) multiplied by that expense. To illustrate, the relative demands of P150, P200, P250, P300, and P350 are 20%, 50%, 20%, 10%, and 0% respectively. Therefore, the $33,963 of electrical maintenance, see Table 5, is subdivided among P150, P200, P250, and P300 as $6,792.61, $16,981.53, $6,792.61, and $3,396.31, respectively. Therefore, the overhead cost per unit volume of each product (CO) equals $5.727.

Table 5 presents the yearly demands and materials consumption for the four products. Table 6 presents estimated and traditional cost per cubic meter of materials of the company's RMC products. The traditional on-floor costing method of the company takes into account today's materials' cost and adds a flat overhead cost of $6.00. Where, the unit cost of a material is obtained by dividing the total cost of that material over the total amount of material used to produce all product types over the year. To illustrate, the total weight of coarse aggregate used to produce the 90,000m^3 of RMC products equals 52,677,000 (18,000 × 593 + 45,000 × 574 + 18,000 × 559 + 9,000 × 679) kilograms. Hence, the average unit cost of coarse aggregate equals the per-year cost of coarse aggregate ($263,385) divided by the total weight of the material used during the year. This yields a unit cost of $0.005 per kilogram of coarse aggregate. Note that P250 cost more than P300 although it is offered to customers at a lower price. Obtained results illustrate that the RMC company over estimated their yearly production cost by more than $24,000 since no scraped mixes or penalties were reported over that year. On the other hand, a scrap level of more than 0.8% (about 720m^3) of RMC mixes at the average price of $33.457 may justify the difference.

Table 5: Yearly demand and consumption of materials for RMC products.

Products	Yearly Demand (m^3)	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (Lit/m^3)	Chemical Component (Lit/m^3)
P150	18,000	235	605	593	215	4.5
P200	45,000	300	585	574	215	5
P250	18,000	360	570	559	215	5
P300	9,000	340	607	679	202	5.5

Table 6: On-Floor Cost per m^3 of RMC products.

Products	**Proposed**			**Traditional**		
	Materials	**Overhead**	**On-Floor**	**Materials**	**Overhead**	**On-Floor**
P150	22.595	5.727	28.322	22.595	6.000	28.595
P200	26.725	5.727	32.452	26.725	6.000	32.725
P250	30.475	5.727	36.202	30.475	6.000	36.475
P300	30.034	5.727	35.761	30.034	6.000	36.034

For delivery operations, the company limits their maximum reach to customers' sites within an 80km radius to prevent cold joint. Deliveries are made using mixing trucks with a maximum capacity of 9m^3. Customers within the circle of 20km are charged $6 per trip. Beyond the 20km limit, the customer is charged an extra $0.25 – $0.30 per kilometer per trip depending on traffic conditions. For the purpose of this research, company experts estimated a markup percentage of 35% to estimate traditional delivery cost. Moreover, they estimated the cost for hauling and returning at $0.175 and $0.125 per kilometer per trip, respectively. Furthermore, they estimated the impact of traffic at w_h = 1.25 and w_r = 1.15. Table 7 illustrates examples of the delivery charges of volumes of RMC to various customers' locations. Note that the traditional system is not sensitive to distances within the 20km limit. Moreover, note that while the company over estimates their delivery costs for various scenarios, they largely under estimate it for the rest of the scenarios especially for long distance deliveries. Summing up on-floor and delivery cost yields the total cost of RMC products. Figure 4 shows the difference in total cost (Traditional – Proposed) per cubic meter of RMC for various combinations of demand, distance, and traffic conditions. Where, 5, 9, 12, 25, and 45 represent delivery volumes, and NT stands for "no traffic" and WT for "with traffic" conditions.

Table 7: Traditional vs. proposed delivery costing systems.

Volume (m^3)	# of km	Without Traffic		With Traffic	
		Traditional	Proposed	Traditional	Proposed
5	5	0.889	0.300	0.889	0.363
	14	0.889	0.840	0.889	1.015
	23	1.000	1.380	1.022	1.668
	48	1.926	2.880	2.133	3.480
9	5	0.494	0.167	0.494	0.201
	14	0.494	0.467	0.494	0.564
	23	0.556	0.767	0.568	0.926
	48	1.070	1.600	1.185	1.933
12	5	0.741	0.250	0.741	0.302
	14	0.741	0.700	0.741	0.846
	23	0.833	1.150	0.852	1.390
	48	1.605	2.400	1.778	2.900
25	5	0.533	0.180	0.533	0.218
	14	0.533	0.504	0.533	0.609
	23	0.600	0.828	0.613	1.001
	48	1.156	1.728	1.280	2.088
45	5	0.494	0.167	0.494	0.201
	14	0.494	0.467	0.494	0.564
	23	0.556	0.767	0.568	0.926
	48	1.070	1.600	1.185	1.933

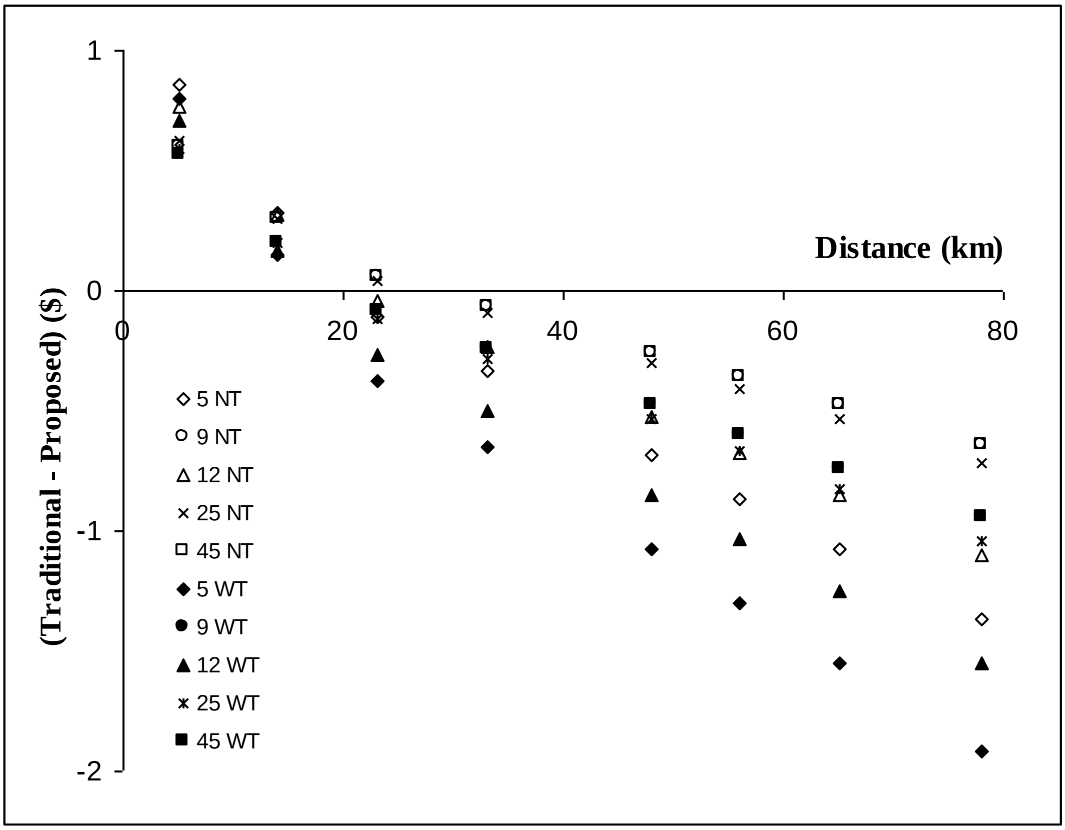

Figure 4: Differences between traditional and proposed costing systems.

To stay competitive, companies put efforts to reduce their expenses through the better management of their resources. Improvement efforts should take into account the value that the process/activity contributes to the final product. Hence, activities with no added value should be eliminated. Moreover, efforts should focus on simplifying value-added activities to save time, effort, and cost. The expense categories and their cost shown in Table 2 show that raw materials contribute to the maximum percentage of expenses and cannot be changed because of specifications. Hence, improvement efforts should focus on 1. Improving work schedules to reduce overtime, 2. Adapt preventive and predictive maintenance to ensure optimum levels of availability, enhance the performance of machines and vehicles, and decrease the rate of depreciation, and 3. Improve the costing practices adapted in the company.

5. Summary and Conclusions

The paper presents a model for costing RMC based on the type of mix and customer's information. The model divides the cost into on-floor, delivery, waste riding, and penalties related cost. The model utilizes ABC to identify activities and assign cost of resources products according to the actual consumption of each product from recourses. ABC helps management arrive at the true cost of a product to avoid under or over costing. Moreover, the analysis of expense categories and their cost help management set their improvement priorities. The model accounts for product and vehicle constraints including expected life of the mix during transportation and the capacity of the vehicle.

The proposed model is applied at a local RMC company where cost differences were recognized compared to the current costing model of the company. While on-floor and scrap management cost are similar and depend only on demand volumes and product type, delivery cost take into account distance and traffic conditions to customer location. This helps management distinguish among customers in charging delivery cost. Although materials account for the largest percentage of expenses, RMC management should investigate potentials to reduce or eliminate some elements for each expense. Among the many, savings associated with depreciation and maintenance can be easily obtained through applying maintenance best practices.

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