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Implementing Activity-Based Costing in Architectural Aluminum Projects: Case Study and Lessons Learned

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***Abstract*—**This study explains how to construct an actionable activity-based costing and management system to accurately track and account the total costs of architectural aluminum projects. Two Activity-Based Costing (ABC) models were proposed to accomplish this purpose. First, the learning and development model was introduced to examine how to apply an ABC model in an architectural aluminum firm for the first time and to be familiar with ABC concepts. Second, an actual ABC model was built on the basis of the results of the previous model to accurately trace the actual costs incurred on each project in a year, and to be able to provide a quote with the best trade-off between competitiveness and profitability. The validity of the proposed model was verified on a local architectural aluminum company.

***Keywords*—**Activity-based costing, activity-based management, construction, architectural aluminum.

I. Introduction

BUILDING an enclosure system that separates the exterior from the interior environment is one of the primary systems in the construction industry. In addition to security function, enclosure systems, such as doors and windows, provide ventilation, natural lighting, and balanced thermal performance [1]. Aluminum framed glass is widely used in these systems to produce various products, including windows, storefronts, curtain walls, roof sheeting, skylight, and entrances [2]-[6]. Architectural glass and aluminum companies usually provide the required engineering, design, fabrication, and installation of these products in customized and made-to-order projects [6], [7]. These projects are usually carried out under some constraints, such as scope, quality, time, and cost. Project managers should overcome these constraints and ensure balance through a good project plan that defines the project's objectives, specifications, stakeholders, timeframe, deliverables, and budget [8], [9].

Project budget, as one of the main components of a project plan, should be accurately estimated to help project executors and the client to make informed decisions about project pricing and implementation [10]. If a project's cost is underestimated, then the firm will make losses, likewise, if a project's cost is overestimated, the competitive edge of the firm will decrease [11]. In the construction industry, accurately estimating a project's direct and indirect costs is essential to winning tenders and new contracts [12], [13]. Material and labor costs as well as other used resources at each site should be carefully monitored and managed to achieve this vital goal [14]. Traditional cost systems focus on direct costs, such as direct labors and materials and divide overhead cost among products or projects, using a single cost driver, which usually is direct labor hours [15]. The study of [16] mentioned that the higher the product's variety and customization, the higher the complexity in their cost accounting. ABC system has mitigated this challenge. Overhead expenses are divided into homogeneous cost pools, where each pool associates the overhead expenses that have the same cause–effect relationship with a cost driver, and these expenses are then allocated to activities based on these cost drivers. Then the total cost of each activity is allocated to cost objects based on the extent of their consumption of the activities [17]-[19].

The current study presents a roadmap to implement an actionable ABC system based on preliminary ABC model that uses the available data to develop, calibrate, and refine the major ABC components. Then the actual ABC model to track the actual cost of projects is constructed and analyzed.

II. Literature Review

Project cost estimation is the process of predicting the direct and indirect resources needed to complete a project within a predefined scope. Many researchers have investigated the application of different cost estimation methods in construction projects. For example, based on past records of key construction costs, [20] used neural networks, linear regression, and time series methods to calculate the construction cost index for concrete structures. The study of [21] investigated the applicability of Decision Aid for Tunnelling, a risk assessment tool, as an early construction cost and time predicting tool in large underground construction projects. The study of [22] used the case-based reasoning model and simulation to improve the reliability of early construction cost estimation process. The study of [23] investigated the use of an artificial intelligence approach to improve the accuracy of construction cost estimation in the early stages of projects. The study of [24] used joint probability distribution functions to propose a Monte Carlo simulation method to predict the total costs of construction projects with reasonable accuracy. However, these cost estimation methods are difficult to apply in real-world cases due to the complexity of such sophisticated methods and

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high computational cost.

Construction cost overruns and factors that influence the accurate estimate of construction costs have also been thoroughly investigated in the literature. For example, [25] explored the factors that contribute to maintaining a stable cost estimate of construction projects. They concluded that critical factors that cause cost overrun include the contractor's inexperience, inadequate planning, inflation, and change in project design. The study of [26] concluded that factors affecting the accuracy of cost estimate are clear and detail drawings and specification, pricing experience, project complexity, clear definition of scope, accuracy and reliability of cost information, site constraints, material availability, and availability of a database of bids on similar projects. The study of [27] found that client's quality requirements is the most critical factor that influences the cost of construction projects in Malaysia. Additionally, [28] investigated the main causes of time delay and cost overruns in construction projects, and they found that changing the scope of the project and poor planning are the main reasons for cost overrun. The study of [29] used the fuzzy logic technique to predict design cost overruns in building projects, whereas [30] employed data mining classification algorithms to predict the level of construction overruns.

Difficulty in estimating the overhead cost in construction projects is a challenge to providing a competitive quote, which may cause financial losses and bankruptcy in some construction companies [31]. However, [32] argued that using the ABC system will help to mitigate this challenge and properly allocate overhead cost among projects. Nevertheless, few studies have tried applying the ABC system in construction projects. For example, [33] constructed an ABC model to properly determine the cost of production and delivery of ready-mix concrete. The study of [34] explored applying the ABC system to allocate the cost of rebar fabrication to projects. The results outlined the steps and benefits of applying the ABC system in the construction industry.

III. ABC and Management System

ABC is a cost accounting system that was fundamentally developed to overcome the limitations of traditional costing (TC). The TC method uses a single allocation base, which is normally the volume of direct labor hours, to assign the costs of resources to cost objects directly. Meanwhile, ABC goes a step further by assigning costs of resources to activities and then the activity costs to cost objects by matching the consumption of resources with each activity [35]. Successful implementation of an ABC system allows organizations to accurately assign indirect costs to products and services, make informed decisions about costs and prices, check the usefulness of processes, and thus, enhance the strategic planning process [36]. Generally, the ABC system has been applied to get rid of cost distortions and to set the cost reduction and process improvement strategies [37].

The ABC method assigns an organization's expenses through its activities to its products and services. First, all expenses are identified and grouped as either direct or overhead costs. It is often easy to track direct costs, such as labor and material costs, to cost objects by their actual consumption, whereas overhead costs are divided into suitable and homogenous categories and are then shared among the activity cost pools based on the extent that these resources are consumed. This step is the first stage allocation process. The process of identifying activities and categorizing overheads can be done simultaneously. Each task that is performed in the organization should be identified and analyzed, and then, the tasks with the same cost driver whose costs can be allocated to a specific cost object are grouped under the same activity. A cost driver is a factor that is directly proportional to the costs of an activity and can be used to assign the costs of activities to cost objects. This step is the second stage allocation process. Finally, the total cost of a cost object is calculated by adding its direct and indirect costs [17], [19], [38], [39].

Activity-based management (ABM) is the process of using ABC data to manage the organization processes and resources efficiently [40], [41]. It is built on the premise that financial information alone is not enough to improve customer satisfaction and profitability [42]. ABM has shown good potential to support the decision-making process, especially about pricing, product mix, and continuous improvement initiatives [43], [44]. The first stage is to identify value added and non-value-added activities [45]. Value added activities are essential to meet customer needs and sustain the organization, and therefore, the organization should focus on improving and optimizing such activities. By contrast, non-value-added activities should be eliminated or minimized. Then, various attributes, such as quality, lead time, flexibility, cost, and customer satisfaction, should be used to rate the analyzed activities according to similar activities in other competitive organizations. The next stage of ABM implementation is to set a robust performance measurement system with appropriate financial and non-financial performance indicators [45].

IV. Proposed Methodology

The road map to implement an actionable costing and management system in architectural aluminum projects is explained in the following subsections.

A. Phase One: Constructing the Learning and Development ABC Model

Implementing an ABC system in a firm for the first time is usually accompanied by various challenges, such as the availability of data, staff training, and the validity of the constructed model. The firm can overcome these challenges by implementing a preliminary ABC model in which it can calibrate, double-check, and fine-tune data sources and ABC tools that will be used to construct the actual model in phase two. The following subsections explain the process.

1. Define the ABC Charter

A team charter should be established in order to implement the ABC system successfully and build consensus. Some of the basic elements that should be defined in the charter are the objectives, work breakdown schedule, and estimated timeframe for each stage [37]. This step may also involve conducting a seminar to explain the concepts and benefits of ABC and to gain the necessary management support.

2. Determine Direct and Indirect Costs

Construction projects, like many cost objects, incur both direct and overhead costs. Direct costs include resources, such as material and labor costs that are directly expended on a specific project. By contrast, overhead costs consist of resources that are shared among various projects, such as rent, utilities, transportation, management salaries, and other organizational sustainability costs. First, all the elements of an organization's expenses should be identified and categorized into direct and overhead costs, and then, the overhead cost should be grouped into homogeneous categories in which each cost element can be allocated to activities using the same cost driver.

3. Identify the Activities

This step includes conducting interviews, intensive meetings, and round tables in the organization to review the stages and workflow of projects, identifying the main tasks of each department and resources consumed to create cost object, and clarifying the stages and processes of implementing the project. Then, the identified actions and tasks are grouped into major activities, where each activity contains homogeneous tasks and actions, that is, the cost of each activity can be allocated to projects based on the same cost driver.

4. Assign Overhead Costs to Activities

In this step, the overhead costs are allocated to activities by estimating the proportions of consumption of activities of the overhead categories based on real data or educated guess [19]. For example, the "electricity bill" category associated with some activity can be allocated on the basis of the number of electrical units, so the allocation rate of electricity is the amount incurred by each electrical unit. Equation (1) shows how to calculate the total cost of activity i (AC_i):

$$AC_i = \sum_{j=1}^{n} r_j * E_{ij} \quad (1)$$

where r_j represents the allocation rate of expense j, which can be calculated as follows:

$$\text{Allocation rate} = \frac{\text{Total expenses in category } j}{Total\ number\ of\ units\ in\ category\ j} \quad (2)$$

E_{ij} represents the extent of consumption of activity i from expense category j.

5. Allocate Costs of Activities to Projects

In this step, the extent of the projects' consumption of each activity is identified. For example, the overhead cost of "project management" activity is allocated to projects by using "number of hours" spent on each project as the allocation base. The allocation rate for each activity represents the cost of each unit of allocation base, which is an hour in this example. Equation (3) shows how to calculate the total overhead cost allocated to project k (POC_k):

$$POC_k = \sum_{l=1}^{m} R_{l*} D_{kl} \quad (3)$$

where R_l represents the actual allocation rate of activity l, which can be calculated as follows:

$$R_l = \frac{Total\ actual\ cost\ of\ activity\ l}{Total\ allocation\ base\ for\ all\ projects\ in\ activity\ l} \quad (4)$$

D_{kl} represents the quantity of the allocation base of activity l consumed by project k.

The allocation bases can be selected from the following types [37]:

- Transactional allocation bases represent the number of times an activity occurs.
- Duration allocation bases capture the time spent to perform an activity.
- Budgetary allocation bases refer to the budget ratio of the projects.

6. Calculate the Total Cost of Each Project and Propose Initiatives to Improve the Efficiency of the Processes

Finally, the total cost of each project equals all direct and indirect costs. The cost data provided by the ABC system can then be used to effectively manage decisions about process quality and cost reduction.

B. Phase Two: Constructing the Actual ABC Model

The data and results that were extracted by applying the learning and development model were used to construct the actual ABC model. This model is used to follow up and document the projects' actual cost in the year. Moreover, it is useful for estimating the allocation rates of activities that can be used for the following year to achieve more accurate pricing and cost control. The activities and second stage allocation bases of this model may be different from those in the learning and development model, where the best trade-off between accuracy, simplicity, applicability, and measurability should be considered. After continuously using the ABC system, the estimated allocation rates are expected to be more accurate, which leads to efficient cost estimation and control. The application of this model is summarized in the following steps:

1. Review and modify the activities in the learning and development model and their allocation bases after considering the best trade-off between accuracy, simplicity, and applicability.
2. Review and modify the overhead categories in the learning and development model and their allocation bases.
3. Calculate the total actual cost of projects at the end of each year by following the steps in the learning and development model.

V. Results and Discussion

BETA company was selected in this study to verify the proposed methodology. Its products consist of windows and doors, curtain walls, cladding, skylight, shutters, internal partitions, garage doors, and other architectural metal elements. These products are fabricated and assembled in the BETA factory.

A. Learning and Development Model

The learning and development ABC model provides BETA managers with complete conceptualization and clear understanding of the ABC method. The following subsections explain the implementation process.

1. Defining the ABC Charter

The initial meetings with BETA's management were focused on determining the working charter, which outlines the aims of work, team members, and time frame. The workflow, job description, and accounting statements for previous years were investigated and studied in detail. Moreover, meetings were held with each department to identify the main tasks and present a brief view of the ABC system.

2. Determining Direct and Indirect Costs

After reviewing the financial statements of previous years and meeting with the accounting department, all direct costs were classified as follows:

- Material costs (metal and glass): The total costs of metal and glass consumed by projects in 2020 were $3,785,655 and $203,715, respectively.
- Bank guarantees: with some projects, BETA must deposit an amount of money as a guarantee against the contract's specifications, duration, and quality. The total cost of bank guarantees in 2020 was $132,469.

As shown in Table I, the overhead expenses in 2020 were collected, analyzed, and then categorized into 20 groups.

TABLE I
OVERHEAD CATEGORIES AND THEIR AMOUNTS IN 2020

Overhead category	Overall annual cost ($)
Salaries	6,058,964
Office Supplies	42,752
Travel& Transportation	237,210
Cleaning & Communication of Headquarters	58,258
General & Administrative Expenses	1,746,886
Purchasing Software	12,586
Agency Fees	71,369
Vehicles Services	226,758
Miscellaneous	39,507
R&D	218,696
Maintenance of Scaffolds	12,096
Migrant Workers	14,595
Rental Winches	32,034
Safety	35,669
Factory’s Communication	7,279
Headquarters’ Insurance & Utilities	253,960
Factory’s Insurance & Utilities	132,654
Maintenance	85,860
Factory’s Cleaning &Transportation	191,256
Depreciation	435,157
Total	**9,913,542**

3. Identifying the Activities

This is a major step in implementing an ABC system, where establishing these activities represents the main difference between ABC and TC systems. In this study, a considerable amount of time was spent on identifying the activities and their cost drivers. First, BETA's organizational chart was reviewed to identify the types and role of each department in the company. Preliminary meetings were conducted to study and discuss the job descriptions in each department. The projects' workflow was also investigated to identify the role of each department in preparing and implementing projects. After these investigations and discussions, each department was considered as a separate activity because each has its specific functions and responsibilities. Nevertheless, some departments were grouped under one activity because they do not work on projects directly, and some departments were split into multiple activities because they have many major tasks that cannot be allocated to projects using the same allocation base. In this study, 18 activities, 11 in the headquarters, and seven in the factory, were selected, they are presented in Table II.

TABLE II
LIST OF BETA’S DEPARTMENTS WITH THEIR ACTIVITIES

Department	Activity
Project Management	Project Management
Installation	Installation
Procurement	Procurement
Technical Services	Technical Services
Pricing	Pricing
Sales	Sales
Customer service	Customer Service Paid Maintenance
Quality Control	Quality Control
Contract control	Contract Control
Top management Accounting Human Resource (HR) Safety	Administrative Works
Warehouse (factory)	Warehouse
Maintenance (factory)	Maintenance
Material Handling (factory)	Material Handling
Planning (factory)	Aluminum Planning Glass Planning Steel Planning
Fabrication (factory)	Fabrication

4. Performing the First Stage Allocations

The overhead expenses that were previously categorized were allocated to activities based on the extent of their actual consumption of each category. Most of the meetings with the accounting department were held to establish suitable bases to allocate overhead costs to their consuming activities. As shown in Table III, these allocation bases were refined and finalized. Then, the total cost of each activity was calculated using (1) and (2); they are summarized in Table IV.

5. Allocating Costs of Activities to Projects

Although BETA's projects are usually implemented by repeating the same activities and tasks, some projects may require few or many activities and effort. Accordingly, fair estimation of the real effort made by the activities on projects is almost difficult without using the appropriate second stage allocation bases. The second round of interviews and brainstorming sessions were conducted to define an accurate, simple, and applicable allocation base for each activity. The trade-off between accuracy and data availability was carefully considered in this stage because BETA's projects vary in size (small, medium, and large) and type of material (local and imported). In some departments, the team faced a challenge in defining and applying the appropriate allocation base for activities lacking accurate data. To explain this challenge, the process used to select an appropriate allocation base in the pricing department is illustrated as follows. Because of their significant impact on market share and the competitive value of the company, the data of the pricing department should be highly accurate. If the pricing department estimates the costs of projects inaccurately, the actual costs of projects will be either overestimated or underestimated. Thus, clients will be attracted to the lower prices of competitors. The company may also lose bids or tenders if the actual budget is overestimated because the quote that is based on the estimated budget will be more than the normal price. By contrast, the company may incur losses if the actual budget is underestimated. Therefore, many allocation bases in the pricing department, such as budget, the area of implemented projects, and duration, were discussed. Duration was considered as the most accurate allocation base because it observes the actual efforts made on projects. However, there were no actual data on the time spent by the pricing department on projects implemented in the last year. To overcome this challenge, the team agreed with the head of the pricing department to use the estimated area of implemented projects as the allocation base for allocating the pricing department's overhead costs among the projects priced in the last year. The cost incurred by the pricing department on a project was calculated, using (3), by multiplying the pricing department allocation rate with the total estimated area of the project. The allocation rate was calculated using (4):

$$= \frac{234{,}936}{51{,}323} = 4.58 \text{ \$/estimated m}^2$$

The overhead cost incurred by each activity on each project is calculated by using the same equations, (3) and (4). Table V summarizes the activities and their second stage allocation bases.

The total cost of the project was calculated by adding the overhead cost spent on each project under each expense category to the direct costs. Table VI illustrates the total cost for some sample projects in 2020.

6. Proposing Initiatives to Improve the Efficiency of the Processes

The ABC system's cost information can be used to make efficient managerial decisions about cost categories and quality of processes. This can be achieved by analyzing the categories of expenses and activities. As shown in Fig. 1, the categories of expenses were analyzed by identifying those with the highest percentage of total overhead. Salaries and administrative expenses are approximately 78% of the total overhead costs. Thus, it is highly recommended to study and investigate the elements of these categories to reduce cost and ensure efficient use of resources without compromising the quality of work.

TABLE III
OVERHEAD CATEGORIES AND THEIR FIRST-STAGE ALLOCATION BASES

Overhead Category	Allocation Base Type	Allocation Base
Salaries	Actual data	HR and payroll department data
Office supplies	Actual data	Actual bills
Travel& Transportation	Actual data	Movement department reports
Cleaning & Communication of Headquarters	Educated guess	Number of headquarters employees
General & Administrative Expenses	Educated guess	Salaries percentage
Purchasing Software	Actual data	Direct beneficiary
Agency Fees	Actual data	Promoter department
Vehicles Services	Educated guess	Rate of using vehicles
Miscellaneous	Educated guess	Number of all employees
Research and development (R&D)	Actual data	Direct consumer
Maintenance of Scaffolds	Actual data	Direct consumer
Migrant Workers	Actual data	Direct consumer
Rental Winches	Actual data	Direct consumer
Safety	Educated guess	Number of labors
Factory's Communication	Educated guess	Number of factory employees
Headquarters' Insurance & Utilities	Educated guess	Percentage of utilized area
Factory's Insurance & Utilities	Educated guess	Percentage of utilized area
Maintenance	Actual data	Maintenance department reports
Factory's Cleaning & Transportation	Educated guess	Number of factory employees
Depreciation	Actual data	Accounting department reports

TABLE IV
THE TOTAL COSTS OF ACTIVITIES IN 2020

Activity	Total Cost ($)	Activity	Total Cost ($)
Project Management	908,974	Quality Control	170,218
Pricing	234,936	Administrative Works	1,132,043
Technical Services	250,170	Warehouse	525,405
Procurement	136,829	Machines Maintenance	184,270
Sales	439,117	Material Handling	157,844
Contract control	57,540	Aluminum Planning	161,367
Installation	3,653,961	Steel Planning	30,352
Customer service	40,023	Glass Planning	43,129
Paid Maintenance for Projects	120,069	Fabrication	1,667,294
The Grand Total = 9,913,542 $			

The activities that consume a high percentage of expenses, such as value engineering principles and performance management, were also considered for improvements and cost reduction initiatives. As illustrated, the activities were established by identifying the tasks and functions of each department, so the tasks of each activity should be analyzed and categorized into value added and non-value-added tasks. Value added tasks are essential to meet the needs of customers and sustain the organization. Thus, this information will support the decision-making process about the tasks that should be prioritized. By contrast, the non-value-added tasks can be reduced or eliminated without affecting customer satisfaction and the organization's sustainability. As shown in Fig. 2, the critical activities that consume the highest percentage of total overhead are installation, project management, administrative works, and fabrication. In addition, some activities, such as pricing activity, are considered critical because they are related to customers or the sustainability of the organization. Identifying critical activities makes it possible to make significant improvements. The following points were identified as improvement initiatives:

- Because the installation activity consumed approximately 37% of the total resources, the rationality of this volume was further evaluated. The team found that the core installation efforts are made on small projects, which make fewer profits than the other types of projects. Therefore, it is recommended that medium and large projects should be prioritized over small projects.
- Pricing work on cancelled projects does not provide any revenue for BETA. The total budget of these projects in 2020 was $14,000,000. Hence, BETA should consider collecting a small payment in advance as consulting fees if a client wants to price a project while taking the current competition and impact on customer satisfaction into account.
- The developed cost drivers can be considered as performance indicators of the activities.

TABLE V
LIST OF ALL ACTIVITIES WITH THEIR ALLOCATION BASES AND ALLOCATION RATES FOR THE LEARNING & DEVELOPMENT MODEL

Activity	Allocation Base Type	Allocation Base	Allocation Rate
Project Management	Transactional	Meter square of total quantities	Small type (120.373 $/m^2$) Medium type (16.32 $/m^2$) Large type (33.35 $/m^2$)
Pricing	Transactional	Meter square of total estimated quantities	4.58 ($/estimated m^2)
Technical Services	Budget	Budget of project	0.0069 ($/budgeted $)
Procurement	Budget	Cost of direct material	0.036 ($/material $)
Sales	Budget	Budget of project	0.067 ($/budgeted $)
Contract Control	Budget	Budget of project	0.0016 ($/budgeted $)
Installation	Transactional	Meter square of total quantities	38.88 ($/m^2)
Customer Service	Budget	Budget of project	0.0011 ($/budgeted $)
Paid Maintenance	Budget	Revenue of maintenance	0.565 ($/revenue $)
Quality Control	Transactional	Meter square of total quantities	1.81 ($/m^2)
Administrative Works	Budget	Budget of project	0.031 ($/budgeted $)
Warehouse	Budget	Cost of direct material	0.139 ($/material $)
Machines Maintenance	Budget	Budget of project	0.005 ($/budgeted $)
Material Handling	Transactional	No. of moved items/units	60.83 ($/unit)
Aluminum Planning	Duration	Actual duration of fabrication	2.284 ($/h)
Steel Planning	Budget	Budget of project	0.0008 ($/budgeted $)
Glass Planning	Budget	Glass expenses	0.212 ($/glass $)
Fabrication	Duration	Actual duration of fabrication	23.6 ($/h)

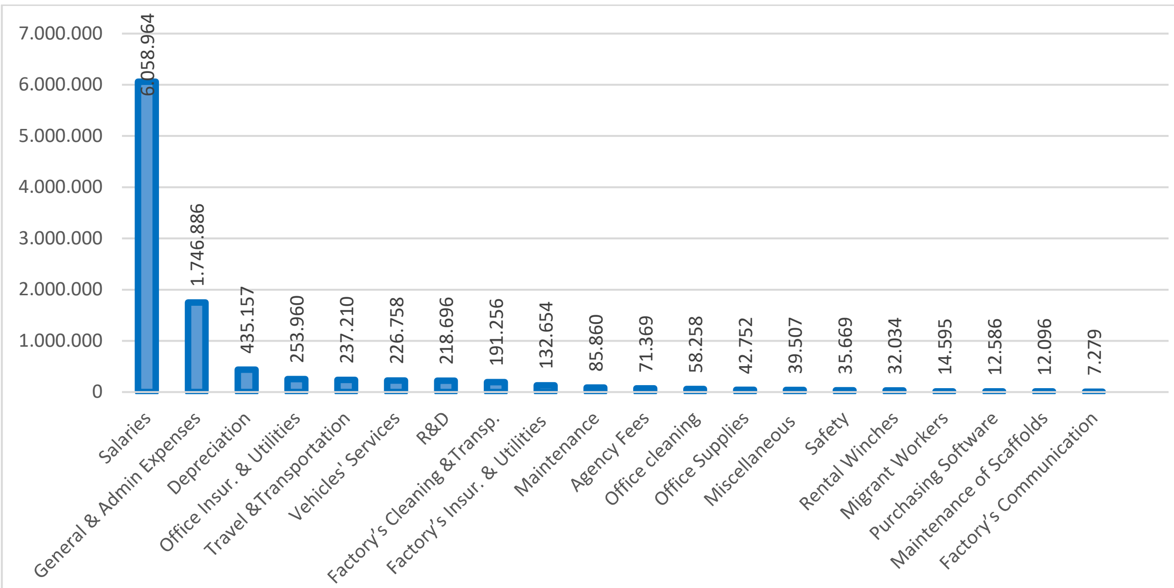

Fig. 1 Pareto chart for overhead categories

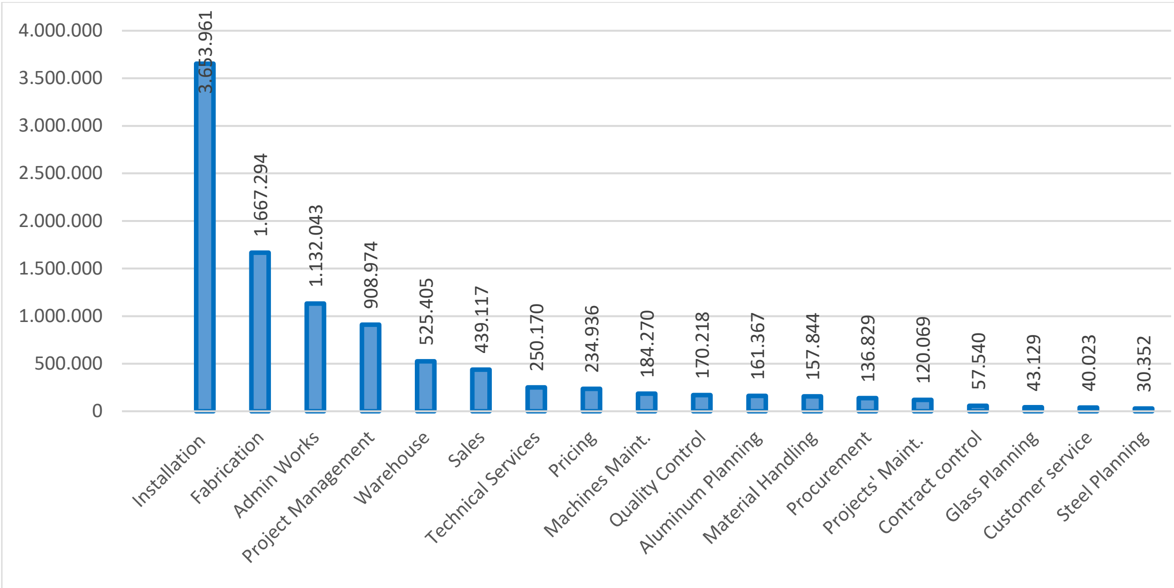

Fig. 2 Pareto chart for overhead costs of activities

TABLE VI
TOTAL COSTS FOR SOME SAMPLE PROJECTS, USING THE LEARNING AND DEVELOPMENT MODEL, IN 2020

Cost Source (Activity)	Project Number									
	P-15	P-27	P-244	P-145	P-274	P-2	P-66	P-71	P-110	P-277
PM	5,005	1,169	26,089	12,411	20,489	308	16,144	7,389	1,113	8,314
Pricing	226	129	13,673	2,659	4,091	0	0	0	0	0
Technical Services	25	38	4,059	1,277	8,045	29	10,818	41,642	1,314	2,713
Procurement	61	65	3,021	2,331	2,856	26	9,885	7,234	709	190
Sales	242	364	9,417	2,399	8,122	0	0	0	0	0
Contract Control	8	9	941	296	1,866	7	2,509	9,656	305	629
Installation	1,617	378	64,742	33,598	92,583	766	240,321	73,350	55,216	29,915
Customer Service	4	6	647	204	1,283	5	1,725	6,639	209	433
Paid Maintenance	0	0	0	0	0	0	0	0	0	0
Quality	75	17	3,014	1,564	4,310	35	11,187	3,414	2,570	1,392
Administrative Works	112	169	18,238	5,737	36,146	132	48,602	187,085	5,901	12,190
Warehouse	235	250	11,664	9,002	11,029	100	38,166	27,930	2,736	733
Machines Maintenance	18	27	2,942	925	5,830	21	7,839	30,175	952	1,966
Material Handling	0	183	0	3,467	6,022	122	10,402	0	2,859	122
Aluminum Planning	171	86	2,183	1,136	5,297	207	1,062	3,069	545	121
Steel Planning	3	4	471	148	933	3	1,254	4,828	152	315
Glass Planning	95	0	17	131	9	15	23	2,958	124	0
Fabrication	1,765	885	22,560	11,733	54,734	2,136	10,972	31,713	5,635	1,255
Direct Material (metal)	1,688	1,795	83,912	64,760	79,342	718	274,574	200,935	19,685	5,274
Direct Material (glass)	448	0	79	616	41	71	108	13,954	585	0
Bank Guarantees	0	0	0	0	3,500	0	9,525	17,525	0	0
Total project Cost ($)	**11,798**	**5,575**	**297,669**	**164,394**	**416,528**	**4,702**	**695,117**	**669,497**	**100,611**	**65,563**

B. Actual ABC Model

The actual ABC model is essential for tracking the actual overhead costs incurred in the year and checking the validity of a pricing policy by comparing the budgeted costs estimated by the pricing department with the actual costs. First, all categories of expenses and their allocation bases used in the learning and development model were analyzed and used in this model. The available data on last year's projects were used to identify the activities and their allocation bases in the learning and development model. Hence, these activities and their allocation bases were also evaluated and refined to be used in all ABC models in the following years, considering the best trade-off between accuracy, simplicity, applicability, and measurability.

The allocation bases for project management, technical services, procurement, sales, contract control, customer service, paid maintenance, administrative works, warehouse, material handling, aluminum planning, steel planning, glass planning, and fabrication activities are the same as the allocation bases in the learning and development model. Regarding the remaining activities, there are some differences in the selected allocation bases, they are explained in the following points:

1) *Pricing activity:* The pricing time for each project will be used as the allocation base to distribute the costs of this activity between projects. Timesheets will be used by the pricing employees to document and record the time spent on project pricing.
2) *Installation activity:* This activity was divided into two i.e., installation and garage doors, because works on garage doors are implemented in specific projects. Duration cost driver was recommended as the allocation base for installation overhead among projects. Because laborers usually have a low level of education, they will face difficulties in filling timesheets and storing data on the system, so it was neglected. However, the team and head of the department used the area of installed quantities in the year as the allocation base. For example, if the total area to be installed in a project is 100 m^2, but the area of installed quantities in 2020 is 70 m^2, and the remaining 30 m^2 will be installed during 2021, the allocation base for installation cost for this project in 2020 is only 70 m^2.
3) *Garage doors activity:* Because some projects include installation of garage doors and the installation department has employees who work on garage doors only, a separate activity was formed for garage doors. The cost of this activity will be pooled by 2020, and the cost of direct material used to install garage doors was used as the allocation base.
4) *Quality assurance activity:* Because this activity is somehow associated with installation processes, the area of installed quantities is used as the allocation base.
5) *Computer Numerical Control (CNC) fabrication activity:* Because there are employees who are responsible for CNC tasks, we created an activity for this work. The allocation base is the number of fabricated units for each project.
6) *Glass planning activity:* The glass area is used as an allocation base for this activity because it is more related to glass planning than glass expenses, which are used in the learning and development model.

The total actual cost of each project at the end of each year is calculated by following the same steps and equations used in the learning and development ABC model.

The following points summarize some lessons learned and the benefits of applying the actual ABC model:

- Applying the learning and development model reveals that there is a lack of documented data about projects, in addition, extracting and sorting these data to be analyzed was a time-consuming process. Therefore, applying the actual model will help in organizing the documentation and recording process because employees of each activity are required to record the requested data for the activity's allocation base.
- There was a substantial waste in the pricing activity about the canceled and re-priced projects, and the consulting fees were proposed to compensate this waste, these fees may negatively affect customer satisfaction and market share, so this decision should be analyzed extensively. Fortunately, the pricing employees will fill timesheets to be used in the actual model as the allocation base of pricing. The data from these timesheets will show the volume of time spent on these projects accurately, thereby supporting the decision-making process.
- Fair allocation of overhead expenses among projects is fulfilled by applying this model, where the overheads are allocated to each project based on the extent of its actual consumption of the total overhead. In the coming years, BETA will be aware of the actual volume of overhead spent on each type of project, this can be used to study the potential profit of each type of project and focus on the most profitable types.
- Persistently applying the actual model will help to continuously refine the developed allocation rates to be used in the normal and estimation models because using the allocation rates of one year may be risky because the sales volume in a particular year may be different from the company's sales trend. Thus, using the average allocation rates of several years will produce more accurate rates.

VI. Conclusions

This study uses the ABC approach to fairly allocate the overhead costs of architectural aluminum companies among their projects, which are made-to-order. This will assist the management of these firms to accurately track, control, and estimate the total cost of projects. Additionally, the data extracted with the ABC approach are used to make managerial decisions objectively by implementing ABM. To achieve these purposes, two ABC models, learning and development and actual models, are constructed and proposed. The following are the conclusions of this study:

1) The learning and development model facilitates the identification of the primary overhead categories and activities with their allocation bases. In addition, this model ensures that employees of each activity are familiar with the ABC concepts and how to select and measure the appropriate allocation bases.
2) The actual model, which is constructed on the basis of the hands-on feedback about the limitations and problems faced in applying the learning and development model, helps management to accurately trace the total costs consumed by each project at the end of each year and compare these costs with the estimated costs for feedback and auditing purposes.

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