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Activity-Based Cost Estimation Model for Foundry Systems Producing Steel Castings

Mohammad D. Al-Tahat*[,a] and Al-Refaie Abbas[a]

[a]Industrial Engineering Department, University of Jordan, Amman 11942 – Jordan

Abstract

Attention in this work is directed to estimate the manufacturing costs by using Activity-Based Costing (ABC) method for the castings that are produced by steel foundry. ABC is a cost accounting method that can overcome many of the limitations of Traditional Cost Accounting (TCA) methods. Cost rates for each department in the foundry are estimated by engineering procedures. Consequently, cost- estimating relationship model that mathematically describes the cost of final castings as a function of all consumable resources is constructed. A Work-In-Process (WIP) flow through the different production centers is analyzed and costs of available resources are allocated for all foundry centers, cost rates are derived, accordingly the ABC method for estimating production cost is discussed and presented. Comparison between the results of ABC method and the results of TCA method has been carried out. Finally results are discussed, recommendations are presented, and avenues for related future works are proposed.

Keywords: ABC; Manufacturing cost; Foundry cost; Activity-based management; Casting technology.

1. Introduction

Manufacturing organizations are looking to produce high-quality products more quickly and with the lowest possible cost. To achieve that, companies are required to become more productive, integrated, highly flexible, and to have a realistic and more precise cost estimation approach. Managers need to fully understand the cost, time, and quality of activities performed by employees or machines throughout an entire organization. Traditionally direct labor was typically chosen as the base for assigning overhead cost to products and there was a high correlation in most foundries between direct labor and the incurrence of overhead cost. Presently automation has greatly decreased the amount of direct labor required, and a total overhead cost has increased to the point that a correlation no longer exists between it and direct labor. Wherever these changes have exist, foundries that have continued to use direct labor as a basis for overhead assignment has experienced major distortions in unit costs.

In order to overcome these problems some foundries can use Activity Based Costing (ABC) method. ABC involves a two-stage allocation process, with the first stage overhead costs are assigned to cost centers, the centers represent a set of activities, such as casting design, drawing, measurement, prototyping, pattern making, quality control, melting, molding, etc. In the second stage, cost rates are assigned to jobs according to the nature of activities required. The roots of ABC approach were introduced in 1984 by respected professor, Dr. Robert Kaplan of Harvard Business School who began to expound the shortcomings of TCA method, and who developed the new ABC method [1, 2, 3]. From these beginnings, ABC gained attention and spread widely over the world. ABC models the relationships between products and the resources used in their production at all production centers that enable managers to cost out measurements to business simplification and process improvement. ABC provides a more accurate and consistent way of calculating manufacturing costs [4, 5] Costing systems accumulate data and aggregate them into information for financial reporting and managerial decision-making. It is important, therefore, that the definitions of costing parameters are understood by industrial engineers and production managers to make accurate decision. ABC method attempts to provide an accurate interpretation of factors generating all the cost. Improper classification of costs can distort management's perception of the process and lead to poor decision- making, therefore, decision-makers must be careful when using costing data to know precisely what is included and how the data relate to their engineering choices [6]. Recently, the remarkable success implementations of ABC introduced a new paradigm to literature of the manufacturing cost accounting and, ABC has been increasingly used in multi-level complex manufacturing organizations. A number of sources about ABC are available on [7, 8, 9, 10]. Several researchers applied ABC in different real life application can be found in the literature, among these [11, 12, 13, 14, 15].

Ginoglou D., 2002 [1] addressed that ABC improves the costing system of organizations in the following ways:

- ABC increases the number of cost pools used to accumulate overhead costs. Rather than accumulating all overhead costs in a single, company wide pool, or

* Corresponding author.e-mail: altahat@ju.edu.jo

accumulating them in departmental pools, costs are accumulated by activity.

- ABC changes the base used to assign overhead costs to products. Rather than assigning costs on a basis of direct labor or some other inaccurate measure of volume, costs are assigned on a basis of the portion of cost-driving activities that can be traced to the products.
- ABC changes also a manager's perception of many overhead costs in that costs that were formerly thought to be indirect (such as power, inspections and machine setup) are identified with specific activities and therefore are recognized as being traceable to individual products.
- As a result of having more accurate product costs, managers are in position to make better decisions relating to product retention, marketing strategy, product profitability and so forth
- Moreover ABC leads to better-cost control because it eliminates distortions that are caused by the labor-based costing systems and also helps investment decisions. Labor-based cost systems under cost capital intense processes, while over costing labor intense processes. ABC provides more accurate process cost information, which lays the foundation for better capital justification. Using activity-based costing, companies not only know what each process' real overhead amounts to, but what it consists of. The system tells management how much tooling, maintenance and utilities each process consumes. These costs can be used in capital justifications or as targets in cost reduction programs.

The primal objective of this paper is to present a costing model that uses ABC to estimate the production costs of steel castings an experimental case study will be conducted to demonstrate the costs calculation under specific production conditions to gain an insight into the effects of production parameters on costs. The output of the ABC model will be considered separately in order to be distinguished and to be compared with the result obtained by TCA under the same production environment.

2. Modeling of Foundry Activities Resources Consumption

This paper is considering a multi products steel foundry system that uses mainly Ferro-alloys, steel scrap and return, to convert them into finished steel castings, and finally deliver the finished casting to the customers. This considered foundry has the layout shown by figure1 the produced castings conforming to DIN, JIS, ASTM, BS, and some other international quality standards. The foundry includes all the necessary production lines to manufacture, produce casting and form the different types of steel castings used in industry, agriculture, construction, and the infrastructure for the engineering industries and supported engineering complementary industries, which depend on castings. The initial product mix comprises steel castings, but in the longer term, the foundry can support further development of mechanical engineering industries in the region. The product mix of the foundry includes but not limited the following main casting alloy types: low alloy steel castings; stainless steel; 12/14 Mn-steel castings (Mn-B1); 2Cr- 14 Mn-steel castings (Mn-C); heat resistance steel castings (H.R.SCH22, H.R.SCH13); Ni-hard cast iron; high Chrome cast iron (High Cr-CI); 25 Cr-12 Ni steel castings; and ductile rolls.

Different mould sizes and heights can be accommodated within a reasonable range. Box molding produces components falling outside the range. Medium frequency coreless induction furnaces each of 1.5 tones capacity are installed, rated at 1.8 tones of molten metal per hour, during which the metal temperature should be raised to more than 1650 ^{o}C.

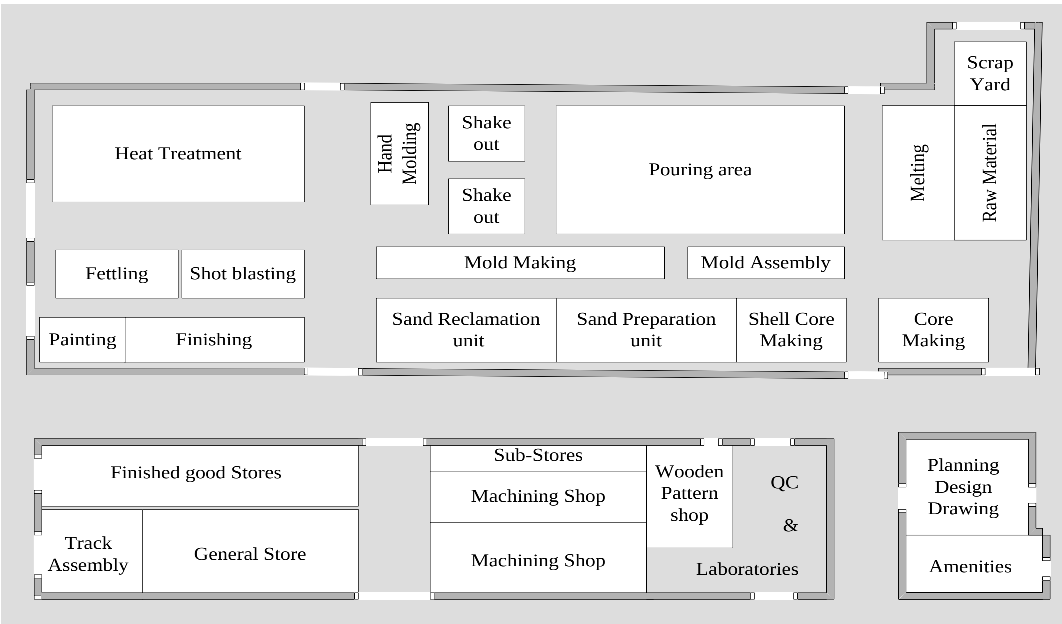

Figure1: Layout of the proposed steel foundry and its support departments

Pouring operations on pattern flow molding section is utilizing crane ¬suspended ladles suitable for bottom pouring. In the site plan, the plant occupies one separate manufacturing building for melting, molding, pouring operations, and casting cleaning and finishing operations.

New silica sand handling, chemically bonded sand reclamation plant, and core shop facilities are housed in the ancillary production bay alongside the main casting production building. Other service departments, such as laboratories, garage, pattern shop, general stores, maintenance department, compressor house, and electrical sub-station are established in separate buildings on the site. The manufacture of casting is described as shown in figure 2. Starting from the development of foundry technology (casting design), chemical composition is selected, mass calculations is performed, dimensions and tolerances are prepare. If customer order can be fulfilled, the needed technology, production method, requirements, and documents, are prepared, than production is triggered and flow as in the sequence described in figure 2.

Capacity Factor (CF) is defined as the ratio of the average output production to the maximum production capacity over a year. As depicted in figure 3, the average CF of the foundry over the past five years is equal to (0.50).

To achieve the objective of our work a capacity factor of 0.5 is considered, only line molding process is considered, and only furan cores are used. Under this scenario, cost rates for every used resource is derived to be used to estimate total production cost by TCA and/or ABC methods.

The monthly production can be estimated by spreading the average of the actual yearly production over the working months (12 month), therefore the monthly estimated production quantity is:

$$MP = Monthly\ production = \frac{Average\ actual\ \ production\ output}{Working\ months\ per\ year}$$

$$= \frac{700}{12} = 58000\ Kg\ of\ saleable\ casting$$

2.1. Activities and activity centers:

Figure 2 indicates that, many activities being carried out in the foundry. These activities represent the process of acquisitioning raw materials, casting them into finished products in accordance with the general sequence depicted in figure 2, and delivering them to customers. In the case of this paper more than fifteen main activity centers are traced, some of these centers are: melting center, automatic molding, furan core making, shakeout, shot blasting, cutt-off, grinding, heat treatment, machining, track assembly, painting, shipping, testing and inspection (QC), planning, design and technology, maintenance, and administration center.

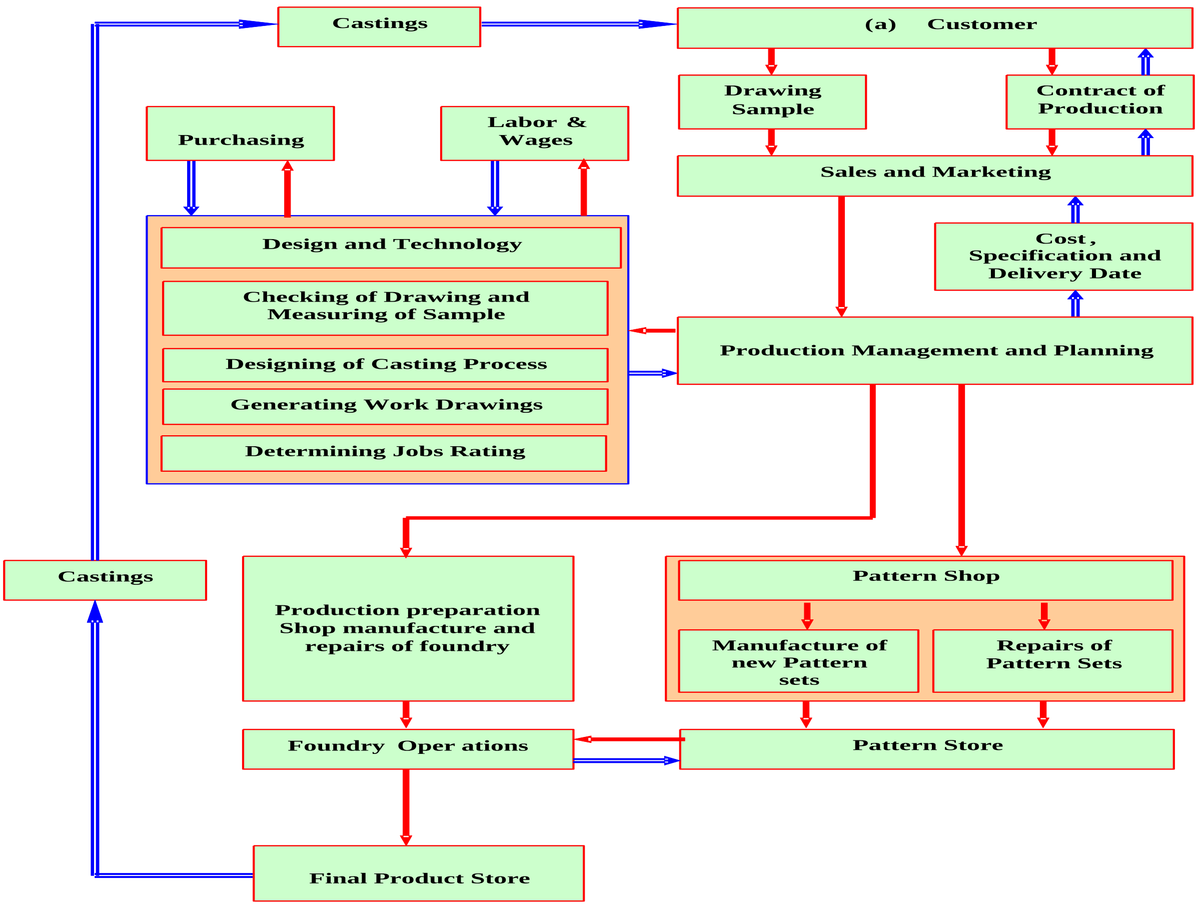

Figure 2: Standard sequence of operations for the manufacture of casting in the considered foundry.

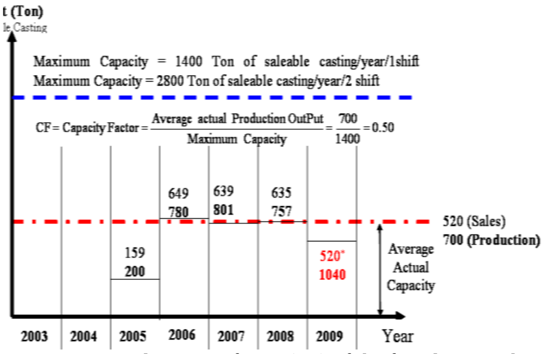

Figure 3: Actual capacity factor (CF) of the foundry over the past five years.

It is assumed that these centers consume certain levels of resources. The resource consumption is calculated using utilization levels of these centers per Kilogram of production.

2.2. Resources and resource consumption:

The major goal in ABC is to calculate the activity costs. The calculation of total product cost is a secondary operation. The aim is to manage the activities that contribute to the total product cost (PC) cost. In this context, the total cost of a product is the summation of the costs of activities that take place to produce that product. Therefore, after determining the activities, one should calculate how much resource each activity consumes. Different resources are available in the foundry, see figure 4. These can be classified into four categories: 1) Production Cost (PC) related resources, or casting cost, 2) resources related to Manufacturing Overhead Cost (MOC), 3) resources related to Selling Cost (SC), and 4) Administrative Cost (ADC) related resources, these classes are demonstrated by figure 4, and are explained in the following paragraphs.

2.2.1. Production or casting cost (PC):

This represents the converted values disbursement of direct labor and direct materials. The major cost items involved in this resource consumption are:

- Direct Material, (DM): Is the material whose cost is directly charged to the casting. The sum of charges for materials that accumulate against the product during its passage through the plant constitutes the total direct material cost. This cost element is considered as furnaces charging materials, molding materials such as silica sand, furan resin, catalyst, mold coating materials, release agent, consumed materials for core making and coating, and consumed materials during the assembly of some products.
- Direct Labor, (DL). It is the labor whose cost is charged directly to the casting. This cost element includes wages and salaries of blue dress workers in melting; molding; fettling; heat treatment and finishing; painting and shipping.

2.2.2. Manufacturing Overhead Cost (MOC):

MOC is converted to a cost figure when they are used for the purpose of manufacturing throughout the years. This cost embraces all expenses incurred in the production of castings that are not directly charged to the products as direct material or direct labor. Costs such as indirect material and indirect labor are combined, with other cost that cannot be directly related to the product being manufactured. The major cost items involved in this resource consumption are:

- Indirect Material, (IDM). These are small amount of a number of consumed items of material that are not directly charged to the casting. Indirect materials assumed as; materials consumed in melting, particularly, lining materials, refractory bricks, nozzles, and stoppers, and supplies used in the foundry that includes water, lighting current, heating fuel, electric power and maintenance supplies.Also steel shots, consumed materials for cutting off, grinding, and heat treatment of castings (grinding wheels, heat treatment media, cutting off tools etc.), lubricant, coolant and painting materials. Indirect elements of material cost are charged to manufacturing overhead expense as shown in figure 4.
- Engineering Cost, (IDL). The labor of personnel engaged in, engineering department (Eng), technology office (Tech), planning (Plan), quality control, inspection, quality check, and laboratories (Labs), production maintenance, services, and stores (PMS); Indirect labor is charged to manufacturing overhead expense as shown in figure 4.
- Factory Capital Recovery (CRF). CRF includes deprecation of physical place of production shop, depreciation of production equipment and production facilities, taxes, insurance, interest, rent, and maintenance of production buildings.
- Maintenance and service (MS). PMS represents the cost of all necessary services for survival of the organization and it covers all maintenance services, equipments, materials, labor, etc.
- Laboratories and quality cost (Labs). This cost item includes the money spent to buy machines for laboratories, spare parts, standards, references, manuals, and other needed materials. It also includes salaries of operators, and calibration cost.

2.2.3. Selling expense (SC):

Selling expense includes salaries, commissions, operation of office equipments and automobiles, travel, market surveys, entertainment of customers, displays (exhibition), sales space and other selling everyday expenditure.

2.2.4. Administrative expense (ADC):

- Administrative expense arises from expenditures for such items as; salaries of executive, clerical, and technical personnel; offices supplies; travel, and fees for legal, technical and auditing services that are necessary to direct the enterprise as a whole.

- Capital Recovery (CRA). CRA is considered to be independent of production volume, it represent the depreciation on such equipments as cars, land, offices, Computer hardware and software systems used, and other facilities belong to the company but not related directly to the production, CRA can be nominated as Indirect capital recovery.
- Total Capital Recovery (CR) which is the summation of CRF and CRA.

3. Cost of Resources and Cost of Activity Centers Based on ABC Method

An activity cost is the summation of costs of resources that are used by that center. The determination of which activity consumed which resource and how much of the resource is used by that activity is the means by which activity cost can be estimated.

Production cost consists of direct materials like charging materials, molding materials, consumed materials for core making and coating, consumed materials for assembly, and direct wages and salaries of blue dress workers in melting; molding; fettling; heat treatment and finishing; painting; shipping; and all other working centers. Manufacturing overhead cost consists of indirect, indirect labor cost, depreciation on factory equipments, tools, and devices, maintenance and storing cost, and quality cost. Selling cost includes salaries, commissions, operation of office equipments and automobiles, travel, market surveys, entertainment of customers, etc. Administrative cost includes of executive, clerical, and technical personnel; capital recovery of land, cars, office equipments and depreciation on such equipments as cars, land, offices, computer hardware and software systems used, and other facilities belong to the company but not related directly to the production, CR can be nominated as indirect capital recovery. Input-output relationship between resources and activity centers are demonstrated by figure 5.

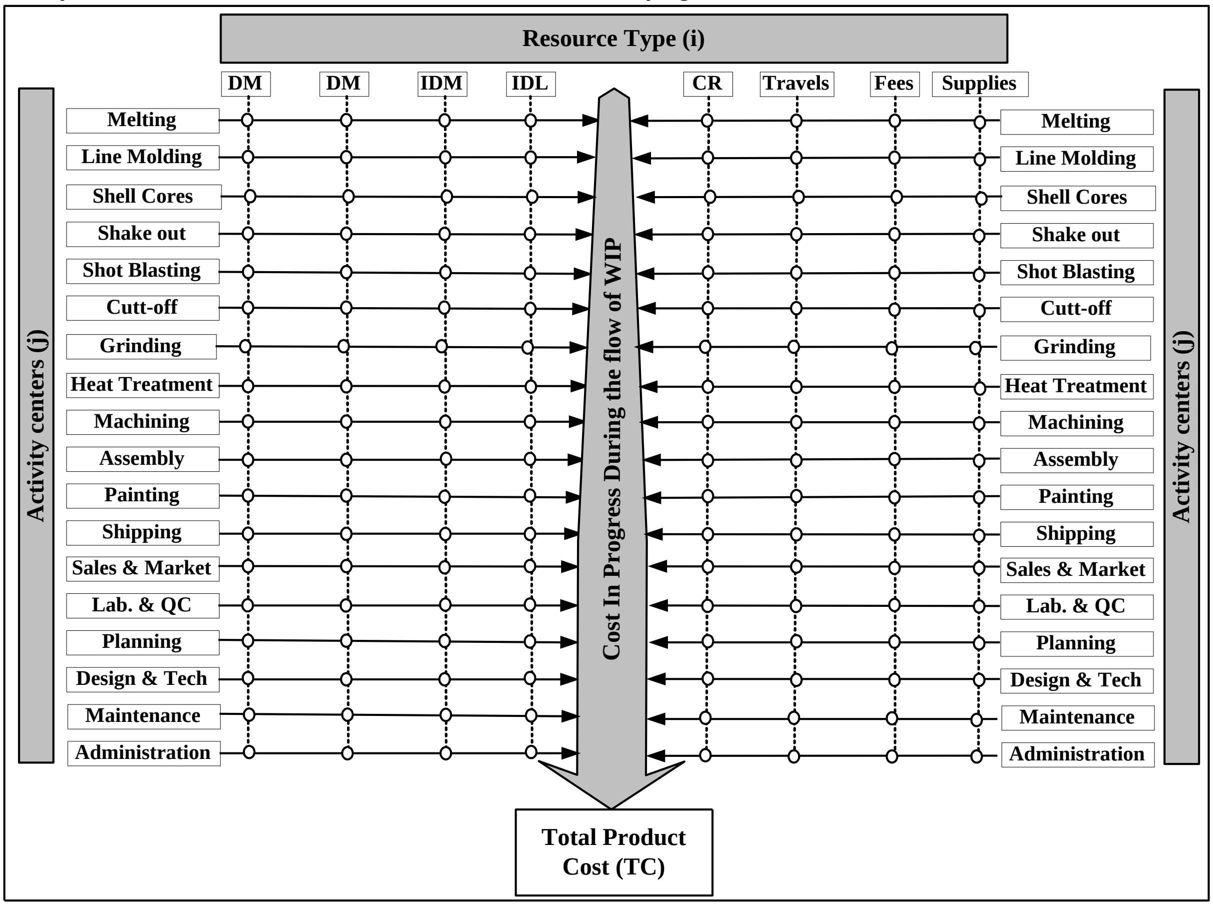

Figure 5: WIP flow and input-output relationship between resources and activity center.

Figure 5 shows that the cost of castings is accounted for as casting's components physically move from activity center to the other through the deferent department of the foundry. The production cost of final products reflects summery data indicating the Work-In-Process (WIP) inventory cost accounts at each activity center of the foundry [16].

4. Activity Based Calculation (ABC) of Total Product Cost

The following notation is used to describe the mathematical expression built to calculate the total product cost,TC, based on ABC:

- TC Total product cost of a considered product ($/product)
- W Saleable weight of the product (Kg)
- I Total available number of resources
- i Resource index (i = 1, 2. . . . I)
- J Total available number of activity centers
- j Activity center index (j = 1, 2 . . . . J)
- Rij Cost rate of consuming the ith resource at the jth activity center for producing a product of one Kilogram weight ($/1Kg)

$$TC = W\sum_{i=1}^{I}\sum_{j=1}^{J}R_{ij} \quad (1)$$

The flow of WIP represented by figure 5 is a general illustration for any type of casting. For a specific casting type some modifications are needed. For example some castings are requested by the customer to be used as cast – without machining- therefore this type of casting is not pass through the machining center and hence the allocated machining cost that will be added to the summation in equation (1) is zero. Also few castings pass through the assembly activity; therefore a value of assembly cost equal to zero will be allocated for most of the products.

4.1. ABC cost rates:

The main concern of this paper is to estimate the manufacturing costs by using ABC method then to compare that with the cost obtained by TCA; therefore the work will not consider the detailed explanation of how the rates (Rij) are derived. ABC cost rates for each consumed resources at each work center are computed by engineering procedures method at a low level of detail. The computation of these rates is highly depending on the skills and on the experience of the industrial engineers of the foundry. As a result of this work phase cost rates are presented in table 1. These cost rates covering the whole range of the product mix which represented by 10 family groups as indicated previously in section two of this paper.

4.2. ABC calculations:

Using the cost information given in table 1 and the activity-resource relationships shown in figure 5

Total production cost for any casting type can be calculated by the mathematical expression presented in equation (1). This equation states that the total production cost of a casting is the sum of the allocated costs for each activity center the part undergoes in its production process. Consider a product of a weight equal to 12 Kilogram made from Mn-B1 alloy type. The total production cost of this item is the summation of cost for all consumed resources.

As it is shown in table 2 total production cost covers direct and indirect material cost, indirect and indirect labor cost, depreciation cost, travels and transportation cost, fees and insurances cost, and cost of consumed supplies.

The allocation of cost to the considered casting from all the resource areas associated with its production is shown in figure 6. The allocation has been shown as a percentage of the total production cost for clarity.

Table 1: Resource cost rate at each activity center for each alloy type Rij ($/Kg) of saleable casting.

Resource cost rate at each activity center for each alloy type, R_{ij}($ per one saleable Kilogram)																					
			Activity Center (j)																		
Resource Type (i)	Alloy type	Alloy Yield%	j = 1 = Melting	j = 2 = Line Molding	j = 3 = Shell core	j = 4 = Shake out	j = 5 = Shot blasting	j = 6 = Cutt-off	j = 7 = Grinding	j = 8 = Heat treatment	j = 9 = Machining	j = 10 = Assembly	j = 11 = Painting	j = 12 = Shipping	j = 13 = Sales & Market	j = 14= Labs & QC	j = 15 = Planning	j = 16 = Design/ Tech	j = 17 = Maintenance	j = 18 = Administration	Sub-Total
i = 1 = DL	*Mn-B1*	39	0.064	0.060	0.040	0.001	0.002	0.010	0.001	0.006	0.000	0.042	0.001	0.001	0.011	0.054	0.000	0.023	0.004	0.000	**0.32**
	Mn-C	50	0.050	0.047	0.031	0.000	0.002	0.008	0.000	0.005	0.000	0.000	0.001	0.001	0.009	0.042	0.000	0.018	0.003	0.000	**0.22**
	low alloy	55	0.045	0.042	0.028	0.000	0.002	0.007	0.000	0.004	0.004	0.000	0.001	0.001	0.008	0.038	0.000	0.016	0.003	0.000	**0.20**
	cast iron	65	0.038	0.036	0.024	0.000	0.001	0.006	0.000	0.004	0.004	0.000	0.001	0.001	0.007	0.032	0.000	0.014	0.002	0.000	**0.17**
	High Cr-CI	55	0.045	0.042	0.028	0.000	0.002	0.007	0.000	0.004	0.020	0.000	0.001	0.001	0.008	0.038	0.000	0.016	0.003	0.000	**0.22**
	H.R.SCH13	50	0.050	0.047	0.031	0.000	0.002	0.008	0.000	0.005	0.016	0.000	0.001	0.001	0.009	0.042	0.000	0.018	0.003	0.000	**0.23**
	H.R.SCH22	50	0.050	0.047	0.031	0.000	0.002	0.008	0.000	0.005	0.016	0.000	0.001	0.001	0.009	0.042	0.000	0.018	0.003	0.000	**0.23**
	Ductile Iron	65	0.038	0.036	0.024	0.000	0.001	0.006	0.000	0.004	0.008	0.000	0.001	0.001	0.007	0.032	0.000	0.014	0.002	0.000	**0.17**
	Stainless	50	0.050	0.047	0.031	0.000	0.002	0.008	0.000	0.005	0.014	0.000	0.001	0.001	0.009	0.042	0.000	0.018	0.003	0.000	**0.23**
	Ductile rolls	70	0.035	0.033	0.022	0.000	0.001	0.006	0.000	0.004	0.008	0.000	0.001	0.001	0.006	0.030	0.000	0.013	0.002	0.000	**0.16**
i = 2 = DM	*Mn-B1*	39	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.000	2.240	0.000	0.000	0.008	0.000	0.000	0.000	0.051	0.000	**2.58**
	Mn-C	50	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.040	0.000	**0.33**
	low alloy	55	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.067	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.036	0.000	**0.39**
	cast iron	65	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.067	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.031	0.000	**0.38**
	High Cr-CI	55	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.335	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.036	0.000	**0.66**
	H.R.SCH13	50	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.268	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.040	0.000	**0.59**
	H.R.SCH22	50	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.268	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.040	0.000	**0.59**
	Ductile Iron	65	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.134	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.031	0.000	**0.45**
	Stainless	50	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.235	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.040	0.000	**0.56**
	Ductile rolls	70	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.134	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.029	0.000	**0.45**
i = 3 = IDM	*Mn-B1*	39	0.077	0.087	0.087	0.000	0.008	0.015	0.003	0.000	0.000	0.000	0.008	0.003	0.004	0.114	0.000	0.002	0.007	0.000	**0.42**
	Mn-C	50	0.060	0.068	0.068	0.000	0.006	0.012	0.003	0.000	0.000	0.000	0.008	0.003	0.003	0.089	0.000	0.002	0.005	0.000	**0.33**
	low alloy	55	0.055	0.062	0.062	0.000	0.005	0.011	0.003	0.000	0.009	0.000	0.008	0.003	0.003	0.081	0.000	0.002	0.005	0.000	**0.31**
	cast iron	65	0.046	0.052	0.052	0.000	0.005	0.009	0.003	0.000	0.009	0.000	0.008	0.003	0.002	0.069	0.000	0.001	0.004	0.000	**0.26**
	High Cr-CI	55	0.055	0.062	0.062	0.000	0.005	0.011	0.003	0.000	0.045	0.000	0.008	0.003	0.003	0.081	0.000	0.002	0.005	0.000	**0.34**
	H.R.SCH13	50	0.060	0.068	0.068	0.000	0.006	0.012	0.003	0.000	0.036	0.000	0.008	0.003	0.003	0.089	0.000	0.002	0.005	0.000	**0.36**
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	Stainless	50	0.060	0.068	0.068	0.000	0.006	0.012	0.003	0.000	0.032	0.000	0.008	0.003	0.003	0.089	0.000	0.002	0.005	0.000	**0.36**
	Ductile rolls	70	0.043	0.049	0.049	0.000	0.004	0.009	0.003	0.000	0.018	0.000	0.008	0.003	0.002	0.064	0.000	0.001	0.004	0.000	**0.26**
i = 4 = IDL	*Mn-B1*	39	0.060	0.006	0.005	0.000	0.001	0.003	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.069	0.023	0.030	0.001	0.019	**0.23**
	Mn-C	50	0.047	0.006	0.004	0.000	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.053	0.018	0.023	0.001	0.015	**0.17**
	low alloy	55	0.043	0.006	0.003	0.000	0.001	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.049	0.016	0.021	0.001	0.013	**0.16**
	cast iron	65	0.036	0.006	0.003	0.000	0.000	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.041	0.014	0.018	0.001	0.011	**0.13**
	High Cr-CI	55	0.043	0.006	0.003	0.000	0.001	0.002	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.049	0.016	0.021	0.001	0.013	**0.17**
	H.R.SCH13	50	0.047	0.006	0.004	0.000	0.001	0.003	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.053	0.018	0.023	0.001	0.015	**0.18**
	H.R.SCH22	50	0.047	0.006	0.004	0.000	0.001	0.003	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.053	0.018	0.023	0.001	0.015	**0.18**
	Ductile Iron	65	0.036	0.006	0.003	0.000	0.000	0.002	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.041	0.014	0.018	0.001	0.011	**0.14**
	Stainless	50	0.047	0.006	0.004	0.000	0.001	0.003	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.053	0.018	0.023	0.001	0.015	**0.18**
	Ductile rolls	70	0.034	0.006	0.003	0.000	0.000	0.002	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.038	0.013	0.017	0.001	0.010	**0.13**
i = 5 = CR	*Mn-B1*	39	0.224	0.206	0.025	0.000	0.010	0.038	0.027	0.048	0.000	0.019	0.003	0.002	0.004	0.019	0.000	0.000	0.071	0.239	**0.93**
	Mn-C	50	0.175	0.161	0.020	0.000	0.008	0.030	0.021	0.037	0.000	0.000	0.002	0.001	0.003	0.015	0.000	0.000	0.056	0.187	**0.71**
	low alloy	55	0.159	0.146	0.018	0.000	0.007	0.027	0.019	0.034	0.010	0.000	0.002	0.001	0.003	0.014	0.000	0.000	0.052	0.170	**0.66**
	cast iron	65	0.134	0.123	0.015	0.000	0.006	0.023	0.016	0.029	0.010	0.000	0.002	0.001	0.003	0.011	0.000	0.000	0.044	0.144	**0.56**
	High Cr-CI	55	0.159	0.146	0.018	0.000	0.007	0.027	0.019	0.034	0.050	0.000	0.002	0.001	0.003	0.014	0.000	0.000	0.052	0.170	**0.70**
	H.R.SCH13	50	0.175	0.161	0.020	0.000	0.008	0.030	0.021	0.037	0.040	0.000	0.002	0.001	0.003	0.015	0.000	0.000	0.056	0.187	**0.75**
	H.R.SCH22	50	0.175	0.161	0.020	0.000	0.008	0.030	0.021	0.037	0.040	0.000	0.002	0.001	0.003	0.015	0.000	0.000	0.056	0.187	**0.75**
	Ductile Iron	65	0.134	0.123	0.015	0.000	0.006	0.023	0.016	0.029	0.020	0.000	0.002	0.001	0.003	0.011	0.000	0.000	0.044	0.144	**0.57**
	Stainless	50	0.175	0.161	0.020	0.000	0.008	0.030	0.021	0.037	0.035	0.000	0.002	0.001	0.003	0.015	0.000	0.000	0.056	0.187	**0.75**
	Ductile rolls	70	0.125	0.115	0.014	0.000	0.006	0.021	0.015	0.027	0.020	0.000	0.001	0.001	0.002	0.011	0.000	0.000	0.041	0.133	**0.53**
i = 6 = Travels	*Mn-B1*	39	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.057	0.000	0.000	0.000	0.000	0.000	**0.06**
	Mn-C	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	**0.04**
	low alloy	55	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.041	0.000	0.000	0.000	0.000	0.000	**0.04**
	cast iron	65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.000	0.000	**0.04**
	High Cr-CI	55	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.041	0.000	0.000	0.000	0.000	0.000	**0.05**
	H.R.SCH13	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	**0.05**
	H.R.SCH22	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	**0.05**
	Ductile Iron	65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.000	0.000	**0.04**
	Stainless	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	**0.05**
	Ductile rolls	70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000	**0.04**
i = 7 = Fees	*Mn-B1*	39	0.013	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.003	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	**0.03**
	Mn-C	50	0.010	0.006	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	**0.02**
	low alloy	55	0.009	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	**0.02**
	cast iron	65	0.008	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**0.02**
	High Cr-CI	55	0.009	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	**0.02**
	H.R.SCH13	50	0.010	0.006	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	**0.02**
	H.R.SCH22	50	0.010	0.006	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	**0.02**
	Ductile Iron	65	0.008	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**0.02**
	Stainless	50	0.010	0.006	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	**0.02**
	Ductile rolls	70	0.007	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	**0.02**
i = 8 = Supplies	*Mn-B1*	39	0.036	0.003	0.003	0.000	0.000	0.002	0.000	0.001	0.000	0.007	0.000	0.000	0.000	0.002	0.000	0.000	0.005	0.055	**0.12**
	Mn-C	50	0.028	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.004	0.043	**0.08**
	low alloy	55	0.026	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.006	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.003	0.039	**0.08**
	cast iron	65	0.022	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.006	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.003	0.033	**0.07**
	High Cr-CI	55	0.026	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.030	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.003	0.039	**0.11**
	H.R.SCH13	50	0.028	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.240	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.004	0.043	**0.32**
	H.R.SCH22	50	0.028	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.024	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.004	0.043	**0.11**
	Ductile Iron	65	0.022	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.012	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.003	0.033	**0.08**
	Stainless	50	0.028	0.002	0.002	0.000	0.000	0.001	0.000	0.001	0.012	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.004	0.043	**0.10**
	Ductile rolls	70	0.020	0.002	0.001	0.000	0.000	0.001	0.000	0.001	0.012	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.003	0.031	**0.07**

Table 2: Computations of total production cost ($) for a 12 Kg Mn-B1 alloy casting.

Resource cost rate at each activity center (R_{ij}) for Mn-B1 alloy type ($ per one saleable Kilogram)																					
Resource Type (i)	Alloy type	Alloy Yield%	Activity Center (j)																		Sub-Total
			j = 1: Melting	j = 2: Line Molding.	j = 3: Shell core	j = 4: Shake out	j = 5: Shot blasting	j = 6: Cutt-off	j = 7: Grinding	j = 8: Heat treatment	j = 9: Machining.	j = 10: Assembly	j = 11: Painting	j = 12: Shipping	j = 13: Sales & Market	j = 14: Labs & QC	j = 15: Planning	j = 16: Design=tech	j = 17: Maintenance	j = 18: Administration	
DL	Mn-B1	39	0.064	0.060	0.040	0.001	0.002	0.010	0.001	0.006	0.000	0.042	0.001	0.001	0.011	0.054	0.000	0.023	0.004	0.000	**0.32**
DM	Mn-B1	39	0.240	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.000	2.240	0.000	0.000	0.008	0.000	0.000	0.000	0.051	0.000	**2.58**
IDM	Mn-B1	39	0.077	0.087	0.087	0.000	0.008	0.015	0.003	0.000	0.000	0.000	0.008	0.003	0.004	0.114	0.000	0.002	0.007	0.000	**0.42**
IDL	Mn-B1	39	0.060	0.006	0.005	0.000	0.001	0.003	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.069	0.023	0.030	0.001	0.019	**0.23**
CR	Mn-B1	39	0.224	0.206	0.025	0.000	0.010	0.038	0.027	0.048	0.000	0.019	0.003	0.002	0.004	0.019	0.000	0.000	0.071	0.239	**0.93**
Travels	Mn-B1	39	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.057	0.000	0.000	0.000	0.000	0.000	**0.06**
Fees	Mn-B1	39	0.013	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.003	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	**0.03**
Supplies	Mn-B1	39	0.036	0.003	0.003	0.000	0.000	0.002	0.000	0.001	0.000	0.007	0.000	0.000	0.000	0.002	0.000	0.000	0.005	0.055	**0.12**
Total cost ($/Kilogram) =																					**4.6779**
For a casting of wieght, W = 12 Kg													**Total Production Cost, TC($) =**								**56**

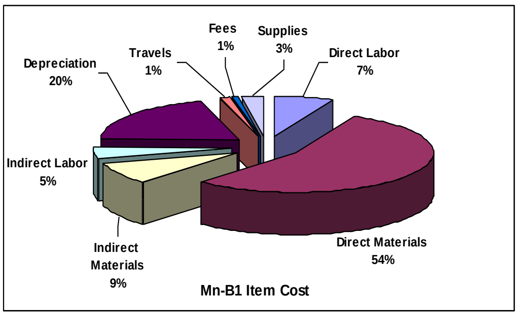

Figure 6: Division of the contributing costs of Mn-B1 Item cost.

5. Traditional Calculation of Total Cost

The following notation is used to describe the mathematical expressions built to calculate the total product cost based on TCA:

W	Saleable weight of a product *(Kg)*
MC	Total manufacturing related cost *($/Kg)*
NMC	Total non-manufacturing related cost ($/Kg)
PC	Production (casting) cost of a product of one Kilogram weight ($/Kg)
DM	Direct material cost for a product of one Kilogram weight ($/Kg)
DL	Direct labor cost for a product of one Kilogram weight ($/Kg)
IDM	Indirect material cost for a product of one Kilogram weight ($/Kg)
MP	Monthly production (Kg)
IDL	Indirect labor cost for one month of production ($/Month)
IDL2	Indirect management cost for one month ($/Month)
CRF	Monthly depreciation cost of foundry equipments ($/Month)
CRA	Monthly depreciation cost of administration facilities ($/Month)
MS	Maintenance cost for one month of production ($/Month)
SC	Selling cost for one month of production ($/Month)
QC	Laboratories and QC cost for one month of production ($/Month)
MOC	Manufacturing overhead cost for one month of production ($/Month)
Supplies	Electricity, oil, diesel, water, and other material cost consumed by administration during a one month of production ($/Month).
Engineering	Engineering cost for one month of production ($/Month).
Technology	Technology and design cost for one month of production ($/Month).
Plan	Planning cost for one month of production ($/Month)
Travels	Transportation and traveling cost for one month ($/Month)

$$TC = MC + NMC \tag{2}$$

$$MC = PC + MOC \tag{3}$$

$$PC = DM + DL \tag{4}$$

$$\mathrm{MOC} = \mathrm{IDM} + \mathrm{IDL} + \mathrm{CRF} + \mathrm{QC} + \mathrm{Supplies} \tag{5}$$

$$\mathrm{IDL} = \mathrm{Engineering} + \mathrm{Technology} + \mathrm{Planning} \tag{6}$$

$$NMC = ADC + SC \tag{7}$$

$$\mathrm{ADC} = \mathrm{IDL2} + \mathrm{SUP} + \mathrm{CRA} + \mathrm{Travels} \tag{8}$$

5.1. TCA cost rates:

Total production cost is split into two categories: manufacturing related and non-manufacturing related cost. Manufacturing related costs include the cost of operating processes on several work centers that relate directly to the produced products like melting cost, molding cost, and core making cost, shake out cost, and others as shown in table 3.

Manufacturing related costs rates are derived and presented in table 3, these TCA rates are measured as follows: direct labor (DL) is measured by $ per month, depreciation in $, and the rest of the rates are measured by $ per oneKilogram of Saleable Castings ($/Kg).

Table 3: Manufacturing related TCA Cost rates at each work center for each alloy type. Measuring unit is $/Kg except where indicated.

Cost Element	Casting alloy type	Yeild %	TCA Costs Rate in Each Work Center for Each Casting Type									
			Melting	Molding Line	Core Shell	shake out	shot blast	Fettling and H.T Cutt	Grind	H.T.	Track Asmb.	paint shipp
DL $/Month	All Casting	52	2786	4357.00		2800						
(DM)	Mn-B1	39	0.240								2.24	
	Mn-C	50	0.240									
	low alloy	55	0.210									
	cast iron	65	0.150									
	High Cr-CI	55	0.400	0.02		0.00						
	H.R.SCH13	50	2.000									
	H.R.SCH22	50	2.500									
	Ductile Iron	65	0.450									
	Stainless	50	1.800									
	Ductile rolls	70	0.600									
(IDM)	Mn-B1	39	0.077	0.087	0.087		0.008	0.015	0.0034			0.011
	Mn-C	50	0.060	0.068	0.068		0.006	0.012	0.0034			0.011
	low alloy	55	0.055	0.062	0.062		0.005	0.011	0.0034			0.011
	cast iron	65	0.046	0.052	0.052		0.005	0.009	0.0034			0.011
	High Cr-CI	55	0.055	0.062	0.062	0.000	0.005	0.011	0.0034	0.00		0.011
	H.R.SCH13	50	0.060	0.068	0.068		0.006	0.012	0.0034			0.011
	H.R.SCH22	50	0.060	0.068	0.068		0.006	0.012	0.0034			0.011
	Ductile Iron	65	0.046	0.052	0.052		0.005	0.009	0.0034			0.011
	Stainless	50	0.060	0.068	0.068		0.006	0.012	0.0034			0.011
	Ductile rolls	70	0.043	0.049	0.049		0.004	0.009	0.0034			0.011
	Mn-B1	39	0.277									
	Mn-C	50	0.216									
Supplies	low alloy	55	0.196									
	cast iron	65	0.166									
Electricity	High Cr-CI	55	0.196									
Water	H.R.SCH13	50	0.216									
Diesel	H.R.SCH22	50	0.216									
	Ductile Iron	65	0.166									
	Stainless	50	0.216									
	Ductile rolls	70	0.154									
(CRF) $/Month	All Casting		117520	108036	13241	0.000	5491	33952		24976	9730	2329
Engineering			3975 $/Month									
Technology			2472 $/Month									
Planning			1049$/Month									
QC			20348 $/Month									
(PMS)			85018 $/ Year									

Non-manufacturing related operations directly relate to the administration unit of the foundry and non-engineering operations like selling cost, general expenses cost, and salaries, for the general administration. TCA cost rate of these non-manufacturing related operations is also analyzed and categorized as indicated in table 4. Total administration salaries are 9813 $/Month. And over all expenses that included supplies, capital recovery, travels and other fees and auditing cost is 154397 $/Month. Selling cost SC is also computed, SC is equal to 20038 $/Month. This amount represents salaries of salesmen and representatives, and all other selling expenses.

TCA rates in table 3 and table 4 are presented in different cost unit, for example direct labor is presented by $ per month, and direct material is presented by $ per kilogram of saleable casting, where as the depreciation cost is presented by $ per year. To compute and derive a reasonable and accurate cost value for any product the units must be consistence. The best unit consistency is found when the monthly production is estimated.

Table 4: Non-Manufacturing related TCA Cost rates.

ADC				SC
Salaries of IDL2 $/Month	Supplies $/Year	Travels $/Year	CRA $/Year	Salaries $/Month
9813	28833	17888	125564	2195
Total $/ Month		24170		2195

5.2. TCA Calculations:

The complete cost figures of the products of any alloy type under TCA are given table 5. Consider again the product that is made from Mn-B1alloy type. The total production cost of this item under TCA is $32, see table 6. this cost value covers direct and indirect material cost, direct labor cost, cost of supplies, depreciation cost, engineering cost, technology cost, planning cost, QC cost, maintenance cost, administration cost and sales cost. The allocation of cost to the considered casting from all cost elements associated with its production is shown in figure 7.

Table 5: Complete cost under TCA in $/Kg.

Cost Element	Alloy Type	Yeild (%)	Complete Cost figure $/Kg Saleable casting
(DL)	All Casting	52	0.17
(DM)	Mn-B1	39	0.32
	Mn-C	50	0.32
	low alloy	55	0.29
	cast iron	65	0.23
	High Cr-CI	55	0.48
	H.R.SCH13	50	2.08
	H.R.SCH22	50	2.58
	Ductile Iron	65	0.53
	Stainless	50	1.88
	Ductile rolls	70	0.68
(IDM)	Mn-B1	39	0.45
	Mn-C	50	0.35
	low alloy	55	0.32
	cast iron	65	0.27
	High Cr-CI	55	0.32
	H.R.SCH13	50	0.35
	H.R.SCH22	50	0.35
	Ductile Iron	65	0.27
	Stainless	50	0.35
	Ductile rolls	70	0.25
Supplies Elictricity Water Diesel	Mn-B1	39	0.28
	Mn-C	50	0.22
	low alloy	55	0.20
	cast iron	65	0.17
	High Cr-CI	55	0.20
	H.R.SCH13	50	0.22
	H.R.SCH22	50	0.22
	Ductile Iron	65	0.17
	Stainless	50	0.22
	Ductile rolls	70	0.15
(CRF)	All Casting		0.40
Engineering			0.07
Technology			0.04
Planning			0.02
(QC)			0.34
(MS)			0.12
ADC	All Casting		0.38
SC			0.06

Table 6: Cost calculation under TCA of an item of 12 Kg made from Mn-B1 Alloy.

Cost Element	Alloy Type	Yeild (%)	Complete Cost figure $/Kg Saleable casting
Direct Labor	All Casting	52	0.17
Direct materials	Mn-B1	39	0.32
Indirect Materials	Mn-B1	39	0.45
Supplies	Mn-B1	39	0.28
Depreciation	All Casting	52	0.40
Engineering		52	0.07
Technology		52	0.04
Planning		52	0.02
Quality Control		52	0.34
Maintenance		52	0.12
Adminstartion	All Casting	52	0.38
Selling		52	0.06
Production cost ($/Kilogram) =			2.63
For a casting of wieght,W, in Kg =			12
Total Production Cost, TC($) =			32

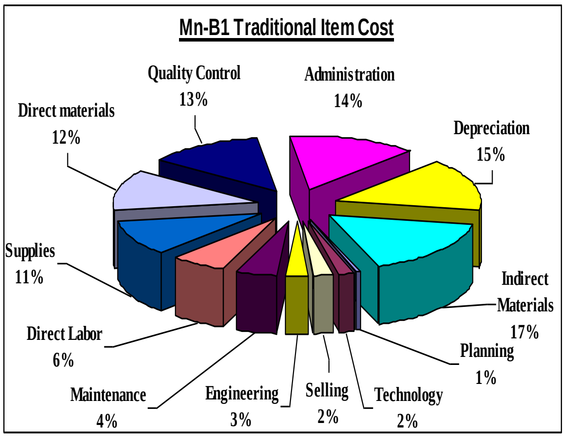

Figure: 7: Division of the contributing costs of Mn-B1 item cost under TCA.

6. Discussion and Concluding Remarks

A comparison of producing the different alloy types under variant production rate is carried out based on ABC and TCA, the comparison as shown in figure 8, indicates that, the target of the company should be to produce 2800 ton of saleable casting per one year in two shifts with the full designed capacity. This logical result has been concluded based on both TCA and ABC as shown by figure 8 and figure 9 respectively. For any alloy type the production cost under a production rate of 2800 tons per year per 2 shafts is smaller than the production cost under a production rate of 1400 tons per year per 1 shaft as will as a production rate of 700 tons per year per 1 shaft.

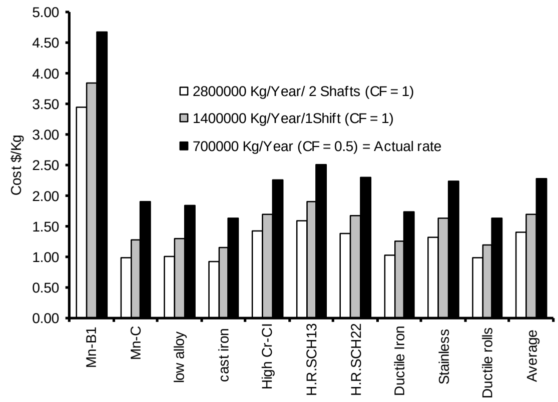

Figure 8: A comparison of cost of different alloy types under variant production rate based on ABC.

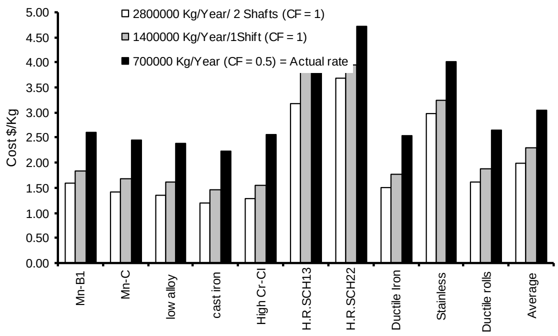

Figure 9: A comparison of cost of different alloy under variant production rate based on TCA.

Based on ABC, the most expensive alloy in all scenarios is Mn-B1 that accurately reflects the cost of the assembly center, while the cheapest alloy is the cast iron alloy. Based on TCA, the most expensive alloy in all scenarios is H.R.SCH22 alloy, while the cheapest one is cast iron alloy. One advantage for ABC over TCA is that ABC can be used as a continuous improvement tool for internal cost reduction; ABC results can provide quantitative figures to determine the cost effectiveness of the foundry and to justify strategic production policies. It can be used to investigate the effectiveness of consuming the available resources by every activity center independently. These advantages relate to the way the costing process is assessed and the improved visibility of cost items. ABC improves the visibility of costs and shows how costs are passed down to products by activities as depicted by figure 10, which shows the allocation of cost as a percentage to a stainless steel casting from all available resources areas associated with every activity center.

The process of allocating cost from resources to activities is a second benefit of ABC. By understanding the hierarchy of costs and the way products consume the lower cost items, the visibility of overhead cost is improved. Under TCA, the attention of management would be drawn only to the higher cost elements, which in this case as shown in figure 11, are the direct and direct materials, capital recovery, supplies and quality cost.

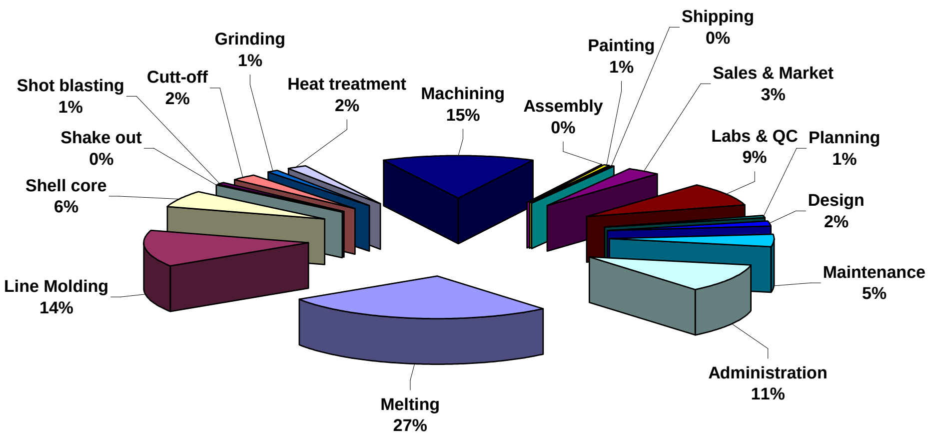

Figure 10: Resources consumption % by activity centers under ABC for stainless steel.

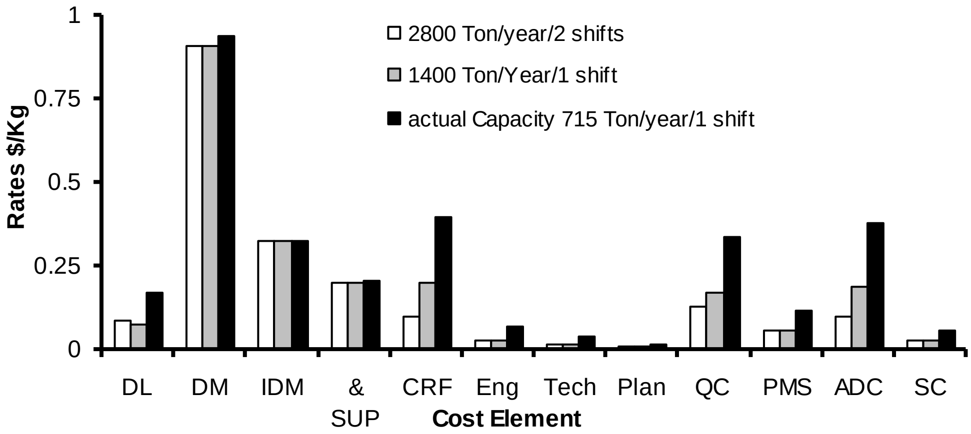

Figure 11: Cost rates for every cost element under different production scenarios based on TCA.

Figure 7 as well as figure 6 show that the most important cost parameters are direct material, indirect material, quality cost and capital recovery. The final production cost is highly sensitive to such highlighted parameters. For model verification purposes, the proposed costing model has been implemented on a local big foundry, and then results are compared to that obtained using the traditional costing model. It has been concluded that the analysis and the methodology followed in this work is valuable for many foundries and expected to be used as a tool for accurate cost analysis for strategic production decision.. As seen ABC has been developed considering current foundry practices, and therefore is amore credible costing system, since it traces cost from resources according to the way they are consumed by castings, rather than by some arbitrary basis.

ABC calculation also implies that the dynamic cost of components whenever they pass from one resource centre to another can be calculated. This also gives the cost of WIP or finished casting at any stage of the production process at any time. ABC improves the costing systems of organizations but also has some limitations such as: high measurement costs that are required for its operation. As the number of activities involved in the production process increases, the cost of gathering data for ABC system becomes higher. Also it is more difficult to gather activity data in service companies, since so many of the activities tend to involve human tasks that cannot be automatically recorded. A study that included a sufficient analysis to each one of such important cost parameters recommended to be carried out as a future work.

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