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Product-mix decision from the perspective of time-driven activity-based costing

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1. INTRODUCTION

This study addresses the theme "product-mix decision" that, in a Production and Operations Management perspective, can be understood as the definition of the optimum quantity to be produced for each type of product in a given period, considering these products compete for limited resources (HODGES; MOORE, 1970) in order to maximize the firm economic result (e.g. net profit) (FREDENDALL; LEA, 1997). The current research follows the following line of thought, as pointed by Lea and Fredendall (2002, pp. 280): "when a firm has more demand than capacity, managers must determine which product to produce in a given period. The product-mix decision typically attempts to maximize profit”. Thereby, the relevance of the research is anchored in the fact that the product-mix decision problems are one of the most critical issues in manufacturing (BEGED-DOV; 1983; WANG *et al.*, 2009), having an important role in predicting future returns and economic robustness of business (HASUIKE; ISHII, 2009).

From the second half of the twentieth century, mathematical models (e.g. HODGES; MOORE, 1970; GRINNELL, 1976) and heuristics (e.g. GOLDRATT, 1990) have been developed in order to determine the mix of products to be produced and sold by a company in a given planning period. These models and heuristics use information on profitability, which is determined from analysis and confrontation between sales prices and costs of the products supplied by the company. These products costs are measured by costing methods. Among the existing costing methods in the literature, Absorption Costing, Direct Costing, Activity Based Costing (ABC) and Time-Driven Activity-Based Costing (TDABC) are highlighted. TDABC, despite appearing in the literature in 2004 and being detailed in 2007 from a book written by Robert Kaplan and

Steven Anderson, has not been directly explored in the literature that deals with the product-mix decision, unlike the other costing methods mentioned.

In this context, the aim is to build a quantitative model to underpin the product-mix decision incorporating the TDABC approach. To direct the study in order to attain the objective, the following research question is defined: How to build a quantitative model that considerers the logic of Time-Driven Activity-Based Costing to underpin the product-mix decision?

The paper is organized into seven sections considering this introduction (1), namely: (2) research methodology, (3) literature research on TDABC and on product-mix decision, (4) proposition of a quantitative model to answer the research question, (5) application of the proposed model, (6) findings analysis, and (7) conclusions, limitations and recommendations for future research.

2. RESEARCH METHODOLOGY

In order to attain the objective and answer the research question, the paper is methodologically developed in two moments: (i) literature research; and (ii) quantitative modeling. The literature research was performed, mainly, from international academic journals to discuss concepts and positioning the research on product-mix decision and on costing methods, emphasizing TDABC.

Model-based quantitative research is defined by Bertrand and Fransoo (2002, pp. 242) as a "research where models of causal relationships between control variables and performance variables are developed, analyzed and tested." This type of research assumes that it is possible to build models that can explain the behavior of a real operational process or can capture and deal with decision-making problems that are faced by managers. As control variables, the current study considered: the capacity, the consumption of productive resources by products, sales prices and unit costs of products. As a performance variable, the net income was considered. Thus, all the variables mentioned were quantitatively treated to build a model based on TDABC to assist the product-mix decision. Finally, an application of the proposed model is illustrated from a didactic example involving a manufacturing environment.

3. LITERATURE RESEARCH

3.1. Time-Driven Activity-Based Costing

As pointed by Tsai *et al*. (2008, pp. 210), "one of the most important decisions made in production systems is determining the most profitable products”. Determining the products profitability is conducted from analysis and comparison between sales prices and costs of goods supplied by the company (GALESNE; FENSTERSEIFER; LAMB, 1999). These costs are measured by costing methods. Due to the fact that different costing methods determine the costs and profitability of products in an idiosyncratic way, and product-mix decision models use information on products costs and profitability, various combinations of decision models and costing methods create a variety of product-mix solutions that impact the organization performance (LEA; FREDENDALL, 2002). A summary of the previous argument can be obtained from the follow statement (FREDENDALL; LEA, 2002, pp. 280):

> If the calculated product cost is not correct, whenever the demand is greater than a firm’s production capacity, it is possible that a product mix decision will result in the less profitable product in demand being manufactured, while a more profitable product that is in demand is not manufactured.

Thus, the costing method has a direct impact on the product-mix decision. The costing methods differ from each other in the way they appropriate the costs of production resources to the supplied products. In the literature, the costing methods commonly used to measure the product costs are: Absorption Costing, Direct/Variable Costing, ABC, and TDABC. Before detailing the costing logic of TDABC, it is necessary to understand ABC. Figure 1 shows the ABC conceptually:

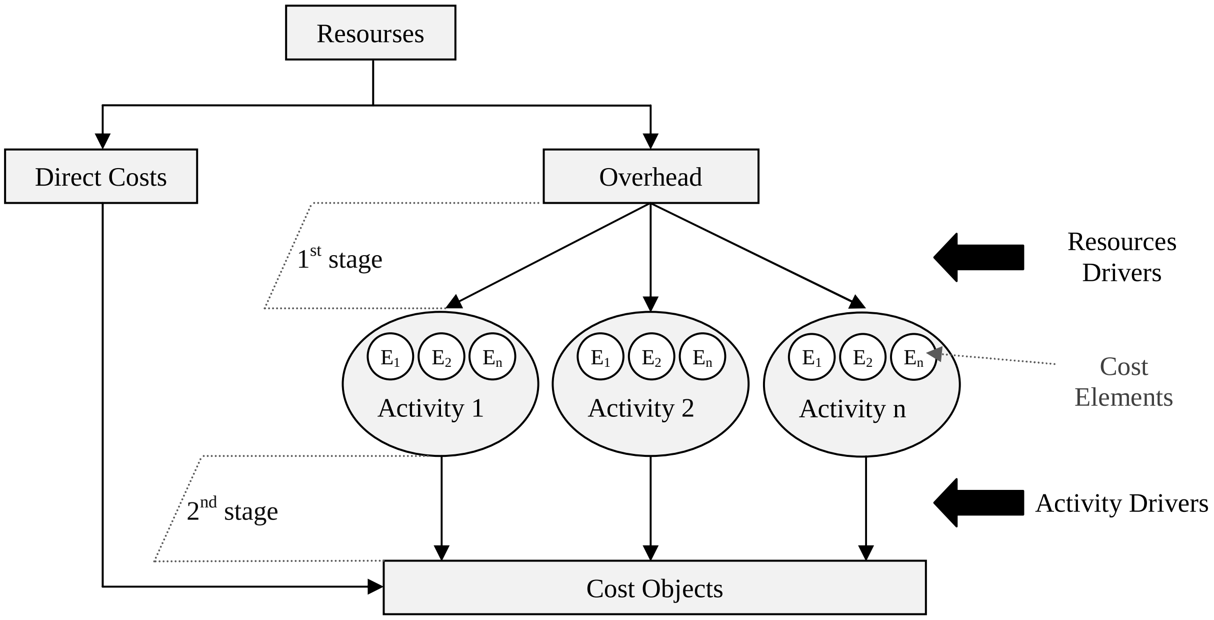

Figure 1 - Conceptual model of ABC
Source: Adapted from Turney (1991) and Innes, Mitchell and Yoshikawa (1994)

Conceptually, the ABC assumes that cost objects (e.g. products, processes and customers) generate the need for activities that, in turn, generate the need for company resources. First, the resources are divided into direct and indirect, regarding the cost object to be measured. In the case of products, for example, raw materials can be mentioned as direct resources and the company engineering staff can be considered as an indirect resource, commonly called overhead. The resources direct costs are transferred directly to the cost object. In turn, the overhead is allocated to the cost objects from a two-stage procedure based on ABC that uses cost drivers.

In the first stage, the overhead is allocated to the various company activities from resource drivers. The resource drivers identify the way in which activities consume resources and are used to costing, that is, demonstrates the relationship between resources spending and activities (TURNEY, 1991; TSAI; LAI, 2007; TSAI *et al.*, 2008).

The estimates of the resources spent on activities can be obtained through interviews, questionnaires and cards time reporting. Tsai (1996) indicates work sampling as the best way to measure the effort (resources) spent on activities. However, Kaplan and Anderson (2007a, 2007b) argue that the resource costs allocations to activities in the first stage normally occur via interviews with personnel from each department and gathering information to determine the percentage of time and resources (historically - three to six months) used in each activity. Each resource allocated to an activity becomes a cost element (e.g. engineers, production supervisors, materials used in quality inspection, etc.) and is represented in monetary measures. In the second stage, each activity is distributed to cost objects using activities drivers. The activities drivers identify the way in which cost objects consume activities and are used to costing them, that is, they show the relationship between consumed activities and cost objects (TURNEY, 1991; TSAI; LAI, 2007; TSAI *et al.*, 2008).

Cooper (1990) categorizes activities into four types: (i) unit-level activities (e.g. machining), (ii) batch-level activities (e.g. equipment preparation/setup), (iii) product-level activities (e.g. product design/engineering), and (iv) facility-level activities (e.g. plant security). The costs of activities at different levels can be traced to cost objects through different activity drivers. Tsai *et al.* (2008) illustrate that the drivers "number of machine hours ", "hours of setup" and "number of designs" could be used for activities "machining", "equipment setup" and "product design”, respectively. It is worth mentioning that the costs of activities at the level of facilities are difficult to be traced to cost objects from drivers, since the cause-effect relationship is not clear between cost objects and activities. Therefore, in case the choice is not to disregard the costs of facility-level activities, it is necessary to use arbitrary criteria (e.g. square footage for plant security) so that they are allocated to cost objects (DEMMY; TALBOTT, 1998).

From the presentation of real business situations in which the ABC was implemented, Kaplan and Anderson (2004; 2007a; 2007b) point out that the processing times of the information generated by ABC (mainly related to activities and to cost drivers) and to generate management reports were too long and entailed high costs, for example, in terms of personnel. Moreover, Kaplan and Anderson (2004; 2007a; 2007b) report that, in the ABC first stage, the information gathering required too much effort for focusing on periodic surveys (e.g. monthly) with employees, of the work time devoted to the activities. These problems, according to Kaplan and Anderson (2004; 2007a; 2007b), made many of the companies that have employed ABC no longer update the information necessary for the method operation or even completely abandon the use of ABC to estimate costs and profitability of products, processes and customers.

Based on the criticism directed to ABC, Kaplan and Anderson (2004) published an article in the Harvard Business Review and present a new costing method, the TDABC. Three years later, the same authors published a book by the Harvard Business School Press in which cases of TDABC applications are presented. According to the authors, the “new ABC” is superior to "traditional or conventional ABC" in terms of cost drivers used, implementation easiness, and flexibility to make changes/updates (KAPLAN; ANDERSON, 2007b). General description of TDABC is given by Kaplan and Anderson (2007a, pp. 8):

> TDABC simplifies the costing process by eliminating the need to interview and survey employees for allocating resource costs to activities, the evolution of time-driven activity-based costing, before driving them down to cost objects (orders, products, and customers). The new model assigns resource costs directly to the cost objects using an elegant framework requiring only two sets of estimates, neither of which is difficult to obtain. First, it calculates the cost of supplying resource

> capacity. […] In this first step, the TDABC model calculates the cost of all the resources - personnel, supervision, occupancy, equipment and technology - supplied to this department or process. It divides this total cost by the capacity - the time available from the employees actually performing the work - of the department to obtain the capacity cost rate. Second, TDABC uses the capacity cost rate to drive departmental resource costs to cost objects by estimating the demand for resource capacity (typically time, from which the name of the approach was chosen).

TDABC ignores the first stage costs allocation (used by traditional ABC), allocating resource costs directly to cost objects. For this, TDABC needs two parameters to be estimated: (i) the capacity cost rate for the operational department, and (ii) the capacity usage by each transaction processed in the operational department. Kaplan and Anderson (2007a, pp. 8) argue that "both parameters can be estimated with easiness and objectivity." Moreover, TDABC makes use of (iii) "time equations" to deal with the complexity of the company's activities in terms of changes in processes, activities and products. Each of the three elements that underlie TDABC operationalization is conceptually discussed below.

The (i) capacity cost rate can be calculated by the mathematical expression (1):

$$Capacity\ cost\ rate = \frac{Cost\ of\ capacity\ supplied}{Pratical\ capacity\ of\ resources\ supplied} \tag{1}$$

To estimate the numerator, all costs of the operational department are aggregated, including: wages and fringe benefits of supervisors, occupation costs, equipment costs (e.g. depreciation), utilities costs (e.g. energy, water, compressed air and natural gas), administration costs (e.g. auditors, CEO/board, accountants and attorneys), and support units/departments that provide services to the operational department (e.g. quality inspection, engineering and equipment preparation/setup). It is worth mentioning that the costs of central administration and of support units can be allocated to operational departments according to the real work (time) that the central administration and support units dedicate (or dedicated) to the operational department.

Moreover, the costs of support units/departments capacity which can be directly related to cost objects (e.g. products), can be measured similarly to the costs of operational departments.

To estimate the denominator, Kaplan and Anderson (2007a; 2007b) indicate that the actual capacity of the operational department should be measured. Kaplan and Anderson (2007b) argue that in the case of a department in which the production rhythm is determined by the work of employees (labor-intensive), the capacity is measured by how many employees minutes or hours are available to perform the work. In automated departments (capital-intensive), in which the production rhythm is determined by equipment capacity, the capacity is measured by the amount of equipment work time available, after subtracting the breaks for maintenance and repair.

The second estimate/parameter required by TDABC, namely (ii) the capacity usage by each transaction processed in the operational department, is obtained in a different way to that obtained via traditional ABC. Kaplan and Anderson (2007a, pp. 10) establish the differences between the capacity utilization measurements made by the two approaches/models:

> Conventional ABC uses a transaction driver whenever an activity – such as setup machine, issue purchase order, or process customer request – takes about the same amount of time. TDABC, instead of using such transaction drivers, simply has the team project estimate the time required to perform each of these transactional activities. The time estimates can be obtained either by direct observation or by interviews. As with the estimate of practical capacity precision is not critical, rough accuracy is sufficient. And unlike the percentages that employees subjectively estimate for a conventional ABC model, the capacity-consumption estimates in a time-driven model can be readily observed and validated.

The capacity cost rate multiplied by the use (time) estimated for each transaction or activity, results in "cost driver rates" for each transaction or activity. Therefore, the

TDABC uses time as a major cost driver, as Kaplan and Anderson (2007b) consider that the capacity of most resources / departments (in terms of personnel and equipment) can be measured immediately by the length of time they are available to do the job.

As a way of determining the cost of a cost object (e.g. product or service), TDABC adopts (iii) "time equations." In other words, TDABC needs the development of a mathematical equation that represents the basic time required to process a client request or a common product, plus the incremental time for each possible variation (e.g. customized products and orders). For the TDABC, time equation can be used in an operational department/process; all basic/common and all the major variations (incremental/additional activities) around them should be described. Moreover, it is necessary to identify the changes drivers and to estimate the standard times for the basic activity and for each variation.

Making a comparison with the conventional ABC, Kaplan and Anderson (2007b) discuss the advantages of using the TDABC time to deal with the business environment complexity (possible combinations and customization of products/services that require idiosyncratic resources usages). According to Kaplan and Anderson (2007b), the model size increases linearly in TDABC, as a function of business complexity, not exponentially, as in the conventional ABC model. This is a great benefit provided by the use of time equations, instead of number of transactions. If the initial model, by chance, omits some important variations of a process/activity or sub process/activity, the analyst simply adds new terms to the time equation to reflect the need to increase the resources capacity (usually time) to meet this alteration not considered in the beginning. In the conventional ABC, in contrast, a new sub process/activity requires that all the prior percentage allocations be measured again to add a new sub process/activity to the model. Thus, Kaplan and Anderson (2007b) show how the conventional ABC systems inhibit reassessment of the model and its adaptation to changes in business operations. In order to prevent the TDABC time equations from being affected by changes arising from re-engineering or large process improvements, TDABC analysts recalculate and introduce the new activities standard times to ensure the time equations accuracy continuously (KAPLAN; ANDERSON, 2007a; 2007b).

3.2. Product-Mix Decision

Analyzing the history of publications on product-mix decision, it is concluded that considerations of costing methods in this type of decision date to at least the 70s. As an example, the academic paper published by Grinnell (1976) in Management Accounting journal can be cited, which discusses the application of absorption and direct costing in optimizing product-mix decision using mathematical programming. However, it should be noted that the product-mix decision is a theme already discussed in the Operations Research literature even before the 70s. The justification for this assertion is the fact that the papers published by Hodges and Moore (1970), Byrd and Moore (1978) and Reeves and Sweigart (1981) announced the existence of a "conventional model" for a product-mix decision. This model is based on linear programming with deterministic variables. it is worth mentioning that the objective function to be maximized has the variable "profit" that is expressed by the difference between the sale price and the costs of each type of product. The model can be represented as follows:

$$Objective\ Function\ (Maximize\ Profit) = \sum_i P_i\ x_i \qquad (2)$$

Subject to the following constraints:

$$Equipment\ capacity. \ldots\ldots\ldots\ldots\ldots \sum_i t_{ij}\ x_i \leq C_j \qquad for\ all\ j$$

$$Avaliable\ raw\ material\ldots\ldots\ldots\ldots \sum_i r_{ik}\ x_i \leq R_k \qquad for\ all\ k$$

$$Labor\ capacity \ldots\ldots\ldots\ldots\ldots\ldots \sum_i l_{iw}\ x_i \le L_w \qquad for\ all\ w$$
$$Demand \ldots\ldots\ldots\ldots\ldots\ldots\ldots L_i \le x_i \le U_i \qquad for\ all\ i$$

Where:

x_i = number of units of product type *i* to be manufactured

P_i = profit per unit of product type *i*

t_{ij} = time required per unit of product type *i* on equipment type *j*

C_j = capacity of equipment type *j*

r_{ik} = material requirements per unit of product type *i* for raw material type *k*

R_k = availability of raw material type *k*

l_{iw} = time required per unit of product type *i* on labor type *w*

L_w = capacity of labor type *w*

L_i = lower demand limit for product type *i*

U_i = upper demand limit for product type *i*

Historically, the evolution of mathematical models and heuristics on product-mix decision was directly related to the development of two research strands:

i). Mathematical techniques and algorithms: This statement can be verified from the analysis of the following academic publications: (1a) Byrd Jr. and Moore (1978) that used linear programming to construct a model for product-mix decision; (1b) Onwubolu and Muting (2001a, 2001b) that worked on the selection of product-mix using genetic algorithms; (1c) Onwubolu (2001) that proposed a decision model for product-mix using tabu search-based algorithm; (1d) Vasant and Barsoum (2006) that addressed the product-mix decision using fuzzy linear programming; and (1e) Wu, Chang and Chiou (2006) that used a psycho-clonal algorithm to construct a model for product-mix selection.

ii). New ways of costing products: This can be verified from the analysis of the following academic publications: (2a) Grinnell (1976) that compared a model for product-mix decision based on Absorption Costing with another model based on Direct/Variable Costing method; (2b) Patterson (1992) that compared a model for product-mix decision based on the Theory of Constraints (throughput accounting) with another model based on Direct/Variable Costing method (2c) Kee (1995) and Kee and Schmidt (2000) that compared a decision model for product-mix decision based on the Theory of Constraints (throughput accounting) with other models based on ABC; and (2d) Kee (2001) that compared three models for product-mix decision based on ABC.

The current study contributes to the product-mix decision research following the second evolution line (costing methods), as it proposes a quantitative model to support the product-mix decision considering the propositions of TDABC. The model being proposed adheres to the model developed by Kee (2001) for product-mix decision in the short term, called "Operational ABC” model, which considers as the cost of goods, besides the direct costs of raw material, the flexible costs of direct labor and activities/departments. It is worth mentioning that the short-term reported by Kee (2001) refers to a period of about a year and is consistent with the planning horizon in which Bahl, Taj and Corcoran (1991) insert the product-mix decision (one to three years). It should also be noted that the Operational ABC model is not based on linear programming, but rather on a heuristic model for decision-making.

The flexible costs in the model developed by Kee (2001) refer to the portion of the costs of an activity or department that is subject to managerial control in a given period, or may be relocated or even left unused, having similar behavior to a variable cost and being relevant to product-mix decision for reflecting the incremental products costs. In turn, committed costs refer to the portion of an activity or department that is not subject to managerial control in a given period, i.e., it is a sunk cost that behaves as a fixed cost, being irrelevant to product-mix decision in the short-run (KEE, 2001).

In order to set the economic metric for prioritization of products production and sale from the perspective of the Operational ABC model, Kee (2001) performs the following calculus for each type of product: profit per unit (flexible) calculated by ABC divided by the consumption of the resource with the lowest capacity (production system constraint or bottleneck). The unit profit results from the subtraction of all product flexible costs of the product sale price estimated for the period under analysis. It is worth noting that the products committed costs are not taken into account in determining the economic metric that underlies the product-mix decision from the Operational ABC perspective. Thus, products that present the highest economic metric values for product-mix decision-making (flexible profit per unit divided by the bottleneck usage) should have higher priority for production and commercialization.

Kee (2001) refers to the heuristic for product-mix decision proposed by Kee (1995) that considers both the flexible costs, as well as the committed ones, of activities and labor in determining the profit per unit that, in turn, is also divided by the consumption of the resource with the lowest capacity (system bottleneck) to set the metric for prioritizing production and sale of products. The Kee (1995) logic is called by Kee (2001) "ABC with Capacity” model. Another decision logic considered by Kee (2001) is known as "Traditional ABC” model. In this model, all costs (committed and flexible) of activity and labor are considered in determining the profit per unit, but the resource or activity that constrains the capacity of the production system is not taken into account for determining the product-mix decision metric. It is worth mentioning that the three models proposed, although they may be considered heuristic, are quantitative and are treated from mathematical procedures.

From a numerical example, Kee (2001) comparatively analyzes the solution generated in terms of net profit (also called net income) before income taxes, by the product-mix determined from the perspective of three decision models based on ABC. Considering the net profits obtained in the numerical example, Kee (2001) concludes that the product-mix obtained by the Operational ABC model overcomes the results obtained by the other two models. It should be noted that Kee (2001) deals with a production process which considers the existence of only one system bottleneck with hard behavior (cannot expand the capacity) in the short-term.

Thus, the boundary conditions satisfied by Kee (2001) seek to mitigate the problem of decision heuristics have regarded the product-mix optimization on production systems with multiple constraints, such as pointed by Plenert (1993), Balakrishnan and Cheng (2000), Souren, Ahn and Schmitz (2005), Linhares (2009) and Wang *et al.* (2009). For situations involving multiple hard constraints (also called binding bottenecks), Kee (2001) suggests the adoption of the General Model proposed by Kee and Schmidt (2000) to define the optimal product-mix in the short-term, despite the limitations of the General Model due to its failure in not taking into account the product-level activities.

4. PROPOSED MODEL

Next, the assumptions that make up the boundary conditions for the construction of the model for product-mix decision from the perspective of TDABC to be applied in manufacturing environments are presented:

i). The company produces multiple products;

ii). The demand for each type of product is known and given at the beginning of the production period under analysis/planning;

iii). The sale price of each type of product is market-driven, is constant and is given at the beginning of the planning horizon;

iv). Each type of product uses a fixed proportion of resources (direct material, direct labor, utilities, etc.) and activities;

v). The cost of resources/activities/departments can be divided into flexible and committed costs;

vi). The productive capacity cannot be expanded during the period under planning (short-term);

vii). The demand for productive resources to manufacture all products in the period is greater than the company productive capacity;

viii). The resource or department that limits the production system capacity cannot have its capacity expanded during the period under planning (hard type bottleneck);

ix). Information on costs, sales prices, demand, consumption of resources and productive capacity are given deterministically.

Considering the boundary conditions exposed, the model for product-mix decision being proposed has a quantitative nature and its unit of analysis is each type of product supplied by the company. The model is the economic metric for decision-making that serves as a basis for prioritization of products in terms of contribution to maximize the performance variable, i.e., the economic outcome measured in terms of net profit before income taxes. Thus, the product-mix decision model built from the perspective of TDABC which incorporates assumptions of Operational ABC (flexible and committed costs) is given quantitatively by the mathematical expression (3):

$$EMDP_i^{TDABC} = \frac{SP_i - \left\{\sum_j CRD_j + \sum_{i,k}\left[\left(\frac{FCD_k}{PC_k}\right) \times CUD_{i,k}\right]\right\}}{CUDB_i} \tag{3}$$

Where:

i = product index

j = direct resource index (e.g. raw material)

k = department index

$EMDP_i^{TDABC}$ = value of the economic metric for decision-making (production and sale prioritization under the perspective of TDABC) of product type *i*

SP_i = sale price of product type *i*

CRD_j = cost of direct resource type *j*

FCD_k = flexible cost estimated for department type *k*

PC_k = practical capacity estimated for department type *k*

$CUD_{i,k}$ = consumption per unit of product type *i* of practical capacity of department type *k*

$CUDB_i$ = consumption per unit of product type *i* of practical capacity of department with the lowest capacity (productive system bottleneck)

The economic metric for decision of the model proposed based on TDABC is quantified as "profit per unit (flexible) calculated by TDABC divided by the consumption of the resource/department with the lowest capacity (production system bottleneck)”. To determine the profit per unit of a particular type of product, subtract from the sale price the direct and indirect costs (flexible). Direct costs are those that can be directly assigned to products such as raw materials. In turn, indirect costs (overhead) treated from the perspective of TDABC correspond to the flexible costs of each department allocated to products using the “capacity flexible cost rate”. It is worth mentioning that the capacity flexible cost rate is the result of dividing the department flexible cost estimate (FCD_k) by the practical capacity estimated for the same department (PC_k). It should also be noted that consumption per unit of limiting resource/department (productive system bottleneck) corresponds to term $CUDB_i$ in the mathematical expression presented and that the term $CUD_{i,k}$ can be obtained using TDABC time equations or directly.

To underpin the product-mix decision in order to maximize the net profit in the period under planning, the following rule is used: the higher the value of the economic metric for decision-making ($EMDP_i^{TDABC}$), the higher the priority of production and sale to be given to the product. Determining the exact amount to be produced for each type of product during the planning horizon requires that the productive capacity of the resource/department that constraints the production system be taken into account. In short, after running the production of all ordered units of the product with the highest $EMDP_i^{TDABC}$, the company's managers should check whether there is sufficient capacity of the bottleneck (resource/department) to manufacture products with lower $EMDP_i^{TDABC}$. Thus, it is possible to quantify the volume to be produced for each type of product, that is, determine the product-mix to be produced and sold by the company during the period under analysis/planning.

In order to determine the period economic outcome, i.e., the net profit (before income taxes) generated by the product-mix set is calculated. This is achieved by considering the following economic variables: total revenue, costs of direct resources used by the products produced, flexible and committed costs of the department’s capacity used by the products produced, and committed costs of department’s capacity unused by the products produced. It should be observed that the flexible costs of unused capacity do not represent expenditures for the company, because they can be avoided. Thus, the net profit calculated under the aegis of the proposed model for product-mix decision is given quantitatively by the mathematical expression (4):

$$NP_{MIX}^{TDABC} = \sum_i (QPS_i \times SP_i) - \left(\sum_j CDRU_j + \sum_k FCDU_K + \sum_k CCDU_K + \sum_k CCDNU_K\right) \quad (4)$$

Where:

i = product index

j = direct resource index (e.g. raw material)

k = department index

NP_{MIX}^{TDABC}= net profit (before income taxes) generated by the product-mix set through the decision model proposed from the TDABC perspective

QPS_i = quantity produced and sold of product type *i* present in the product-mix set

SP_i = sale price of product type *i* present in the product-mix set

$CDRU_j$ = cost of direct resource type *j* used to produce the product-mix set

$FCDU_k$ = flexible cost of capacity of department type *k* used to produce the product-mix set

$CCDU_k$ = committed cost of capacity of department type k used to produce the product-mix set
$CCDUN_k$ = committed cost of capacity of department type k unused to produce the product-mix set

In the next section, the application of the proposed model for product-mix decision and the net income calculation are illustrated from a didactic example which involves the planning and budgeting of a metal-mechanical manufacturing company.

5. MODEL APLLICATION

In the didactic example, it is conjectured that the managers of the metal brackets manufacturing company ABC Ltd., conducting the planning and budgeting process, must decide the product-mix to be produced and sold in the next accounting period (one year) in order to maximize the economic outcome (in terms of net profit before income taxes), considering that the company productive capacity is unable to meet the total demand requested for the period. In order to facilitate the implementation of the proposed model that the didactic example illustrates, only three types of products (X1, X2 and X3), four types of direct materials (iron mounting kit, adjustment device, hinge and paint) and four operating activities, being two production activities (Assembly and Electrostatic Painting) and two support activities (Equipment Preparation/Setup and Engineering) are considered. It is worth mentioning that each of the four company activities is performed by specialized departments with idiosyncratic labor and equipment. It should also be noted that the Department of Equipment Preparation performs the equipment setups of the Department of Electrostatic Painting.

So as to deal with the managerial problem faced (product-mix decision), the managers use the proposed model based on TDABC. Meanwhile, the managers gather information regarding the productive process, costs and market (demand and sales prices). Initially, information is gathered about the behavior and values of the costs of direct material and activities/departments, and the resources/activities/departments productive capacity. The direct materials costs are considered flexible (variable) for the period under analysis. All other costs are considered overhead, totaling $ 2,258,800.00 (estimated for the one-year period) and distributed through the four departments. Of this total, the managers assess that (based on contracts signed and the labor laws) 75% of overhead can be considered as flexible costs (discretionary /variable) and 25% as committed overhead (non-discretionary/fixed). It should be noted that the "Assembly" and "Electrostatic Painting" activities occur at unit level, the activity "Equipment Preparation/Setup" occurs at batch level and the activity "Engineering" occurs at product level. Table 1 summarizes the information collected on the cost, the consumption of direct materials for each product and the prices and demand estimates for the period under planning and budgeting:

		PRODUCT TYPE					
Direct Material (Flexible)		X1		X2		X3	
	Cost per unit	Consumption	Cost	Consumption	Cost	Consumption	Cost
Iron mounting kit	$ 30,00 per unit	1 unit	$30.00	1 unit	$30.00	1 unit	$30.00
Adjustment device	$ 7,00 per unit	-	-	1 nit	$7.00	1 unit	$7.00
Hinge	$ 5,00 per unit	-	-	-	-	1 unit	$5.00
Paint	$ 5,00 per litre	0,20 litre	$1.00	0,20 litre	$1.00	0,4 litre	$2.00
	Sum	**$31.00**		**$38.00**		**$44.00**	

	PRODUCT TYPE		
	X1	X2	X3
Expected Demand	400,000	250,000	200,000
Sale Price	$35.00	$45.00	$50.00

Table 1 - Information on direct materials, prices and demand for each product

After treating the direct costs, the managers begin the overhead treatment. For this, the TDABC propositions are used. In order to determine the capacity cost (total, flexible and committed) rate of each company department (based on historical data), managers quantify the total expenditures that each department will incur in the year under analysis and the annual practical capacity estimated for each department. It should be noted that the Assembly, Equipment Preparation and Engineering departments are labor-intensive, and their practical capacity are measured in terms of time (minutes) of assembly workers, setup workers and engineers, respectively. In turn, the Department of Painting is capital-intensive, and its practical capacity is measured in terms of machine-time (minutes) of the painting equipment. Then the managers quantify the capacity that each product consumes at the departments (in the case of production departments, the consumption estimates are obtained through time equation).

To build the TDABC time equation, the activities that each operational department (Assembly and Electrostatic Painting) perform are detailed, together with the consumption of their capacity per unit (in terms of time), as shown in the process diagram illustrated by Figure 2:

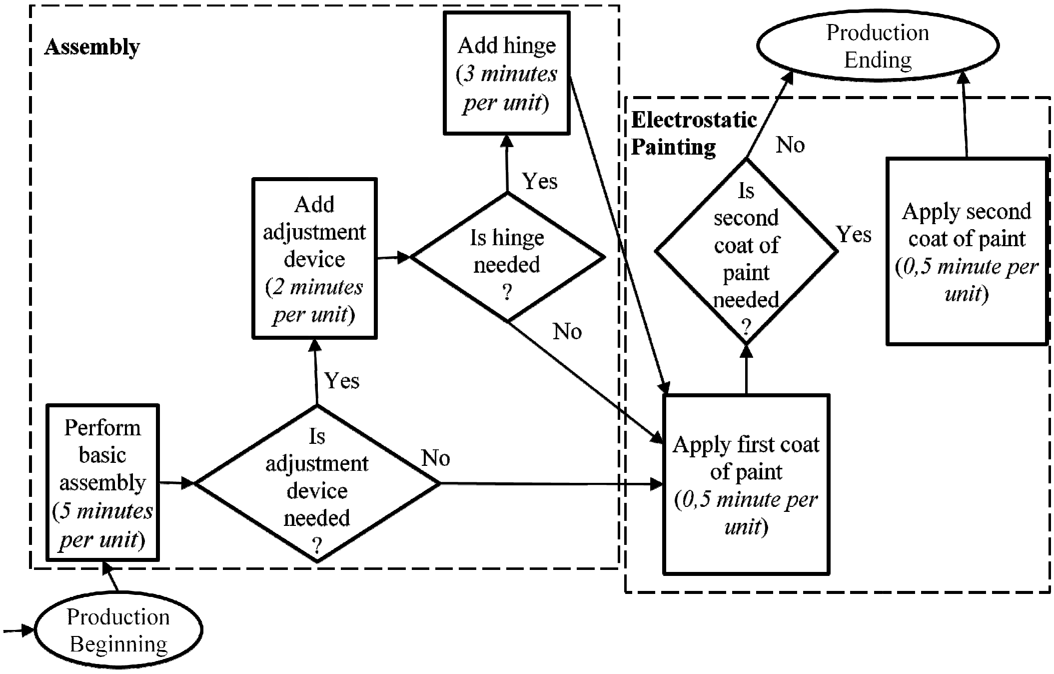

Figure 2 - Production process diagram (productive departments) of ABC Ltd.

Based on the production process diagram, Table 2 displays the basic activities, the drivers of each activity and the standard times of each activity:

Activity/Department	Driver	Time
Assembly	• Perform basic assembly	5 minutes per unit
	• Add adjustment device	2 minutes per unit
	• Add hinge	3 minutes per unit
Electrostatic Painting	• Apply first coat of paint	0.5 minute per unit
	• Apply second coat of paint	0.5 minute per unit

Table 2 - Information required for constructing production process time equation of ABC Ltd.

Based on Table 2, the production process time equation of ABC Ltd. can be expressed as follows:

$$\begin{aligned} Product\ process\ time\ (in\ minutes) &= 5_{perform\ basic\ assembly} \\ &+ \{2_{if\ add\ adjustment\ device}\} \\ &+ \{3_{if\ add\ hinge}\} \\ &+ 0{,}5_{apply\ first\ coat\ of\ paint} \\ &+ \{0{,}5_{if\ apply\ second\ coat\ of\ paint}\} \end{aligned}$$

Having the time equation and knowing the activities that each product consumes at the productive departments, the managers can quantify the total time that each product consumes from departments activities. Table 3 shows, by product, the consolidated calculation of consumption (in minutes) of activities of productive departments (Assembly and Electrostatic Painting), and of activities of operational support departments (Preparation Equipment and Engineering), together with capacity cost rates (total, flexible and committed):

ACTIVITY / DEPARTMENT	PRODUCT TYPE		
Assembly (unit-level)	X1	X2	X3
· Perform basic assembly (in minutes)	5.0	5.0	5.0
· Add adjustment device (in minutes)	-	2.0	2.0
· Add hinge (in minutes)	-	-	3.0
Department capacity usage per unit (in minutes)	5.0	7.0	10.0
	Total Costs	Flexible Costs	Committed Costs
Department Costs	$1,350,000.00	$337,500.00	$1,012,500.00
Cost Driver = Practical Capacity (in minutes of assembly workers)	7,011,000		
Capacity Cost Rate	$0.19	$0.05	$0.14

ACTIVITY / DEPARTMENT	PRODUCT TYPE		
Electrostatic Painting (unit-level)	X1	X2	X3
· Apply first coat of paint (in minutes)	0.5	0.5	0.5
· Apply second coat of paint (in minutes)	-	0.5	0.5
Department capacity usage per unit (in minutes)	0.5	1.0	1.0
	Total Costs	Flexible Costs	Committed Costs
Department Costs	$652,000.00	$163,000.00	$489,000.00
Cost Driver = Practical Capacity (in machine-minutes of painting equipaments)	517,760		
Capacity Cost Rate	$1.26	$0.31	$0.94

ACTIVITY / DEPARTMENT	PRODUCT TYPE		
Equipment Preparation/Setup (batch-level)	X1	X2	X3
· Perform equipmente preparation (in minutes per batch)	120	150	150
Quantity of products per batch	1,000	800	500
Department capacity usage per unit (in minutes)	0.120	0.188	0.300
	Total Costs	Flexible Costs	Committed Costs
Department Costs	$87,000.00	$21,750.00	$65,250.00
Cost Driver = Practical Capacity (in minutes of setup workers)	263,250		
Capacity Cost Rate	$0.33	$0.08	$0.25

ACTIVITY / DEPARTMENT	PRODUCT TYPE		
Engineering (product-level)	X1	X2	X3
· Design and execute projects of improvement (in minutes per product type)	48,000	60,000	72,000
	Total Costs	Flexible Costs	Committed Costs
Department Costs	$169,800.00	$21,750.00	$65,250.00
Cost Driver = Practical Capacity (in minutes of engineers)	182,400		
Capacity Cost Rate	$0.93	$0.12	$0.36

Table 3 - Treatment of indirect costs of the ABC departments based on TDABC

Having the capacity cost (total, flexible and committed) rate of departments, the managers perform the calculus of products profit per unit in order to determine the economic metrics proposed by the product-mix decision model based on TDABC. First, the profits per unit are calculated considering the departments total costs, the profits per unit considering the departments flexible costs, and the profits per unit considering the departments committed costs. The direct materials costs are traced directly to each product, while overhead are allocated through departments capacity cost rates calculated from TDABC as shown in Table 4:

CALCULATION OF PROFIT PER UNIT FROM THE PERSPECTIVE OF TDABC									
	PRODUCT X1			**PRODUCT X2**			**PRODUCT X3**		
ITEM (PER UNIT)	TOTAL	FLEXIBLE	COMMITTED	TOTAL	FLEXIBLE	COMMITTED	TOTAL	FLEXIBLE	COMMITTED
(1) Direct Material Costs	$31.0000	$31.0000	-	$38.0000	$38.0000	-	$44.0000	$44.0000	-
(2) Assembly Costs	$0.9628	$0.2407	$0.7221	$1.3479	$0.3370	$1.0109	$1.9255	$0.4814	$1.4442
(3) Painting Costs	$0.6296	$0.1574	$0.4722	$1.2593	$0.3148	$0.9445	$1.2593	$0.3148	$0.9445
(4) Setup Costs	$0.0397	$0.0099	$0.0297	$0.0620	$0.0155	$0.0465	$0.0991	$0.0248	$0.0744
(5) Engineering Costs	$0.0572	$0.0143	$0.0429	$0.1145	$0.0286	$0.0859	$0.1717	$0.0429	$0.1288
(6) Costs per Unit (TDABC) = (1) +(2) + (3) + (4) +(5)	$32.6893	$31.4223	$1.2670	$40.7836	$38.6959	$2.0877	$47.4557	$44.8639	$2.5918
(7) Sale Price	**$35.0000**			**$45.0000**			**$50.0000**		
Profit per Unit = (7) - (6)	**$2.3107**	**$3.5777**	**$33.7330**	**$4.2164**	**$6.3041**	**$42.9123**	**$2.5443**	**$5.1361**	**$47.4082**

Table 4 - Calculation of products profit per unit based on TDABC

In order to determine the economic metric (for each product type) proposed based on TDABC, managers analyze the company's production process to identify the resource or department which constrains the productive capacity, i.e., the bottleneck. For this, the estimates of annual capacity consumption are confronted with the annual availability of each department in terms of productive capacity, as shown in Table 5:

IDENTIFICATION OF THE CONSTRAINT / BOTTLENECK									
		PRODUCTIVE RESOURCES SUBJECT TO CAPACITY CONSTRAINT (WORKERS AND EQUIPMENTS)							
		ASSEMBLY (minutes of workers)		PAINTING (machine-minutes)		SETUP (minutes of workers)		ENGINEERING (minutes of workers)	
PRODUCT TYPE	**DEMAND**	Usage per Unit	Total Usage	Usage per Unit	Total Usage	Usage per Unit	Total Usage	Usage per Unit	Total Usage
X1	400,000	5.00	2,000,000	0.500	200,000	0.120	48,000	-	48,000
X2	250,000	7.00	1,750,000	1.000	250,000	0.188	46,875	-	60,000
X3	200,000	10.00	2,000,000	1.000	200,000	0.300	60,000	-	72,000
SUM OF CAPACITY USAGE		5,750,000		650,000		154,875		180,000	
AVAILABLE CAPACITY		7,011,000		517,760		263,250		182,400	
EXCESS CAPACITY		1,261,000		-132,240		108,375		2,400	
BOTTLENECK ?		**NO**		**YES**		**NO**		**NO**	

Table 5 - Identification of the production system bottleneck

Based on Table 5, managers estimate that the ABC Ltd. production capacity for the year under analysis is limited to the Department of Electrostatic Painting capacity (517,760 machine-minutes). Thus, to determine the economic metric that underpins the product-mix decision, managers take into account the time that each product consumes of the electrostatic painting equipment, as shown in Table 6:

SETTING OF THE OPTIMAL PRODUCT-MIX THROUGH THE DECISION MODEL BASED ON TDABC			
ECONOMIC METRIC FOR DECISION-MAKING:	***Profit per unit (flexible) calculated by TDABC divided by the consumption of the resource/department with the lowest capacity (production system bottleneck)***		
	PRODUCT TYPE		
	X1	**X2**	**X3**
Profit per Unit (flexible)	$3.5777	$6.3041	$5.1361
Bottleneck capacity usage per unit (in machine-minutes of painting equipaments)	0.500	1.000	1.000
EMDP*i* = Profit (per unit) per bottleneck capacity usage (in $ per machine-minutes)	**$7.1553**	**$6.3041**	**$5.1361**
Ranking	**1°**	**2°**	**3°**
Demand (in units)	400,000	250,000	200,000
Bottleneck Capacity Total Necessity (in minutes)	200,000	250,000	200,000
Bottleneck Capacity (in minutes)	517,760		
Maximun Production (in units)	400,000	250,000	67,760
Bottleneck Capacity Practical Usage (in minutes)	200,000	250,000	67,760
Bottleneck Remaining Capacity (in minutes)	317,760	67,760	0
Optimal Product-Mix (in units)	**400,000**	**250,000**	**67,760**

Table 6 - Setting of the optimal product-mix based on the decision model built from TDABC

Based on Table 6, one can observe that the product type has the highest economic metric value ($EMDP_i^{TDABC}$) "Profit per unit (flexible) calculated by TDABC divided by the consumption of the resource/department with the lowest capacity (production system bottleneck)" is X1 (first place in the ranking), followed by X2 and X3. Note that, to meet the assumptions of the decision model proposed from the perspective of TDABC (similar to the model proposed by ABC Operational Kee (2001)), only the indirect flexible costs were considered in calculating the products cost per unit and, therefore, the calculation of profit per unit. Based on the ranking that underpins the products prioritization and the Department of Electrostatic Painting productive capacity, the optimal product-mix in the next period consists of 400,000 products type X1, 250,000 products type X2, and 67,760 products type X3.

Having the product-mix obtained by applying the decision model proposed under the aegis of TDABC, the managers project the economic outcome in terms of net profit before income taxes for the next accounting period. Table 7 shows the results:

DETERMINATION OF ECONOMIC OUTCOME FOR THE NEXT ACCOUNTING PERIOD (ONE YEAR)		
	TDABC MODEL	
	Production	Sale Price
X1	400,000	$35.00
X2	250,000	$45.00
X3	67,760	$50.00
(1) EXPECTED REVENUE	$28,638,000.00	

EXPECTED COSTS OF **USED RESOURCES**	
Total Direct Material Costs (Flexible)	$24,881,440.00
Assembly Costs (Flexible)	$213,138.64
Assembly Costs (Committed)	$639,415.92
Paintig Costs (Flexible)	$163,000.00
Paintig Costs (Committed)	$489,000.00
Setup Costs (Flexible)	$9,518.20
Setup Costs (Committed)	$28,554.59
Engineering Costs (Flexible)	$21,463.82
Engineering Costs (Committed)	$64,391.45
(2) TOTAL	$26,509,922.61

(3) GROSS MARGIN (USED RESOURCES) = (1) - (2)	$2,128,077.39

EXPECTED COSTS OF **UNUSED RESOURCES**	
Total Direct Material Costs (Flexible)	$0.00
Assembly Costs (Flexible)	$124,361.36
Assembly Costs (Committed)	$373,084.08
Paintig Costs (Flexible)	$0.00
Paintig Costs (Committed)	$0.00
Setup Costs (Flexible)	$12,231.80
Setup Costs (Committed)	$36,695.41
Engineering Costs (Flexible)	$286.18
Engineering Costs (Committed)	$858.55
(4) TOTAL	$547,517.39

(5) AVOIDABLE COSTS (FLEXIBLE)	$136,879.35
(6) **NET PROFIT = (3) - (4) + (5)**	**$1,717,439.35**

Table 7 – Determination of ABC Ltd. economic outcome for the next accounting period based on the proposed model

In Table 7, the expected revenue is calculated by multiplying the product-mix by the sale price of each product type. Both the four departments indirect costs, and the direct materials costs are calculated by multiplying the number of products listed in the mix set by departments costs per unit (flexible and committed) and the direct material costs per unit displayed in Table 4. The sum of these costs represents the costs that the company will incur with the resources to be effectively used in the manufacturing of the product-mix set by the decision model proposed. Thus, all costs (flexible and committed) of the used resources and the committed costs of the unused resources of each department are subtracted from "gross margin” (sales revenue less cost of resources used in production) to obtain the net profit estimated for the period under analysis. In turn, the flexible costs of unused resources do not represent expenditures for the company, because they can be avoided.

6. FINDINGS ANALYSIS

The analysis of results obtained from the implementation of the product-mix decision model based on TDABC is carried out considering the following aspects: (i) visualization of the organizational resources consumption; (ii) visualization of incremental costs; (iii) temporality; (iv) implementation easiness; and (v) flexibility/maintenance easiness.

Analyzing the solution under the auspices of aspect (i), one can conclude that the decision model proposed, in requiring the division of activities and departments costs into flexible and committed, allowed the visualization of the unused resources that can be avoided and that correspond to the idle capacity which represents expenditures for the company (unused resources committed costs).

Under the perspective of aspect (ii), one can conclude that the model based on TDABC, considering only the flexible costs in the net profit calculation (the higher the profit, the better) and the consumption of bottleneck capacity (the lower the consumption, the better), managed to reflect the actual incremental value that a product unit produced and sold created for the company to cover the fixed costs (committed) and thus generate profit. The non-inclusion of committed indirect costs in calculating the numerator of the economic metric proposed (profit per unit), even considering the bottleneck usage, aimed to avoid masking the calculation of the profit unit in relation to the real incremental value that each product might generate for the company.

Analyzed by aspect (iii), the model proposed from the viewpoint of TDABC to underpin product-mix decision in the short-run (one year in the didactic example) is both conceptually aligned with the ABC propositions, as well as with the TDABC, because these models are also suitable for making resource allocation in the long-run, considering that production capacity may be adjusted to better meet demand in future periods.

Aspects (iv) and (v) are positively analyzed, because the product-mix decision model proposed is quantitatively anchored by TDABC costing method, considered in the literature as having implementation and maintenance easiness when compared, for example, with conventional ABC.

With regard to aspect (iv), the didactic example showed that, in using information provided by the TDABC costing method, the model proposed for product-mix decision allocated the resource costs directly to cost objects (products), avoiding the monotonous stage and prone to errors of previously allocating the resource costs to activities (e.g. conducting interviews to determine the dedication of each employee to the different company activities, as required by conventional ABC). For this, two parameters suggested by the TDABC literature were estimated: the capacity cost rate (total, flexible and committed) of operational departments and the capacity utilization for each transaction or activity processed in each department, both estimated with easiness and objectivity.

The numerator of the mathematical expression that determined the capacity cost rates for each department (annual costs estimated) was obtained by simply consulting the company's accounting entries. Since the denominator of the mathematical expression did not concern the nominal capacity of resources and departments, but the practical availability which took into account all the production breaks estimated for the period analyzed. The didactic example also revealed that gathering the time dedicated by each department to different company activities and products in terms of resources (labor/overhead) required conducting interviews and measurements *in loco* at the productive process. These actions for information gathering show that the implementation easiness that characterizes the proposed model for product-mix decision.

The positive analysis of aspect (v) is anchored on the adoption of a TDABC time equation (to measure the departments productive capacity that each product consumes) by the proposed model for product-mix decision. In using a time equation, the proposed model becomes flexible to cope with changes in processes, activities and products. Thus, one can conclude that the proposed model has maintenance easiness because it incorporates the flexibility inherent to TDABC.

7. CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The main contribution of this research lies in showing how the TDABC costing method, recently launched in the literature, can be worked for formulating a model which underpins the product-mix decision. The proposed model took into account information on demand, production capacity, sales prices and costs inherent to the production process, and has its application illustrated from a didactic example.

In the didactic example used to illustrate the proposed model application, it was observed that the detailed information about company cost was essential for determining the products that most contributed to maximize the company economic outcome and serve as a reliable basis for decision-making. For a given period, it was found that the company would be faced with a situation where the demand for its products would be greater than the productive capacity. This fact was due to the existence of a resource/department that limited the capacity of the entire company production process (bottleneck). Thus, it was necessary to decide which products would be more interesting for the company to be manufactured and sold, because the company would be unable to supply, in the period, all the products requested by the market. For this, not only profit per unit based on TDABC and on Operational ABC models were adopted as the economic metric for setting product-mix, but also the consumption per unit ok bottleneck.

As the strong point of this research, the realization of an integrated managerial analysis on costs (flexible and committed) and on the productive capacity (used, unused and avoidable) is highlighted, because the bibliographical material related to this integration is still limited regarding product-mix decision. The fruition of this research in various aspects related to industrial process, an important professional environment for Production/Industrial Engineers, can also be highlighted.

Among the research limitations, first is the little amount of analysis performed on external factors (consumers and competitors) that affect the business. As second limitation of the study, the lack of analysis regarding the product quality in the context of product-mix decision is highlighted. The quality (referred to here in terms of product differentiation) can cause a rise in sale prices and a decrease in the gap between demand and production need. These limitations allow one to affirm that the proposed model for product-mix decision should not be used alone, but in conjunction with other tools and further information about the market (customers and competitors) in which the company operates.

A third study limitation concerns the consideration of only economic/financial measures (e.g. net profit) in the product-mix decision. As pointed out by Lea and Fredendall (2002) and Chung *et al.* (2008), non-financial performance measures could also be considered in product-mix decision, such as work-in-process (stock), customer service level (e.g. timely delivery and product quality), and production process flexibility. Thus, future research could apply the TDABC in product-mix decision mix considering "beyond-financial” variables.

Although the use of didactic/illustrative examples is common in product-mix decision publications, as pointed by Kee and Schmidt (2000), the results of this research should be subjected to a more rigorous analysis with a view towards generalization. Thus, other methodological approaches such as the Case Study and Action Research (for details see, respectively, Yin (2003) and Warmington (1980)) could be used to evaluate the proposed model for product-mix decision under the aegis of TDABC in real manufacturing environments in order to confirm, enhance or even refute the proposed model and the results obtained. Finally, this study is thought to contribute as a reference for future research on product-mix de decision.

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