RECENT EVOLUTIONS IN COSTING SYSTEMS: A LITERATURE REVIEW OF TIME-DRIVEN ACTIVITY-BASED COSTING

Lorena Siguenza-Guzman*, Alexandra Van den Abbeele**, Joos Vandewalle***, Henri Verhaaren**** and Dirk Cattrysse*****

Abstract

This article provides a comprehensive literature review of Time-Driven Activity Based Costing (TDABC), a relatively new tool to improve the cost allocation to products and services. After a brief overview of traditional costing and activity based costing systems (ABC), a detailed description of the TDABC model is given and a comparison made between this methodology and its predecessor ABC. Thirty-six empirical contributions using TDABC over the period 2004–2012 were reviewed. The results and conclusions of these studies are grouped according to the main areas of application of the method such as logistics, manufacturing, services, health, hospitality and nonprofit services. Potential benefits, and challenges are identified.

Keywords: Cost systems; Literature review; Time-Driven Activity-Based Costing

JEL code: M41

* Lorena Siguenza-Guzman is a doctoral student at the Centre for Industrial Management Traffic & Infrastructure, KU Leuven, Belgium. She is also lecturer at the Faculty of Engineering, University of Cuenca, Ecuador. Address: Celestijnenlaan 300a, 3001 Leuven, Belgium. Email: lorena.siguenzaguzman@cib.kuleuven.be.

** Alexandra Van den Abbeele is Associate Professor at the Faculty of Economics and Business, KU Leuven, Belgium. Address: Naamsestraat 69, 3000 Leuven, Belgium. Tel. +32 16 326936, Email: Alexandra.vandenabbeele@kuleuven.be.

*** Joos Vandewalle is Professor at the Department of Electrical Engineering ESAT/SCD, KU Leuven, Belgium. Address: Kasteelpark Arenberg 10, 3001 Leuven, Belgium. Tel. +32 16 321052, Email: joos.vandewalle@esat.kuleuven.be.

**** Henri Verhaaren was professor at the Department of Pediatrics and Medical Genetics at the University of Ghent. He is former Director of the Biomedical Library, Faculty of Medicine and Health Sciences, Ghent University, Belgium. Email: henri.verhaaren@ugent.be.

***** Dirk Cattrysse is Professor at the Centre for Industrial Management Traffic & Infrastructure, KU Leuven, Belgium. Address: Celestijnenlaan 300a, 3001 Leuven, Belgium. Tel. +32 16 322564, Email: dirk.cattrysse@cib.kuleuven.be.

I. INTRODUCTION

Calculating the cost of products or services remains a difficult exercise, especially in highly competitive environments where in order to guarantee long-term profitability, companies must ensure that their product and service costs should not exceed market prices (Hoozée, Vermeire, and Bruggeman, 2009). However, also in the non-profit and public sector accurate cost estimations are crucial given the need to constantly prioritize spending and to minimize costs because of the limited resources and budget pressures (Linn, 2007; Sudarsan, 2006; Wise and Perushek, 1996).

Costing systems help companies determine the cost of a cost object such as a product or service. Direct costs such as direct labor and materials are relatively easy to measure and can be directly attributed to specific products or services. On the contrary, indirect costs such as marketing, depreciation, training and electricity are not directly attributable to a cost object. Indirect costs are therefore allocated to a cost object using an allocation approach.

Time-Driven Activity-Based Costing (TDABC) is a cost allocation approach developed by Kaplan and Anderson in 2004 to better attribute the indirect costs to the cost objects in order to obtain more accurate information to set priorities for process improvements, product variety, price settings, and customer relationships. This paper provides an overview of the recent literature on TDABC. First, the predecessors of TDABC such as traditional costing systems and activity-based costing systems (ABC) are briefly discussed. A detailed description of the TDABC model is then presented, followed by an extensive comparison between TDABC and its main predecessor ABC.

The first aim of this paper is to analyze thirty-six case studies carried out with TDABC over the period 2004–2012. This information is categorized in a way that provides a useful understanding of how TDABC has been applied in specific areas. The second aim is to use the literature review as a platform to identify potential benefits and difficulties encountered by researchers when applying TDABC in real cases. From these results some conclusions and suggestions can be drawn.

II. COSTING SYSTEMS

A. TRADITIONAL COSTING SYSTEMS

Kaplan and Cooper (1998) analyzed several integrated cost systems to drive profitability and performance. One is the *traditional costing system* used mainly in the past and now merely for financial reporting procedures. In a traditional costing system, direct costs are directly attributed to the cost objects. On the contrary, indirect costs are typically allocated to each cost object using a single or a few volume-based cost drivers (e.g. direct labor, machine hours or units of output). This type of costing system was created when companies manufactured

products with little variety and a predominant proportion of direct costs; or when supporting activities and its accompanying indirect costs were limited (Novićević and Ljilja, 1999). Presently, traditional costing systems still work well in stable environments with small or fixed indirect costs and little variation in activities, products or services (Kaplan and Cooper, 1998; Tse and Gong, 2009).

However, because of automation, short product life cycles and high products and services variety, most production and service environment have changed. Therefore, the cost system that was adequate for homogeneous cost pools driven by a single cost rate could now be given distorted signals about profitability and performance when using volume-based allocation rates. The limitation of traditional costing systems is that they are unable to allocate the indirect costs of many resources of a company in an accurate way (Kaplan and Cooper, 1998; Yilmaz, 2008a). Since indirect costs have become increasingly more important than direct costs and those costs are not accurately attributed to the different activities and products, traditional costing systems are unable to estimate adequate cost information for most organizations today (Ellis-Newman and Robinson, 1998).

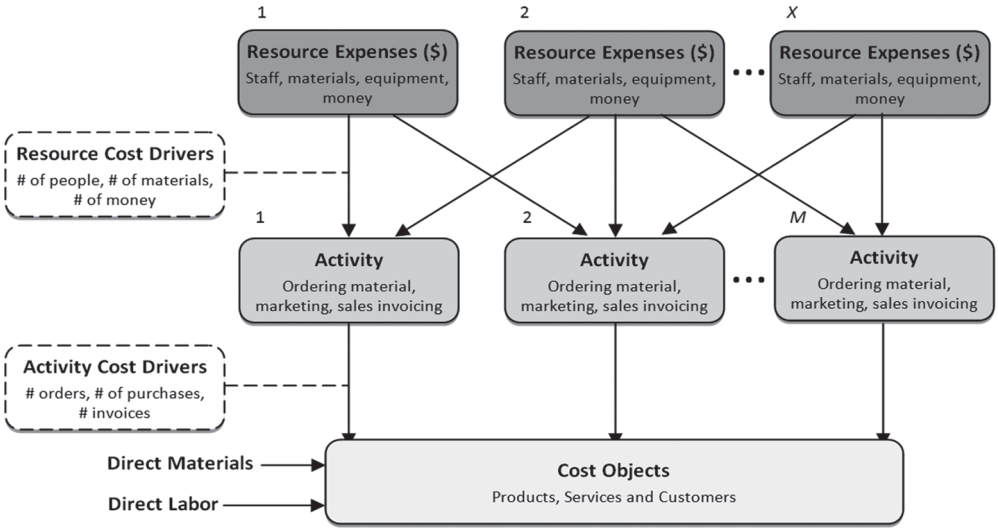
B. ACTIVITY-BASED COSTING SYSTEM

With the rise of the complexity of companies' operations, the weakness of traditional volume-based costing models becomes more evident (Tse and Gong, 2009). Managers have sought other ways of obtaining more accurate information about costs, being ABC one of the most prominent alternatives (Kaplan and Cooper, 1998). ABC was first developed by practitioners and then introduced in some Harvard Business School teaching cases (Bjørnenak and Mitchell, 2002). It was especially promoted by Robin Cooper and Robert Kaplan in the mid-1980s[1] (Cooper and Kaplan, 1988; Kaplan and Cooper, 1998).

Because ABC was first designed for manufacturing processes (Gunasekaran and Sarhadi, 1998; Wegmann, 2010), the theory of its promoters is based on the assumption that products differ in the complexity of manufacturing and that the consumption of activities is also in different proportions. Compared to traditional costing methods, ABC is a process which provides a more accurate and efficient management of activity costs since it draws indirect costs more closely to the different activities (Ellis-Newman and Robinson, 1998). Figure 1 presents the stages that ABC uses for cost allocation, the cost drivers and the relationships between the resources, activities and objects.

[1] For more information about ABC development see Jones and Dugdale (2002) and Gosselin (2006).

Figure 1. Activity-Based Costing Structure (Kaplan and Cooper, 1998)



According to Kaplan and Cooper (1998), ABC is composed of: 1) *Activities* such as ordering materials, marketing, sales invoicing, that consume *resources* (e.g. people, materials, equipment, money). Resource expenses are linked to the different activities through the use of resource cost drivers. A resource cost driver indicates the amount of resources an activity requires. 2) *Objects* such as products or services that require different activities. Activity costs are linked to cost objects using activity cost drivers. An activity cost driver indicates the number of activities an object utilizes. Therefore, resource cost drivers and activity cost drivers are used as a linkage among resources, activities and cost objects.

The information required for an ABC system is collected through interviews, surveys, observations, etc. of the time percentage that employees spend on their several activities. According to Michalska and Szewieczek (2007), it is recommended to divide activity costs as detailed as possible, starting first from the more general activities and then going deeply to more detailed aspects.

Since its creation ABC has been used to achieve better accuracy and to increase profits in manufacturing as well as in services, public sector and non-profit setting (Varila, Seppänen and Suomala, 2007). The use of ABC enhances the traditional costing method contribution, giving the possibility of: 1) including more detailed cost of activities (e.g. direct and indirect costs pools) (Kaplan and Cooper, 1998); 2) getting benefit from a number of indirect-cost pools (e.g. indirect labor cost, indirect material cost, insurance cost, administration cost) (Özbayrak, Akgün and Türker, 2004); 3) lowering costs through the identification of high cost activities (Acorn Systems, 2007); 4) permitting the detection of unprofitable products, services, customers and useless costs (Acorn Systems, 2007; Kaplan and Cooper, 1998; Yilmaz,

2008a); 5) allowing to identify inefficient or unnecessary activities (Michalska and Szewieczek, 2007; Yilmaz, 2008a); 6) better understanding the origin of costs (Dalci, Tanis, and Kosan, 2010).

Despite these advantages of ABC over traditional costing systems (Clarke, Hill, and Stevens, 1999; Cooper and Kaplan, 1988, 1991; Innes, Mitchell, and Sinclair, 2000), several authors have recognized that ABC models are not the real solution (Dalci et al., 2010; Demeere, Stouthuysen, and Roodhooft, 2009; Everaert, Bruggeman and De Creus, 2008; Everaert, Bruggeman, Sarens, Anderson, and Levant, 2008; Kaplan and Anderson, 2004, 2007a; Tse and Gong, 2009; Wegmann and Nozile, 2009). For instance:

- The complexity of the actual services or activities is not captured by ABC because of the degree of subjectivity involved in estimating employees' proportion of time spent on each activity.
- The accuracy of data is biased or distorted, because during the interviews employees tend to ignore their idle or unused time; Demeere et al. (2009) also remark that employees will conveniently supply the information based on how it might be used in the future.
- The time, resources and money for data collection are excessive due to the need to re-interview and resurvey people every time an activity or service is changed, updated or removed.
- The cost driver rate is inaccurate because it is calculated assuming that all committed resources are working to full capacity instead of a practical capacity.
- The computational demand required for storing and processing data is very high because it rises non-linearly if ABC needs to be expanded to reflect more granularity and detail on activities.
- The integration between ABC systems and other organizational information systems is limited.
- The use of a single driver rate for each activity makes it difficult to model multi-driver activities.

III. TIME-DRIVEN ACTIVITY-BASED COSTING SYSTEM

TDABC is an approach developed by Kaplan and Anderson in order to overcome the difficulties presented in ABC systems (Kaplan and Anderson, 2004). Although ABC has the capability of using time as a cost driver in this new version of ABC, time plays a different role in allocating activity costs to cost objects (Hoozée et al., 2009). For each activity, *costing equations* are calculated based on the time required to perform a transactional activity (Yilmaz, 2008a).

A. BRIEF HISTORY

Despite the fact that the term TDABC first appeared in 2004, the idea really originated in 1997 (Kaplan and Anderson, 2007b). On the one hand, Steven R. Anderson and his company

Acorn Systems began experimenting more accurately with the use of time equations and average time estimates (Hudig, 2007). These equations were already fed with information gathered from transaction files of an Enterprise Resource Planning (ERP) system. On the other hand and almost simultaneously, Robert S. Kaplan started thinking about capacity and time as improved concepts for ABC models (Hudig, 2007). For instance, Kaplan proposed the idea that an entire cost system could be built based on two parameters: 1) the cost rate for supplying capacity and 2) the capacity used by each transaction (Kaplan and Cooper, 1998).

In 2001, Kaplan joined Acorn Systems to collaborate with Anderson and improve their approach (Kaplan and Anderson, 2007b). Through several discussions, the idea of integrating Anderson's process time equations with Kaplan's capacity planning vision emerged (Hudig, 2007; Kaplan and Anderson, 2007b). Finally in 2004, Kaplan and Anderson introduced TDABC seeking to remedy ABC pitfalls (Kaplan and Anderson, 2004).

B. THE MODEL

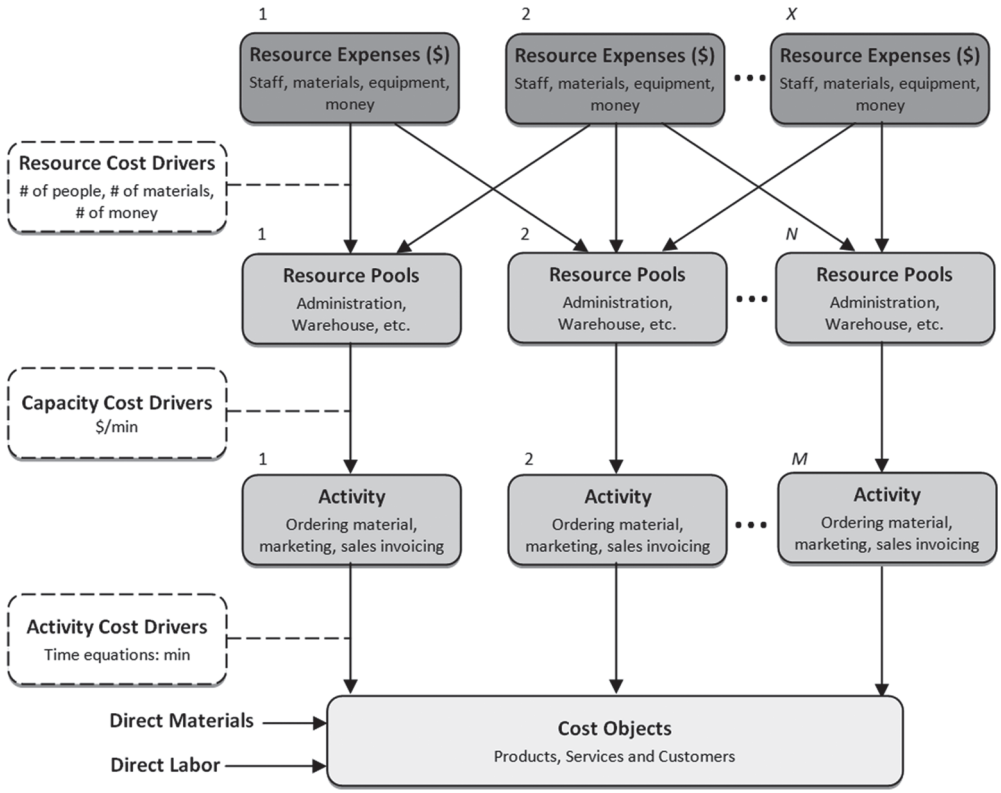
TDABC as its predecessor ABC, starts by estimating the cost of supplying capacity (Demeere et al., 2009). However, TDABC estimates resource usage by means of time equations to determine the time needed to perform each activity (Hoozée and Bruggeman, 2010). TDABC assigns resource costs directly to the cost objects using only two parameters: 1) the cost per time unit of supplying resource capacity and 2) an estimate of the time units required to perform a process, an activity or a service.

The first parameter is gathered by dividing the total cost of supplying resource capacity by the practical capacity. The total cost is defined as the cost of all the resources supplied to this department or process (resources such as personnel, supervision, equipment, technology, and infrastructure). The practical capacity is defined as the amount of time that employees work without idle time (Kaplan and Anderson, 2007a). There are two ways to obtain this value: 1) a percentage of the theoretical capacity: assuming the practical capacity is about 80% for people (because of breaks, arrival and departure, training, and meetings), and 85% for machines (because of maintenance, repair, and scheduling fluctuations) of theoretical full capacity; and 2) calculating the real values adjusted for the company. The second number can be obtained through interviews or by direct observation from employees when performing their work; no additional surveys are required. Authors argue that precision is not critical, that a rough accuracy is sufficient because gross inaccuracies will be revealed either in unexpected surpluses or shortages of committed resources (Kaplan and Anderson, 2007b).

Figure 2 presents the stages that TDABC uses for cost allocation. *Resource expenses* are allocated into the *activities* through the use of resource cost drivers where the unit cost per resource pool is equal to the total cost divided by the practical capacity. Conversely with ABC, TDABC does not contain an activity pool in the model (Tse and Gong, 2009). Activities are represented by *time equations*, which are the sum of individual activity times with time drivers. Through a simple time equation it is possible to represent all possible combinations

of activities (e.g. different types of products do not necessarily require the same amount of time to be produced). Activity costs are then distributed to cost *objects* by multiplying the cost per time unit of the resources by the estimate of the time required to perform the activities.

Figure 2. TDABC model (based on (Everaert, Bruggeman, Sarens et al., 2008))



1. *Time equations*

A time equation is a mathematical expression of the time needed to perform activities as a function of several activity time drivers (Hoozée et al., 2009). It implicitly assumes that the duration of an activity is not constant, but a function of the time consumed by the *k* possible events of an activity and their specific characteristics (i.e. time drivers) (Bruggeman, Everaert, Anderson, and Levant, 2005; Everaert and Bruggeman, 2007). It is represented as follows (Kaplan and Anderson, 2007b):

$$T = \textit{sum of individual activity times} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_i X_i + \ldots + \beta_k X_k$$

With:
T = The time required to perform an activity with k events
β_0 = The basic time to perform the activity (independent of the characteristics of the activity)
β_i = The estimated time for the incremental activity i, with $i = 1,\ldots,k$
X_i = The quantity of incremental activity i (transactional data)
k = The number of time drivers taken into account

Time drivers are an essential part in time equations (Everaert and Bruggeman, 2007). They are the characteristics that determine the time needed to perform an activity (Everaert, Bruggeman, De Creus, and Moreels, 2007). Complexity in the process caused by a particular product or order, may add terms but the process is still modeled with only one time equation (Kaplan and Anderson, 2007a).

Time equations can contain three types of variables: continuous, discrete and dummy variables (Everaert and Bruggeman, 2007). Continuous variables are real variables such as the weights of pallets, water temperature or distance in kilometers. Discrete variables are integer variables such as number of orders. These first two types of variables represent standard activities. However, there are certain activities that can influence the formula and that are denoted by indicator variables (Everaert and Bruggeman, 2007). Indicator or dummy variables can only take the value of zero or one (Boolean values) whether the optional activity is or is not used in a particular case. Examples of dummy variables include the type of customer (new or old), the type of order (normal or rush), the type of shift (morning or evening), etc. The incorporation of these variables in the model simplifies the formulation of the equations (Somapa, Cools, and Dullaert, 2011).

2. *Multiple time drivers and interaction of time drivers*

Multiple time drivers define the time needed to perform an activity and its cost. A time equation provides the ability to include multiple time drivers if an activity is driven by more than one driver (Dalci et al., 2010). It allows to identify and report complex and specialized transactions in a simple way (Everaert et al., 2007). The number of time drivers is unlimited as long as the full complexity is represented in the time equation (Bryon, Everaert, Lauwers, and Van Meensel, 2008). The only restriction is that employees, machinery, etc. performing the tasks must belong to the same resource pool (Everaert and Bruggeman, 2007). According to Varila et al. (2007), the use of multiple variables enables the possibility of collecting more information, the simplification of the estimating process, and the production of a more accurate cost model. It also facilitates a much deeper understanding of the cost behavior of an activity or process. Nevertheless, they also mention that the use of multiple variables will inevitably weaken the traceability of costs.

Another characteristic of time equations is that they might take into account *interactions* between drivers. It is applied if a certain activity depends on the occurrence of other activities,

and the activity time is also influenced by the interaction between the two time drivers (Hoozée et al., 2009). It can be represented by the expression below (Everaert and Bruggeman, 2007):

$$T = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2$$

3. *Activity cost*

Once the estimated time for the activity and the unit cost of each resource group are calculated, then the activity cost is computed (Everaert and Bruggeman, 2007). It is represented by the following mathematical expression:

Cost of an individual event k of activity j performed by resource pool i = $t_{j,k} * c_i$

With:
c_i = The cost per time unit ($/minute) of resource pool *i*
$t_{j,k}$ = The time consumed by event *k* of activity *j*

Finally, the total cost of a cost object (e.g. process, customer, order, product, service, etc.) over all events of all activities is calculated (Everaert and Bruggeman, 2007). It is done by summing all activity costs and can be represented by the following expression:

Total Cost of a Cost object = $\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{l} t_{j,k} * c_i$

With:
c_i = The cost per time unit ($/minute) of resource pool *i*
$t_{j,k}$ = The time consumed by event *k* of activity *j*
n = The number of resource pools
m = The number of activities
l = The number of times that activity *j* is performed

C. TDABC VS. ABC

Adkins (2007) and Yilmaz (2008a) describe ABC as a "push" model, as it starts by estimating the total expenses incurred by the different resources, then by determining the percentage of resources consumed by each product or service, finally by applying this factor to the total cost. Conversely, TDABC is described as a "pull" model because it calculates the total cost by means of the estimation of the unit times required to perform an activity and the cost per time unit of supplying resource capacity. In ABC, the costs of activity-cost pools are apportioned amongst cost objects using activity-cost drivers calculated for each subtask (Kaplan and Cooper, 1998; Tse and Gong, 2009). In TDABC, the costs are allocated to the cost objects on the basis of time units consumed by the activities calculated for the whole

department (Kaplan and Anderson, 2004). Unlike ABC, time unit value refers to the time an employee spends doing an activity, and not the percentage of time that it takes to complete one unit of that activity. This type of measurement allows to reduce errors at the moment of calculating the time (Everaert, Bruggeman, Sarens et al., 2008).

The majority of the differences are based on the weaknesses of ABC (Dejnega, 2011). For instance, Kaplan and Anderson (2004, 2007a) claim that TDABC simplifies the ABC method because of the availability to include multiple time drivers. These time drivers allow to reduce the number of activities and to analyze the costs at the level of the departments or the processes. For instance, the authors present a case study where 1200 activities were reduced in 200 processes. Thus, the model size in TDABC grows linearly with real world complexity (Kaplan and Anderson, 2007b), whereas in ABC growth is exponential to reflect more detail on activities (Kaplan and Anderson, 2004). Likewise, thanks to the use of time equations in TDABC, the high cost and time spent in re-interviewing people every time an activity is changed or updated is reduced because it can be updated based on events rather than by the calendar (Everaert, Bruggeman, and De Creus, 2008).

Barrett (2005) describes the inability of ABC to reveal areas of substantial excess capacity. This is because in ABC, employees tend to ignore their idle time at the moment to estimate the percentage of time spent doing an activity (Yilmaz, 2008a). On the contrary, TDABC is described as a system that automatically exposes differences between the total time needed to perform activities and the total time employees have available. In addition, ABC calculates cost drivers based on the theoretical capacity of the resources supplied while TDABC uses the practical capacity to perform its calculations (Kaplan and Anderson, 2004, 2007a). Eventually, Kaplan and Anderson (2004, 2007a) express the difficulties when integrating ABC with other organizational information systems, while transactional data required for TDABC can easily be obtained from ERP systems, CRM, etc.

D. CASE STUDIES

A Web-based literature research on empirical documents about TDABC applications was conducted in order to identify relevant articles. The data collection was based on materials published in journals, books, Web pages, etc. by means of the search engines: Web of Science, Scholar Google, IDEAS and Google over the period 2004–2012. The search was operated according to the following procedure. First, we searched for relevant articles by combining the terms "time-driven activity-based costing" or "TDABC" with "case study". Then the existing literature was sorted, summarized and discussed in order to generate a final sample consisting of thirty-six papers. In Table 1 the case studies are grouped based on the area that the method is applied and a summary of the main findings is presented for each case study. Strikingly is that a large part of the published case studies on TDABC are case studies in the non-profit sector (health (31%), libraries (8%)). Within the profit sector, a substantial number of case studies have been performed within logistics (31%). Interesting is also to highlight the significant number of case studies conducted in Belgium (25%).

Table 1. Case studies sorted by area

Paper	Activities	Findings
LOGISTICS		
Bruggeman et al. (2005)	Application of TDABC in a distribution company: Sanac	Capture the different types of complexities of the logistics transactions through time equations that employ multiple time drivers.
Everaert et al. (2007; 2008)	Decision of a distribution company on implementing ABC or TDABC: Sanac	TDABC drives costs by transactions, enables to reflect complex contingencies in resource-consumption times, assists to improve inefficient processes, and transforms unprofitable customer relationships.
Everaert et al. (2008)	The experiences of the Belgian wholesaler with TDABC in modelling its complex logistics operations.	Provide opportunities to design cost models for complex operations. Capture the variability of the working methods, by including all possible subtasks in the time equation. Provide insight into the causes of excessive logistics and distribution costs.
Gervais et al. (2010)	Longitudinal assessment of the TDABC implementation in the logistic company: SANAC	Require precise and elaborated analyses that make the starting more lengthy and costly. Use of standard times and costs reduces its complexity. Require regular maintenance. Accuracy is debatable if staff reports their times when it is not possible to observe them directly.
Somapa et al. (2010)	Development of TDABC model in a small-sized road transport and logistics company.	Small-scale firms lack the essential quantitative data to support the buildup of time equations. Difficulty to estimate time in non-continuous activities. Should be implemented a formal time-tracking system. Build and maintain TDABC models with spreadsheets as extensive data is not a problem for small firms.
Somapa et al. (2011)	Development of TDABC model in a small road transport and logistics company	Useful for small firms due to the use of simple parameters. Provide accurate cost information in the transport and logistics activities. Capable to calculate the services costs and provide the cause-and-effect relationship between costs and activities. Better resource utilization. Only require the use of spreadsheets to build and maintain TDABC models for small-scale firms.
Varila et al. (2007)	The applicability of different drivers for assigning activity costs to products in warehouse logistics environment.	Integration with existing systems to collect information for time equations. Increase the accuracy of accounting by measuring the actual durations. Collect an extensive amount of data in order to increase the understanding of the cost behavior of activities and products.

Paper	Activities	Findings
Oztaysi et al. (2007)	Economic analysis of Radio frequency identification (RFID) technology in courier sector Comparison of a barcode system with a potential RFID system.	Suitable model for investment analysis and comparisons between potential systems. Quantify the performance criteria of rapidity of mail delivery. Allow to perform an economic feasibility study of implementing RFID technology.
Hoozée and Bruggeman (2010)	Analysis of four distribution warehouses to examine the role of employee participation and leadership style in the design process of a TDABC system.	Employee participation and leadership style are determinants during the design process of a TDABC system.
Ratnatunga et al. (2012)	Implementation of TDABC in the production logistics of a manufacturing company that produces activated carbon in Sri Lanka.	No different to ABC, if standard-activity times are used as cost drivers. Unable to help organizations solving implementation problems in a manner that will not compromise accuracy.
MANUFACTURING		
Bryon et al. (2008)	Supporting the choice of conversion to batch farrowing in pig production.	Guide managers with the decision problem of switching to batch farrowing. Allow to derive trade-offs between economic and ecological criteria.
Korpunen et al. (2010)	Calculation of the cost of the sawing process.	Assist sawmill management in strategic decision making. Assess the production costs in a sawmill. Enable a sensitivity analysis of production. Accurate, applicable and effective model.
Öker and Adigüzel (2010)	Implementation of TDABC in a manufacturing company.	Provide more relevant information about product profitability and capacity utilization than standard costing.
Stout and Propri (2011)	Implementation of TDABC at a Medium-Sized Electronics Company.	Allow organizations to be accurate with their estimates. Update the model more easily than in ABC models. Capability of implementing TDABC with the support of ERP systems.

Paper	Activities	Findings
Ruiz de Arbulo et al. (2012)	Experience of an auto parts manufacturer who shifted from ABC to TDABC.	Capture the costs of the different products in the product mix. Calculate the cost of a product accurately. Collect data for TDABC seems to be complex. Analyze how capacity is being used (overused or underused).
SERVICES		
Reddy et al. (2011)	Estimating the cost of implementing and managing activities required for digital forensic readiness.	Measure costs at the level of tasks and activities. Less costly and simpler to implement than traditional methods. TDABC is not an automatic fit for any organization. Should be coupled with integrated information systems. Require top management support. Consider potential resistance at the moment of its implementation.
Adeoti and Valverde (2012)	Cost management of Information Technology (IT) Services Operations (Technical Services department).	Identify costly processes which may then allow IT operations managers and supervisors to take critical decisions about cost control, charge-back or costing of services.
HEALTH		
Bank and McIlrath (2009)	Cost estimation of three emergency department (ED) services.	Effective and accurate tool to estimate the true cost of ED services. Help to determine the allocation of ED clinical resources. Help development professional and facility reimbursement strategies with commercial payers.
Demeere et al. (2009)	Analysis of five outpatient clinic's departments: Urology, Gastroenterology, Plastic Surgery, Nose-Throat and Ears, and Dermatology.	Allow managerial recommendations concerning improvement opportunities. Introduce a healthy competition and an open communication between the different departments concerning possible operational improvements. Improve the understanding of the different organizational processes.
Nascimento and Calil (2009a)	Method to create resource consumption profiles for biomedical equipment within medical procedures.	Facilitate the evaluation of equipments used in different conditions. The use of diagrams and tables helps presenting details about the resource consumption structure and the procedure structure itself. Data collection must be driven carefully since it relies on many estimations.

Paper	Activities	Findings
Nascimento and Calil (2009b)	Resource costs estimation that medical equipment consumes during medical procedures Cost evaluation of equipment used during an abdominal aortic aneurysm surgery.	Offer a good insight on where the resources are going and the details about the procedure structure itself. Practical tool to evaluate the equipment cost structure of medical procedures. Assess possible resource or practice changes. Flexible to be used in any kind of medical procedure. The quality of results depends on the quality of the data available.
Szucs et al. (2009)	Assessment of the true acquisition cost of erythrocyte concentrate in different European health care systems.	Reveal activities and resources that were excluded in previous accounting attempts. Provide a complete and documented scope respecting the societal perspective.
Bendavid et al. (2010)	Automation of the nursing unit's supply chain with the RFID two-bin replenishment system.	Identify cost centres and assign them to specific activities and processes.
Bendavid et al. (2011)	Evaluation of a RFID-enabled traceability system for a hospital operating room.	Identify cost centres and assign them to specific activities and processes.
Boehler et al. (2011)	Estimation of the cost of changing physical activity behaviour.	Facilitate the measurement of resources consumed by individual patients and the allocation of single cost items to each patient.
Box et al. (2012)	True cost estimation of flow cytometry experiments Modelling of new fee schedules.	Valuable tool to determine and categorize exact operations costs. Empower the understanding of different types of costs and a better communication to the research organization's leaders. Approach the accounting process to people without background in accounting, business or finance. TDABC cost values should not be used directly to determine service charges.
HOSPITALITY		
Dalci et al. (2010)	Implementation of customer profitability analysis in a Turkish hotel.	Show profitable customer segments which were found unprofitable under the ABC method. Reveal the cost of idle resources.

Paper	Activities	Findings
Hajiha et al. (2011)	Implementation feasibility of TDABC in hospitality industry in Iran.	Provide accurate data on cost and profitability of customers. Distinguish non-added value activities and demonstrate real capacity of each parts of the hotel.
OTHER NONPROFIT SERVICES		
Pernot et al. (2007)	Costing analysis of inter-library loans.	Visualize activities that consume the largest amount of time. Enable to disaggregate per-transaction costs. Visualize the true cost of different activities. Allow managerial recommendations concerning amelioration opportunities.
Stouthuysen et al. (2010)	Implementation of a TDABC model in a library acquisition process.	Identify several factors that drive the cost of the acquisition process of library items. TDABC is well suited for a library setting, involving many activities with complex time drivers. Create more visibility to acquisition process efficiencies and capacity utilization.
Siguenza-Guzman et al. (2013)	Application of TDABC to support loan and return processes.	Better understanding of the costs' origin due to the disaggregated values per activity. An improved alternative evaluation to compare different scenarios. An enhanced communication to analyze the cause of specific problems with stakeholders that can easily understand the methodology. Adaptability when for instance it is required to switch resources in busy periods.
Ratnatunga and Waldmann (2010)	Understanding of university research activities through an accounting technique.	Provide accurate information in "research only" departments and institutes. Inappropriate for determining the indirect research costs of teaching departments.
Everaert et al. (2012)	Introduction of TDABC in a university restaurant in order to allocate operating expenses to cost objects.	Time equations facilitate a detailed understanding of the work activities. The more detailed accounting system offers insights into bottlenecks and capacity utilization of employees.

According to Everaert et al. (2008) and Kaplan and Anderson (2007b), TDABC has been successfully implemented for *logistics and service operations*. This is confirmed in our analysis since a large part of the papers (31%) involve the implementation of TDABC in logistics environments. Bruggeman et al. (2005) discuss the application of TDABC in Sanac, a distribution company in Belgium. They define this company as a distributor of plant-care products with a seasonal trend in the sales and diversity in resource consumptions. In this case study, TDABC is described as a useful cost model to be applied in small and medium-sized enterprises as well as in environments with complex activities such as logistics, hospitals, distribution and servicing companies in general. The authors conclude that TDABC is able to capture the full complexity of the logistics transactions thanks to the use of time equations and multiple time drivers. Everaert et al. (2007; 2008a) describe the decision making of the same company on whether to proceed with the implementation of an ABC system or switch to TDABC. They report that ABC failed to capture the complexity of the company, whereas TDABC could drive costs by transactions and enabled to reflect complex contingencies in resource-consumption times. The authors conclude that TDABC assists managers to improve inefficient processes and to transforms unprofitable customer relationships into profitable relationships. Everaert et al. (2008b) report the two-year experience of implementing TDABC in a Belgian wholesaler. The authors conclude that TDABC is able to trace the full complexity of the logistics operations, capture the variability of the working methods by including all possible subtasks in the time equation, and provide insight into the causes of excessive costs. Eventually, Gervais et al. (2010) perform a longitudinal assessment of the four-year implementation of TDABC in the same company. They conclude that TDABC offers a partial solution to the weaknesses criticized on ABC especially regarding the cost and complexity of implementing and maintaining it as the data gathering process is still substantial. Similarly, Somapa et al. (2010; 2011) report the development of TDABC model in a small-sized road transport and logistics company in Thailand and they also describe some difficulties associated with the study of a small scale operation such as insufficient data to support the time equations and the lack of a time-tracking system (e.g. log book for a manual record). On the other hand, they conclude that the data needed in small-scale firms is not very extensive so that they were able to build and maintain TDABC models with spreadsheets. In addition, they report several benefits of using TDABC such as the application of detailed costs based on the service routes and the different destination types, the revelation of loss-generating routes, the identification of the cause of loss and the utilization of company resources. Varila et al. (2007) use TDABC to examine the applicability of different drivers for assigning activity costs to products in warehouse logistics environment. The authors state that by integrating TDABC with existing systems to collect information for time equations, it enhances the accuracy of accounting. They recommend to collect an extensive amount of data in order to increase the understanding of the cost behavior of activities and products. Oztaysi et al. (2007) apply TDABC to economically justify the use of RFID technology in the courier sector. They compare the current barcode

system with a potential RFID system. They conclude that TDABC is a suitable model for investment analysis and comparison between potential systems. Hoozée and Bruggeman (2010) conduct a case study in four distribution warehouses at a Belgian division of a company to illustrate that employee participation and leadership style are key factors at the moment of implementing TDABC. Finally, the most recent case study in logistics presented by Ratnatunga et al. (2012), makes a comparison of TDABC with ABC by implementing both methodologies in the production logistics of a manufacturing company that produces activated carbon in Sri Lanka. The authors conclude that TDABC does not seem different to ABC if standard-activity times are used as cost drivers. They state that TDABC has similar implementation complexities to ABC.

TDABC has been successfully implemented in several *other sorts of companies* (Yilmaz, 2008a). For instance, Bryon et al. (2008) present an implementation of TDABC in the farming industry. The model is applied for a specific decision problem and adapted for multi-criteria evaluation to analyze whether pig farmers should switch from traditional pig production to batch farrowing. The authors describe TDABC as a useful system to quantify both the economic and ecological impacts of strategic decisions. Korpunen et al. (2010) utilize TDABC to calculate the production cost of the sawing process. The authors conclude that TDABC is a promising method to assist sawmill managers in strategic decision making because it allows to assess the production costs and to perform a sensitivity analysis of production. Öker and Adigüzel (2010) describe the implementation of TDABC in a manufacturing company to conclude that TDABC provides relevant information about product profitability and capacity utilization. Stout & Propri (2011) implement TDABC at a medium-sized electronics company to demonstrate both the potential power of TDABC and the important role of ERP systems in implementing TDABC systems. They conclude that TDABC allows organizations to be accurate with their estimates, to update the model more easily than ABC models and to allocate support cost to products and customers thanks to the integration of ERP systems. In a recent study presented by Ruiz de Arbulo (2012), TDABC is described as a system that can capture the costs of the different products, can accurately calculate the cost of a product and can help to analyze the capacity utilization. The authors describe the experience of an auto parts manufacturer who shifted from ABC to TDABC. Despite the number of advantages stated, the authors indicate that data collection for TDABC is complex.

Szychta (2010) offers a synthetic description of the validity of TDABC applications in *service companies*. The author states that this model is suitable for service activities because they are primarily measured on the basis of the labor time used for performing a given activity. This statement is confirmed in our analysis because the majority of the papers implement TDABC in the service sector (e.g. health, hospitality, libraries, etc.). For instance, Reddy et al. (2011) estimate the cost of implementing and managing activities required for digital forensic readiness (DFR). The authors conclude that TDABC can be used to determine the costs of DRF because it allows to measure cost at the level of tasks and activities and is less costly and simpler to implement than ABC. In order to successfully implement TDABC, the

authors consider that there are certain factors to be taken into account such as the coupling TDABC with integrated information systems, the top management support or the incompatible organizational culture. Adeoti and Valverde (2012) apply TDABC to the Technical Services department of Information Technology (IT) Services Operations. The authors conclude that TDABC is an effective tool to identify costly processes in IT operations and thus to take critical decisions about cost control, charge-back or costing of services.

Within the TDABC literature, a lot of research attention has been devoted to applying TDABC in *healthcare sector* (31%). In this regard, Bank and McIlratha (2009) use data from a high volume pediatric emergency department (ED) to estimate the costs of providing resources and to apply them into three specific clinical scenarios common in any ED service. They consider TDABC to be useful to ED directors in helping to determine the allocation of clinical resources. Demeere et al. (2009) explain how to implement a TDABC model for five outpatient clinic departments (Urology, Gastroenterology, Plastic Surgery, Nose-Throat and Ears and Dermatology). The authors conclude that TDABC offers some additional benefits to those offered by ABC, such as faster model adaptability, a simpler set-up and a higher reflection of the complexity of the real-world operations. They also suggest that TDABC is a useful system to understand the different organizational processes in a healthcare environment. Nascimento and Calil (2009a, 2009b) present two case studies using TDABC to estimate the resource costs that equipment consumes during medical procedures. The authors conclude that TDABC is a flexible system that facilitates the evaluation of equipments used in different conditions. They recommend to manage the data collection carefully since the quality of results depends on the quality of the data available. Szucs et al. (2009) describe TDABC to assess the true acquisition cost of blood products in different European health care systems. According to the authors, TDABC is a complete and transparent cost allocation methodology that provides a detailed process description of activities and resources excluded in previous accounting systems. Bendavid et al. (2010, 2011) utilize TDABC to automate and evaluate RFID systems in a hospital operation room and a nursing unit's supply chain. They select TDABC because of the need to identify cost centers and assign them to specific activities and processes. Boehler et al. (2011) use TDABC to estimate the cost of changing physical activity behavior. The authors select TDABC as it facilitates the measurement of resources consumed by individual patients and the allocation of single cost items to each patient. The most recent case study in the health care sector presented by Box et al. (2012) estimates the cost of flow cytometry experiments. The authors describe TDABC as a valuable tool to determine the true costs of flow cytometry experiments and to determine where significant discrepancies in cost recovery occur. TDABC also helps to model new fee schedules with the goal of more accurately reflecting resource usage in fees. In addition, TDABC is an approach that is easily understandable to people without a background in accounting, business or finance. Despite these advantages, the authors also state that for flow cytometry experiments, TDABC should not be used directly to determine user charges (i.e., the precise cost for a service as determined by TDABC should not be equal to the charge for

that service). An important reason is that service charges should be predictable: a rate schedule should be easily recalled and/or predictable so that the financial expectations for users are clear. Another reason is that sometimes it may be useful to intentionally decouple actual costs from service charges to guide the use (and therefore capacity) of resources. For example, a reduced charge rate for after-hour use of an instrument can increase the instrument's overall used capacity.

Two papers deal with the application of TDABC in the *hospitality industry*. Dalci et al. (2010) describe the implementation of customer profitability analysis (CPA) using TDABC in a hotel. CPA describes the process of assigning costs and obtaining revenues to customer segments or individual customers' accounts in order to calculate the profitability of the segments or accounts (Raaij, 2005). The case study reveals the cost of idle resources devoted to the front desk, housekeeping, food preparation, and marketing activities. They conclude that TDABC provides valuable information to support managerial decision making in a hotel. However, they suggest replicating the analysis to other similar scenarios to see if the results could be generalized. Hajiha and Alishah (2011) present positive results of implementing TDABC in the hospitality industry in Iran. The authors conclude that TDABC provides more proper data on cost and profitability of customers than traditional costing systems. They also state the proposed model distinguishes non-added value activities and demonstrates real capacity of each part of the hotel.

Five papers focus on the application of TDABC on *other nonprofit services*, of which three papers specially focus on the implementation of TDABC in libraries. The first TDABC approach in libraries given by Pernot et al. (2007) calculates the costs of the inter-library loan service. They argue that TDABC can improve the cost management of all library services because it enables to disaggregate "per-transaction costs" which allows taking appropriate actions to improve time consuming activities. Stouthuysen et al. (2010) describe TDABC as a useful system for small to medium-sized academic libraries. The study is focused on the acquisition process. The authors claim that TDABC assists managers in visualizing the acquisition process efficiencies and capacity utilization, leading to potential cost efficiencies. They also state that TDABC can be applied to complex or digitalized acquisition environments. In a recent study, Siguenza-Guzman et al. (2013) present a case study on the loan and return processes. They compare the costs of some specific activities performed by staff or machines, concluding that the usage of robots is well-justified to automate repetitive processes. The authors demonstrate that TDABC is applicable to large library activities, but that involvement of library staff during the TDABC implementation is crucial. They also conclude that TDABC leads to an effective process analysis and better decision-making by librarians and library administrators. Ratnatunga and Waldmann (2010) determine the costs of Australian Competitive Grant (ACG) research projects with the objective of ensuring the full funding of these projects by the government. The authors consider TDABC inappropriate for teaching and research departments since accurate estimations could be obtained from other sort of methods such as studying the workload allocation, and conducting direct interviews of the

staff undertaking research on ACG or other externally funded grants. On the contrary, the use of TDABC for "research only" departments is highly recommended as it is possible to obtain accurate estimation based on 'in-situ' observations, face-to-face interviews and the study of comparative information. Eventually, Everaert et al. (2012) utilize TDABC to calculate the costs of meals offered in a university restaurant. In order to determine the cost per meal, the food cost of each meal component is directly assigned. For all other costs such as preparing, receiving and serving the meal, TDABC is employed. The authors describe TDABC as a costing technique that offers the benefits of ABC with less administration costs. They support the idea that time equations of the meal process allow a detailed understanding of working activities (e.g. a lunch or dinner session consisting of different meals, and meals composed of several meal components). In addition, thanks to the time equations, operational improvements can be identified such as the recommendation of offering less profitable meals on calmer days, while offering more profitable meals on busy days.

E. BENEFITS AND CHALLENGES

1. Benefits

Based on the different case studies, we can expose a number of benefits.

1) *Simplicity*. According to Kaplan and Anderson (2007b), this is the most important attribute of TDABC. It is confirmed by Somapa et al. (2011) who recommend TDABC because of the use of two simple parameters: the cost per time unit of the activity, and the time required to perform an activity. Thanks to this simplicity, TDABC allows to approach the accounting process to people without experience in accounting, business or finance (Box, Park, Semerad, Konnesky, and Haug, 2012; Siguenza-Guzman et al., 2013). TDABC also allows to improve the understanding of the different organizational processes through the lens of an accounting technique (Box et al., 2012; Demeere et al., 2009; Ratnatunga and Waldmann, 2010).
2) *Complex Operations*. TDABC allows to design cost models for complex operations thanks to the use of multiple time drivers (Boehler et al., 2011; Everaert, Bruggeman, Sarens, et al., 2008; Nascimento and Calil, 2009a). TDABC captures the variability of the activities by including all possible subtasks in the time equation (Everaert et al., 2007; Everaert, Bruggeman, Sarens, et al., 2008; Stouthuysen et al., 2010). In turn, time equations can include multiple time drivers without expanding the number of activities. By using multiple time drivers, TDABC allows to disaggregate per-transaction costs and thereby identify processes that are costly, wasteful and inefficient (Everaert et al., 2012; Kaplan and Anderson, 2007b; Pernot et al., 2007; Reddy et al., 2011).
3) *Capacity utilization*. TDABC allows to have a good estimation of resource consumption and capacity utilization (Bank and McIlrath, 2009; Nascimento and Calil, 2009b; Öker

and Adigüzel, 2010; Stouthuysen et al., 2010). According to Szucs et al. (2009) and Dalci et al. (2010), TDABC reveals activities, resources and costs that were excluded in previous accounting attempts. TDABC provides insight into the causes of excessive time or costs occupied by the resources (Everaert, Bruggeman, Sarens, et al., 2008). Managers can review the time and cost of the unused or overused capacity and contemplate actions to improve them (Demeere et al., 2009; Kaplan and Anderson, 2007a; Ruiz de Arbulo et al., 2012). They may also reserve resources for future growth instead of reducing currently unused capacity (Kaplan and Anderson, 2007a).

4) *Versatility and modularity*. According to Stout and Propri (2011), TDABC can be updated more easily than ABC models. Kaplan and Anderson (2007a) state that managers do not have to re-interview personnel when more activities are added to a process. For cost drivers, there are two factors that cause a change: 1) changes in the costs of resources supplied affecting the capacity; 2) modified or updated processes such as new or redesigned processes, products, channels, etc. (Everaert and Bruggeman, 2007; Kaplan and Anderson, 2007a). It can be updated based on events rather than by the calendar (Kaplan and Anderson, 2007a). Likewise, by implementing TDABC with the support of existing systems (ERP systems, CRM, etc.), the system allows for an easy updating as well as a greater accuracy (Kaplan and Anderson, 2007b; Ruiz de Arbulo et al., 2012; Stout and Propri, 2011; Varila et al., 2007). The major benefit occurs when companies link their own information systems to the TDABC system (Hudig, 2007; Reddy et al., 2011). In the case of small-scale environments, TDABC can be built and maintained with relatively simple spreadsheets (Somapa et al., 2010, 2011).
5) *Process simulation*. TDABC can be used in a predictable manner. Managers can modify the behavior of their customers by simulating the future through the use of dynamic what-if analysis (Kaplan and Anderson, 2007a). They can also establish future investment decisions due to the possibility to determine the impact of changes in terms of cost, profit, capacity and time (Acorn Systems, 2007; Hudig, 2007).

2. Challenges

Despite the advantages presented by its authors and supporters, criticisms have been made about TDABC.

1) *Measurement error.* Cardinaels and Labro (2008) report via an experimental analysis that the employees' estimation may not be as accurate as the authors proclaim. A significant degree of subjectivity is still present (Barrett, 2005). Although Kaplan and Anderson (2007b) state that time consumption data can be estimated or observed directly, it still requires a series of interviews with employees. These interviews may adversely affect the work performed by people in charge of enforcing TDABC approach. Hoozée and Bruggeman (2010) show an example where operational employees feel that by

implementing TDABC they are being controlled. Gervais et al. (2010) also present a case study in which certain employees and senior staff members are strongly opposed to state their working time precisely. Reddy et al. (2011) recommend to consider potential resistance at the moment of implementing TDABC models. Cardinaels and Labro (2008) also find a strong overestimation bias when employees provide their time estimates in minutes. Indeed, if the minutes-based model is compared to the percentage-based model (ABC approach), outcomes are definitely more accurate. This is so because few employees tend to report the percentage of their idle time. However, the authors state that more than 77% of their participants consistently overestimated the time spent on all activities. Accuracy is debatable if staff reports their times when it is not possible to observe them directly (Gervais et al., 2010).

2) *Data*. Varila et al. (2007) emphasize the necessity of a considerable amount of data to estimate satisfactorily time equations. This situation is confirmed by Ruiz de Arbulo et al. (2012), and Nascimento and Calil (2009a, 2009b) which indicate that data collection for TDABC seems to be complex and should be managed carefully since the quality of results depends on the quality of the data available. Gervais et al. (2010) claim that TDABC requires a precise and elaborated analysis, making the starting more lengthy and costly. They also stress the necessity of a regular maintenance over time (Gervais, Levant, and Ducrocq, 2009). In addition, for Barrett (2005), TDABC depends on robust and reliable data to deliver an acceptable level of accuracy. If the data comes from automated software and is regularly updated, then the results will probably be accurate. However, if the information is out of date, or if it is based on estimates, the resulting cost information may include substantial errors (Sherratt, 2005). Barret states that for the estimation of only one activity in minutes, a difference of seconds may not seem important. But, when this time in minutes is multiplied by the number of times an activity is performed in a certain period, the difference becomes significant. The author also objects to the accuracy of the costing process results because of the assumption that practical capacity can be calculated as a percentage of the theoretical capacity.
3) *Dedicated to homogeneous and repetitive activities*. Sherratt (2005) states that TDABC is limited to predetermined routines and activities. Barrett (2005) considers TDABC to be simple for a department that performs a single activity, because the total costs of the direct and indirect resources can be divided by the available resource. However, most departments perform more activities that consume direct and indirect resources in different proportions (Barrett, 2005). Wegmann and Nozile (2009; 2010) claim that TDABC is only useful for standard processes such as chain management supplying, some standardized production processes and consulting activities, call centers, hospitals, etc. Ratnatunga and Waldmann (2010) consider the use of TDABC inappropriate to determine the indirect research cost for departments that combine teaching and research activities since accurate estimations can be obtained from other type of methods. Cardinaels and Labro (2008) also state that for incoherent tasks such as research and development

process, marketing, legal or complex productions, some mistakes are possible. Incoherent tasks are activities addressed on the basis of first come, first served, and not in a structured and systematic sequence. In these cases, authors predict less accuracy in time perception when events are presented incoherently rather than coherently. Sherratt (2005) also considers that certain areas of IT and marketing do not perform repetitive and homogeneous activities to be clocked reliably. For these activities, the author still considers ABC as an alternative methodology to be used (Barrett, 2005). This situation is confirmed by Hoozée et al. (2010), who also affirm that ABC is more accurate than TDABC in those types of cases. Through a simulation analysis, the authors compare the overall accuracy of ABC and TDABC in complex and dynamic environments. They identify that when diversity of productive work is low, TDABC tends to be more accurate, especially at higher levels of unused capacity. Conversely, when the diversity of productive work is high, ABC is the best option, especially at lower levels of unused capacity.

F. OPPORTUNITIES

There are several additional opportunities for TDABC such as:

1) *Simulation*. McGowan (2009) states that TDABC may easily use simulation modeling to analyze how to optimize the resources since information is entirely composed of real values. It allows to implement different scenarios in order to identify opportunities for resource management. Moreover, the simulation model can be used for capacity planning to highlight resources gaps and spare capacity (Everaert, Bruggeman, Sarens, et al., 2008). Managers can easily update their simulation model to reflect changes in the operating environment and to measure improvement in efficiencies and costs.
2) *Benchmarking*. With TDABC, companies can compare their processes among other companies because most of them are common across multiple industries (Kaplan and Anderson, 2007b). It is also possible to compare time equations and costs within different company locations (warehouses). Anderson (2006) presents how three companies in different industries use TDABC in a benchmarking way. For this author, TDABC does not replace traditional benchmarking methodologies; it enhances them. This is so because, unlike traditional benchmarking that only reports macro results, TDABC isolates process differences to uncover root causes. Everaert et al. (2008) present a case study where an internal benchmarking was performed in four warehouses. They describe that time estimations were different among all the warehouses. In some cases, because of the different distances that trucks must travel; and for other subtasks, because some warehouses worked more efficiently than others.
3) *Complementary Information Systems*. A fully automated accounting mode is not yet usual. Nevertheless, there are a variety of technologies that help to collect data from processes with minimum manual efforts such as bar codes, RFID technology and time

sheets (Bahr and Lim, 2010; Oztaysi et al., 2007; Varila et al., 2007). This is especially useful in a logistics environment where there are mostly repetitive processes. Moreover, since these technologies allow improving data accuracy by reducing the number of human errors and because they allow a relatively rapid data collection, they may provide an answer for TDABC for non-routine tasks. Varila et al. (2007) also recommend to estimate the time on the bases of parameters through statistical tools such as multiple regression analysis. Neural networks are also another kind of flexible tools to estimate costs, although they are a "black box" which gives no chance to analyze the outcomes (Verlinden, Duflou, Collin, and Cattrysse, 2008).

4) *Balanced Scorecard (BSC).* According to Yilmaz (2008a), TDABC can be used as a basis for a balanced scorecard. The BSC allows organizations to implement a strategy rapidly and effectively by integrating the measurement system with the management system. TDABC facilitates translating strategy into performance measures and provides actionable performance measures for the BSC (Yilmaz, 2008a). Yilmaz (2008b) and Ayvaz et al. (2011) analyze the relation between BSC and the costing systems ABC and TDABC respectively. They mention four existing links: 1) *Operational Connection*, where the outputs of ABC such as costs, quality, time and innovations are usually excellent inputs to a BSC by defining the performance of any process. 2) *Customer Profitability Connection*, through TDABC because of the ability to accurately decompose the aggregate marketing, distribution, technical, service, and administrative costs into the cost of serving individual customers. 3) *Financial Connection* because BSC helps to identify the strategic initiatives and resource requirements that enable companies gaining sustainable competitive power in the long term. Resources for these initiatives are assigned in the annual spending budget. 4) *Analytic Hierarchy Process*, which allows decision makers to model a complex problem in a hierarchical structure.
5) *Total Quality Management (TQM).* TQM means excellent quality of products and services and its objective is to meet customer requirements through the involvement of all the employees (Novićević and Ljilja, 1999). It stresses the need to manage the activities and processes in a continuous improvement framework. In the case of traditional costing systems, they cannot be adapted to the TQM philosophy because they are directed to the product and not to the process. In Novićević and Ljilja (1999), ABC is analyzed to deal with this problem since it provides information on costs and also information on processes. It helps managers in realization of a cost reduction programme by the premise that certain costs can be eliminated, and that action does not make product quality an inferior one. It can be done with the objective to eliminate activities that do not add value to the product. According to Novićević and Antić (1999), ABC is totally compatible with TQM philosophy.

IV. CONCLUSIONS

This document presents a comprehensive literature review on Time-Driven Activity-Based Costing, with a special focus on the case studies published over the period 2004–2012. Thirty-six papers are analyzed and classified along application themes such as logistics, manufacturing, services, health, hospitality and other nonprofit services. Based on the analysis of the selected literature, we conclude that TDABC is highly recommended for repetitive activities. However, the current research is less clear about the advantages of TDABC for non-routine tasks. Technologies such as RFID, bar codes or existing information from time sheets may provide the necessary data required in these cases. Nevertheless, future research is needed to identify whether these data sources may be helpful for non-routine tasks. Comparing TDABC to the traditional ABC costing, TDABC offers several advantages, even if it does not dramatically simplify specific processes. We agree with Adkins (2007) that TDABC should be considered as a complement to the traditional ABC model rather than as a replacement of it.

The results show that in practice TDABC provides most of the advantages its authors claim. Nevertheless, despite advantages, the main remarks made by other authors, which require special attention are: 1) provision of a partial solution to the ABC failings, 2) difficulty to measure the times, the homogeneity and their maintenance over time, 3) degree of subjectivity still present in the model, 4) biased overestimation when employees provide their time estimates in minutes, 5) necessity of a considerable amount of data to estimate satisfactorily time equations, 6) dependence of robust and reliable data to deliver an acceptable level of accuracy, 7) necessity of a regular maintenance with a minimum of required knowledge, 8) limitation of the model to predetermined routines and activities (e.g. repetitive processes), 9) difficulties of estimating time for non-continuous or unpredictable activities.

The studies on the implementation, as well as the criticisms on TDABC are, in most of the cases, written by its creators and not by independent researchers. This can certainly bias the evaluation of the TDABC methodology. Future research is needed by operational case studies in specific areas such as the public services, and in activities that follow an unstructured and non-systematic sequence.

V. ACKNOWLEDGEMENTS

We wish to thank the University of Cuenca, the Flemish Interuniversity Council (VLIR-IUC), and the National Secretariat of Higher Education, Science, Technology and Innovation of Ecuador (SENESCYT) for supporting this research project.

REFERENCES

Acorn Systems (2007), "Higher Profits, Increased Efficiency With Time-Driven Activity-Based Costing – Retail Solutions Online Interview with Steven Anderson", *Retail Solutions Online*, 5.

Adeoti, A., and Valverde, R. (2012), "A Time-Driven Activity Cost Approach for the Reduction of Cost of IT Services: A Case Study in the Internet Service Industry", *AMCIS 2012 Proceedings*, (Paper 4), retrieved from http://aisel.aisnet.org/amcis2012/proceedings/AccountingInformationSystems/4.

Adkins, T. (2007), "Five Myths About Time-Driven Activity-Based Costing: Sorting through the facts about traditional and time-driven costing methodologies" (White paper) (p. 10), SAS, retrieved from www.sas.com/resources/whitepaper/wp_4034.pdf

Anderson, S.R. (2006), "Maximize Benchmarking with Time-Driven ABC: New Techniques that Change How We Measure Performance", *Acorn Systems*, 1–11.

Ayvaz, E., and Pehlivanli, D. (2011), "The Use of Time Driven Activity Based Costing and Analytic Hierarchy Process Method in the Balanced Scorecard Implementation", *International Journal of Business and Management*, *6*(3), 146–158.

Bahr, W., and Lim, M. K. (2010), "Maximising the RFID benefits at the tyre distribution centre", In *Proceedings of the 12th International MITIP Conference The Modern Information Technology in the Innovation Processes of the Industrial Enterprises*, presented at the 12th International MITIP Conference, Denmark, retrieved from http://eprints.aston.ac.uk/15223/1/Bahr_Lim_Maximising_the_RFID_benefits_at_the_tyre_distribution_centre.pdf.

Bank, D.E., and McIlrath, T. (2009), "13: Utilizing Time-Driven Activity-Based Costing in the Emergency Department", *Annals of Emergency Medicine*, *54*(3, Supplement), S5. doi:10.1016/j.annemergmed.2009.06.033.

Barrett, R. (2005), "Time-Driven Costing: The Bottom Line on the New ABC", *Business Performance Management Magazine*, *11*(Supplement), 35–39.

Bendavid, Y., Boeck, H., and Philippe, R. (2010), "Redesigning the replenishment process of medical supplies in hospitals with RFID", *Business Process Management Journal*, *16*(6), 991–1013. doi:10.1108/14637151011093035.

Bendavid, Y., Boeck, H., and Philippe, R. (2011), "RFID-Enabled Traceability System for Consignment and High Value Products: A Case Study in the Healthcare Sector", *Journal of Medical Systems*, 1–17. doi:10.1007/s10916–011–9804–0.

Bjørnenak, T., and Mitchell, F. (2002), "The development of activity-based costing journal literature, 1987–2000", *European Accounting Review*, *11*(3), 481–508. doi:10.1080/09638180022000001019.

Boehler, C.E.H., Milton, K.E., Bull, F.C., and Fox-Rushby, J.A. (2011), "The cost of changing physical activity behaviour: evidence from a "physical activity pathway" in the primary care setting", *Bmc Public Health*, *11*(370), 12. doi:10.1186/1471–2458–11–370.

Box, A.C., Park, J., Semerad, C.L., Konnesky, J., and Haug, J.S. (2012), "Cost accounting method for cytometry facilities", *Cytometry Part A*, *81A*(6), 439–444. doi:10.1002/cyto.a.22052.

Bruggeman, W., Everaert, P., Anderson, S. R., and Levant, Y. (2005), "Modeling Logistics Costs using Time-Driven ABC: A Case in a Distribution Company" (Working Paper No. 2005/332) (p. 47). Belgium: Faculty of Economics and Business Administration, Ghent University, retrieved from http://cosmic.rrz.uni-hamburg.de/webcat/hwwa/edok05/be193g/wp05–332.pdf.

Bryon, K., Everaert, P., Lauwers, L., and Van Meensel, J. (2008), "Time-driven activity-based costing for supporting sustainability decisions in pig production", presented at the Corporate Responsibility Research Congress, Belfast (UK): CRR Conference, retrieved from http://crrconference.org/downloads/lauwers.pdf.

Cardinaels, E., and Labro, E. (2008), "On the Determinants of Measurement Error in Time-Driven Costing", *The Accounting Review*, *83*(3), 735–756. doi:10.2308/accr.2008.83.3.735.

Clarke, P.J., Hill, N.T., and Stevens, K. (1999), "Activity-Based Costing in Ireland: Barriers to, and opportunities for, change", *Critical Perspectives on Accounting*, *10*(4), 443–468. doi:10.1006/cpac.1997.0197.

Colwyn Jones, T., and Dugdale, D. (2002), "The ABC bandwagon and the juggernaut of modernity", *Accounting, Organizations and Society*, *27*(1–2), 121–163. doi:10.1016/S0361–3682(01)00035–6.

Cooper, R., and Kaplan, R.S. (1988), "Measure Costs Right: Make the Right Decision", *Harvard Business Review*, *66*(5), 96–103.

Cooper, R., and Kaplan, R.S. (1991), "Profit Priorities from Activity-Based Costing", *Harvard Business Review*, *69*(3), 130–135.

Dalci, I., Tanis, V., and Kosan, L. (2010), "Customer profitability analysis with time-driven activity-based costing: a case study in a hotel", *International Journal of Contemporary Hospitality Management*, *22*(5), 609–637. doi:10.1108/09596111011053774.

Dejnega, O. (2011), "Method Time Driven Activity Based Costing – Literature Review", *Journal of Applied Economic Sciences*, *6*(1(15)), 7–15.

Demeere, N., Stouthuysen, K., and Roodhooft, F. (2009), "Time-driven activity-based costing in an outpatient clinic environment: Development, relevance and managerial impact", *Health Policy*, *92*(2–3), 296–304. doi:10.1016/j.healthpol.2009.05.003.

Ellis-Newman, J., and Robinson, P. (1998), "The cost of library services: Activity-based costing in an Australian academic library", *The Journal of Academic Librarianship*, *24*(5), 373–379. doi:16/S0099–1333(98)90074-X.

Everaert, P., and Bruggeman, W. (2007), "Time-driven activity-based costing: exploring the underlying model", *Journal of cost management*, *21*(2), 16–20.

Everaert, P., Bruggeman, W., and De Creus, G. (2008), "Sanac Inc.: From ABC to time-driven ABC (TDABC) – An instructional case", *Journal of Accounting Education*, *26*(3), 118–154. doi:10.1016/j.jaccedu.2008.03.001.

Everaert, P., Bruggeman, W., De Creus, G., and Moreels, K. (2007), "Chapter Nine. SANAC Logistics. Time Equations to Capture Complexity in Logistics Processes", In *Time-Driven Activity-Based Costing: A simpler and more powerful path to higher profits* (pp. 165–178), Harvard Business Press.

Everaert, P., Bruggeman, W., Sarens, G., Anderson, S.R., and Levant, Y. (2008), "Cost modeling in logistics using time-driven ABC: Experiences from a wholesaler", *International Journal of Physical Distribution & Logistics Management*, *38*(3), 172–191. doi:10.1108/09600030810866977.

Everaert, P., Cleuren, G., and Hoozée, S. (2012), "Using time-driven ABC to identify operational improvements: A case study in a university restaurant", *Cost Management*, *26*(2), 41–48.

Gervais, M., Levant, Y., and Ducrocq, C. (2009), "Time Driven Activity Based Costing: New Wine, or Just New Bottles?", In *Proceeding of the 32nd Annual congress of the European Accounting Association* (p. 31), presented at the 32nd Annual congress of the European Accounting Association. doi:oai:halshs.archives-ouvertes.fr:halshs-00391265.

Gervais, M., Levant, Y., and Ducrocq, C. (2010), "Time-Driven Activity-Based Costing (TDABC): An Initial Appraisal through a Longitudinal Case Study", *JAMAR (The Journal of Applied Management Accounting Research)*, *8*(2), 20 p.

Gosselin, M. (2006), "A Review of Activity-Based Costing: Technique, Implementation, and Consequences", In *Handbooks of Management Accounting Research* (Vol. 2, pp. 641–671), Elsevier, retrieved from www.sciencedirect.com/science/article/pii/S1751324306020086.

Gunasekaran, A., and Sarhadi, M. (1998), "Implementation of activity-based costing in manufacturing", *International Journal of Production Economics*, *56–57*(0), 231–242. doi:10.1016/S0925–5273(97)00139–4.

Hajiha, Z., and Alishah, S.S. (2011), "Implementation of Time-Driven Activity-Based Costing System and Customer Profitability Analysis in the Hospitality Industry: Evidence from Iran", *Economics and Finance Review*, *1*(8), 57–67.

Hoozée, S., and Bruggeman, W. (2010), "Identifying operational improvements during the design process of a time-driven ABC system: The role of collective worker participation and leadership style", *Management Accounting Research*, *21*(3), 185–198. doi:10.1016/j.mar.2010.01.003.

Hoozée, S., Vanhoucke, M., and Bruggeman, W. (2010), "Comparing the accuracy of ABC and time-driven ABC in complex and dynamic environments: a simulation analysis (Working Papers of Faculty of Economics and Business Administration", Ghent University, Belgium No. 2010/645), Ghent University, Faculty of Economics and Business Administration, retrieved from http://ideas.repec.org/p/rug/rugwps/10–645.html.

Hoozée, S., Vermeire, L., and Bruggeman, W. (2009), "A risk analysis approach for time equation-based costing", (Working Paper No. 2009/556) (p. 47), Belgium: Faculty of Economics and Business Administration, Ghent Univesity, retrieved from http://feb1.ugent.be/nl/Ondz/WP/Papers/wp_09_556.pdf.

Hudig, J.-W. (2007), "Robert S. Kaplan: 'Better information with less effort'", *Fi Next – Wrap up*, pp. 5–6.

Innes, J., Mitchell, F., and Sinclair, D. (2000), "Activity-based costing in the U.K.'s largest companies: a comparison of 1994 and 1999 survey results", *Management Accounting Research*, *11*(3), 349–362. doi:10.1006/mare.2000.0135.

Kaplan, R.S., and Anderson, S.R. (2004), "Time-Driven Activity-Based Costing – Tool Kit", *Harvard Business Review*, (82), 131–138.

Kaplan, R.S., and Anderson, S.R. (2007a), "The innovation of time-driven activity-based costing", *Journal of cost management*, *21*(2), 5–15.

Kaplan, R.S., and Anderson, S.R. (2007b), *Time-driven activity-based costing: a simpler and more powerful path to higher profits,* Harvard Business Press.

Kaplan, R.S., and Cooper, R. (1998), *Cost & effect: using integrated cost systems to drive profitability and performance*, Harvard Business Press.

Korpunen, H., Mochan, S., and Uusitalo, J. (2010), "An activity-based costing method for sawmilling", *Forest Products Journal*, *60*(5), 420–431.

Linn, M. (2007), "Budget systems used in allocating resources to libraries", *Bottom Line: Managing Library Finances, The*, *20*(1), 20–29. doi:10.1108/08880450710747425.

McGowan, C. (2009), "Time-Driven Activity-Based Costing A New Way To Drive profitability", *Accountancy Ireland*, *41*(6), 60–61.

Michalska, J., and Szewieczek, D. (2007), "The improvement of the quality management by the activity-based costing", *Journal of Achievements in Materials and Manufacturing Engineering*, *21*(1), 91–94.

Nascimento, L.N., and Calil, S. J. (2009a), "A Method to Create Resource Consumption Profiles for Biomedical Equipment", In O. Dossel and W.C. Schlegel (Eds.), *World Congress on Medical Physics and Biomedical Engineering. World Congress 2009. Diagnostic and Therapeutic Instrumentation, Clinical Engineering* (pp. 81–84), presented at the World Congress on Medical Physics and Biomedical Engineering, Munich, Germany: Springer-Verlag. doi:10.1007/978–3–642–03885–3_23.

Nascimento, L.N., and Calil, S.J. (2009b), "Allocation of Medical Equipment Costs to Medical Procedures", In J. VanderSloten, P. Verdonck, M. Nyssen, and J. Haueisen (Eds.), *4th European Conference of the International Federation for Medical and Biological Engineering* (Vol. 22, pp. 1730–1733), New York: Springer.

Novićević, B.M., and Ljilja, A. (1999), "Total quality management and activity-based costing", *Facta Universitatis. Series: Philosophy and Sociology*, *1*(7), 1–8.

Öker, F., and Adigüzel, H. (2010), Time-driven activity-based costing: An implementation in a manufacturing company", *Journal of Corporate Accounting & Finance*, *22*(1), 75–92. doi:10.1002/jcaf.20646.

Özbayrak, M., Akgün, M., and Türker, A.K. (2004), "Activity-based cost estimation in a push/pull advanced manufacturing system", *International Journal of Production Economics*, *87*(1), 49–65. doi:10.1016/S0925–5273(03)00067–7.

Oztaysi, B., Baysan, S., and Dursun, P. (2007), "A novel approach for economic-justification of RFID technology in courier sector: a real-life case study", In *1st Annual RFID Eurasia Eurasia Conference, 2007* (pp. 327–331), presented at the 1st Annual RFID Eurasia Eurasia Conference, Istanbul, Turkey.

Pernot, E., Roodhooft, F., and Van den Abbeele, A. (2007), "Time-Driven Activity-Based Costing for Inter-Library Services: A Case Study in a University", *The Journal of Academic Librarianship*, *33*(5), 551–560. doi:16/j.acalib.2007.06.001.

Raaij, E.M. van. (2005), "The strategic value of customer profitability analysis", *Marketing Intelligence & Planning*, *23*(4), 372–381. doi:10.1108/02634500510603474.

Ratnatunga, J., Tse, M.S.C., and Balachandran, K.R. (2012), "Cost Management in Sri Lanka: A Case Study on Volume, Activity and Time as Cost Drivers", *The International Journal of Accounting*, *47*(3), 281–301. doi:10.1016/j.intacc.2012.07.001.

Ratnatunga, J., and Waldmann, E. (2010), "Transparent Costing: Has the emperor got clothes?", *Accounting Forum*, *34*(3–4), 196–210. doi:10.1016/j.accfor.2010.08.005.

Reddy, K., Venter, H., and Olivier, M. (2011), "Using time-driven activity-based costing to manage digital forensic readiness in large organisations", *Information Systems Frontiers*, 1–17. doi:10.1007/s10796–011–9333-x.

Ruiz de Arbulo, P., Fortuny, J., García, J., Díaz de Basurto, P., and Zarrabeitia, E. (2012), "Innovation in Cost Management. A Comparison Between Time-Driven Activity-Based Costing (TDABC) and Value Stream Costing (VSC) in an Auto-Parts Factory", In S.P. Sethi, M. Bogataj, and L. Ros-McDonnell (Eds.), *Industrial Engineering: Innovative Networks* (pp. 121–128), Springer London, retrieved from www.springerlink.com/content/r30ppl004366ml97/abstract/.

Sherratt, M. (2005), "Time-Driven Activity-Based Costing", *Harvard Business Review*, *83*(2), 144–144.

Siguenza-Guzman, L., Van den Abbeele, A., Vandewalle, J., Verhaaren, H., and Cattrysse, D. (2013)", Using Time-Driven Activity-Based Costing to Support Library Management Decisions: A Case Study for Lending and Returning Processes, *submitted to Library Quarterly*.

Somapa, S., Cools, M., and Dullaert, W. (2010), "Time driven activity based costing in a small road transport and logistics company (pp. 281–300)", presented at the Vervoerslogistieke Werkdagen 2010, 18–19 november 2010, Antwerpen, Belgium / Witlox, F.J.A. et al., Antwerp, Belgium: University Press, retrieved from http://hdl.handle.net/10067/866250151162165141.

Somapa, S., Cools, M., and Dullaert, W. (2011), "The Development of Time Driven Activity-Based Costing Models: A Case Study in a Road Transport and Logistics Company", In *Current Issues in Shipping, Ports and Logistics* (pp. 431–445), Asp / Vubpress / Upa.

Stout, D., and Propri, J. (2011), "Implementing Time-Driven Activity-Based Costing at a Medium-Sized Electronics Company", *Management Accounting Quarterly*, *12*(3), 1–11.

Stouthuysen, K., Swiggers, M., Reheul, A.-M., and Roodhooft, F. (2010), "Time-driven activity-based costing for a library acquisition process: A case study in a Belgian University", *Library Collections, Acquisitions, and Technical Services*, *34*(2–3), 83–91. doi:16/j.lcats.2010.05.003.

Sudarsan, P.K. (2006), "A resource allocation model for university libraries in India", *Bottom Line: Managing Library Finances, The*, *19*(3), 103–110. doi:10.1108/08880450610682527.

Szucs, D., Bauwens, J., Alfonso, J., Holtuis, N., Von Knorring, J., and Demey, J. (2009), "Development of a Time-Driven Activity-Based Costing Model for Assessing the Societal Acquisition Cost of Erythrocyte Concentrates in Europe", *Haematologica-the Hematology Journal*, *94*, 51–52.

Szychta, A. (2010), "Time-Driven Activity-Based Costing in Service Industries", *Social Sciences*, *67*(1), 49–60.

Tse, M.S.C., and Gong, M.Z. (2009), "recognition of idle resources in time-driven activity-based costing and resource consumption accounting models", *Journal of Applied Management Accounting Research*, *7*(2), 41–54.

Varila, M., Seppänen, M., and Suomala, P. (2007), "Detailed cost modelling: a case study in warehouse logistics", *International Journal of Physical Distribution & Logistics Management*, *37*(3), 184–200. doi:10.1108/09600030710742416.

Verlinden, B., Duflou, J.R., Collin, P., and Cattrysse, D. (2008), "Cost estimation for sheet metal parts using multiple regression and artificial neural networks: A case study", *International Journal of Production Economics*, *111*(2), 484–492. doi:10.1016/j.ijpe.2007.02.004.

Wegmann, G. (2010), "Compared Activity-Based Costing Case Studies in the Information System Departments of Two Groups in France: A Strategic Management Accounting Approach", In *Proceedings of Business and Information* (Vol. 7, p. 19), presented at the International Conference on Business and Information, retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1620797.

Wegmann, G., and Nozile, S. (2009), "The activity-based costing method developments: state-of-the art and case study", *The IUP Journal of Accounting Research and Audit Practices*, *8*(1), 7–22. doi:oai:halshs.archives-ouvertes.fr:halshs-00482137.

Wise, K., and Perushek, D.E. (1996), "Linear goal programming for academic library acquisitions allocations", *Library Acquisitions: Practice & Theory*, *20*(3), 311–327. doi:10.1016/0364–6408(96)00065–8.

Yilmaz, R. (2008a), "Creating The Profit Focused Organization Using Time-Driven Activity Based Costing", presented at the Business & Economics Conferences (EABR) and Teaching & Education Conferences (TLC), Salzburg, Austria, retrieved from http://rifatyilmaz.net/SLZ08–191.pdf.

Yilmaz, R. (2008b), "The Relations Between Balanced Scorecard and Other Organizational Development Applications", In *Business & Economics Conferences (EABR) and Teaching & Education Conferences (TLC)* (p. 10), presented at the Business & Economics Conferences (EABR) and Teaching & Education Conferences (TLC), Salzburg, Austria.