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Time-driven activity-based costing: Designing a model in a Portuguese production environment

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Designing a model in a Portuguese production environment

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Abstract

Purpose – By designing a pilot time-driven activity-based costing (TDABC) model, this study aims to examine in depth the suitability and the complexity of TDABC in a manufacturing company.

Design/methodology/approach – To obtain a deeper understanding on the matters to analyse, this research adopts an interventionist approach. The host organisation is GP, a Portuguese company in the frozen food sector.

Findings – The authors' experience allows them to assert that TDABC is suitable for a manufacturing company and it is able to deal with the variability of the industrial processes. Nonetheless, through a comparison with the models presented in the literature, TDABC appears to be more complex for manufacturing. The authors argue that this happens for two reasons. First, the two types of resources (human labour and machinery) used in production areas create a need to split tasks and to create two equations for each process, something that does not happen in service companies. Second, times are difficult to individualise for certain highly automated procedures, which could also give rise to some errors.

Research limitations/implications – The designed model is compared to other models presented in the literature.

Practical implications – This study shows a real example of TDABC in manufacturing and the procedural innovation of the time equations.

Originality/value – As the TDABC literature has been mostly focused on examples of service companies, the authors examine the technical suitability and the complexity of TDABC in manufacturing companies.

Keywords Manufacturing, Time-driven activity-based costing, ABC, TDABC

Paper type Case study

1. Introduction

> Time-driven activity-based costing (TDABC) is a new ABC variant that enables you to build powerful and flexible cost models quite simply (Kaplan and Norton, 2008, p. 209).

Described in the literature as a simple model, TDABC can be considered the next generation of activity-based costing (ABC). This new solution was designed by Kaplan and Anderson specifically to simplify the implementation process and the time-consuming and expensive maintenance of its forerunner ABC (Kaplan and Anderson, 2007a, 2007b; Tse and Gong, 2009; Balakrishnan *et al.*, 2012b; Hoozée *et al.*, 2012). Since then, the model has demonstrated great practical applicability (Everaert *et al.*, 2012), given the countless examples of use and

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implementation in the literature (Everaert *et al.*, 2008a; Kaplan and Norton, 2008; Demeere *et al.*, 2009; Hoozée and Bruggeman, 2010; Giannetti *et al.*, 2011; Kont and Jantson, 2011; Tanis and Ozypici, 2012; Campanale *et al.*, 2014). These examples range from companies in the hotel sector (Dalci *et al.*, 2010) to healthcare (Campanale *et al.*, 2014) and even financial services (Kaplan and Norton, 2008). However, it seems that the literature has been mainly focused on companies related to services insofar as examples of TDABC models in manufacturing companies are scarce. This is curious, as Stratton *et al.* (2009) in their quantitative analysis showed that the model from which TDABC evolved has been implemented in manufacturing, and there are also published works on manufacturing companies using ABC (Anderson *et al.*, 2002; Liu and Pan, 2007). Furthermore, TDABC is considered a model capable of handling the complexity and variability of daily activities (Everaert *et al.*, 2008a). Could this be a trivial gap in the literature or is there another reason? In fact, to the best of our knowledge, only the study by Öker and Adigüzel (2010) illustrates a model in a manufacturing company and ends by concluding that TDABC is more suitable for service companies. This is because, as the authors say, in service companies, resources can be assigned through labour hours. However, using only this measure for manufacturing companies is difficult, as machinery time must also be considered, which means that two practical capacities must be calculated and two time equations must be created for each production process.

Taking the results of Öker and Adigüzel (2010) as a starting point, we aim to examine in further detail the suitability and the complexity of building a model for manufacturing companies. To do so, we adopt an interventionist approach allowing us to take part in the model designing process from the very beginning, and thus collect more sensible, richer and detailed insights (Suomala *et al.*, 2014). Based on this insider experience and on the model that resulted from the fieldwork, we then report the model and compare and discuss other models that are available in the literature for service companies. The host company in this study was GP (a fictitious name for the purpose of confidentiality), namely, a Portuguese company in the frozen food sector. Given the competitive environment in which GP operates, the managers felt the need to modify their costing practices and expressed interest in the researchers' suggestion to design a pilot TDABC model for the company. Prior to this, a very rudimentary costing system had been used, which simply attempted to identify the cost of each production batch.

Therefore, this study contributes to the body of TDABC literature in two complementary ways. First, by using an interventionist research, we analyse if the TDABC model is viable and technically suitable for a manufacturing company, as the literature has mainly focused on service companies. Second, recognising the potential of being part of the designing process, as typically the model is already built when researchers initiate their studies, we draw on that experience to shed more light and better understand the complexity that may exist in TDABC manufacturing models. Furthermore, given the practical nature of the study, the results are likely to be of great interest to practitioners. This study illustrates the TDABC technique in detail, providing a real example of how to design a model for a manufacturing company, and, particularly, provides examples of equations built for real situations.

At the end, we believe that TDABC and, in particular, the procedural innovation of the time equations have allowed us to fairly represent the inherent complexity of the production operations, and thereby, we conclude that the model is viable and suitable for this environment. On the other hand, while Öker and Adigüzel (2010) stated that TDABC is best for service companies, we believe it is definitely easier than for manufacturing companies. In this respect, in addition to reinforcing the reason pointed out by Öker and Adigüzel (2010) that in industry or manufacturing tasks, it is necessary to use working time and machinery in the model, we add one more point. For some production processes that run in a continuous cycle, without human influence, it is not possible to isolate the time for a final product. Furthermore, this very sensitive situation may lead to overestimation of time and, therefore, represents a source of possible errors.

The rest of this paper is organised as follows. Section 2 examines the evolution from ABC pitfalls to TDABC and the way this new solution works and reviews the related literature. Section 3 describes the methodology adopted, and Section 4 explains the model developed. Section 5 discusses and compares the designed model and the models presented in the literature for service companies. The final section outlines the conclusions, limitations and possible directions for further research.

2. Literature review

2.1 From ABC pitfalls to TDABC

Developed in the 1980s by Cooper and Kaplan, in response to widespread dissatisfaction with traditional costing systems (Cooper and Kaplan, 1991; Wickramasinghe and Alawattage, 2007; Dalci *et al.*, 2010; Coulter *et al.*, 2011), the ABC model demonstrated disappointing utilisation rates, and the vast majority were short-lived, as companies stopped updating their systems (Kaplan and Anderson, 2007a, 2007b; Tse and Gong, 2009; Stratton *et al.*, 2009; Hoozée and Bruggeman, 2010; Stout and Propri, 2011). As proof of this, Innes *et al.* (2000), surveying English companies, found that ABC adoption rate was only 17.5 per cent and that approximately 15 per cent of the companies rejected ABC after assessment. Several reasons could be provided for this. Too much data are required to implement the model (Balakrishnan *et al.*, 2012b) and employees must conduct time-consuming and expensive regular surveys to determine the time spent among the various activities (Kaplan and Anderson, 2007a; Demeere *et al.*, 2009; Stout and Propri, 2011). Moreover, employees make subjective estimates in this surveying process, which raises doubts about accuracy (Kaplan and Anderson, 2007a; Demeere *et al.*, 2009). Despite the large number of activities foreseen, the model is not sufficiently accurate or detailed to capture the complexity of daily operations (Kaplan and Anderson, 2007a, 2007b). In trying to resolve this problem, more activities were added to the model, generating a kind of snowball effect (Kaplan and Anderson, 2007a, 2007b). This led to increasingly complex ABC models (Anderson *et al.*, 2002; Kaplan and Anderson, 2007a, 2007b; Mortaji *et al.*, 2013).

To overcome these situations, without entirely abandoning the ABC concept, Kaplan and Anderson proposed a new approach called time-driven activity-based costing (Kaplan and Anderson, 2004, 2007a, 2007b; Dalci *et al.*, 2010; Mortaji *et al.*, 2013). Unlike ABC, TDABC does not require regular in-depth employee surveys, which makes the costing process more straightforward and accurate as well as less expensive (Kaplan and Anderson, 2007a, 2007b; Namazi, 2009; Reddy *et al.*, 2012). In practical terms, TDABC promotes the direct allocation of resource costs to cost centres, using the easily obtained estimation of two parameters for each group of resources: the capacity cost rate and the time required to complete a transaction or an activity (Kaplan and Anderson, 2004, 2007a, 2007b; Everaert *et al.*, 2008b; Kaplan and Norton, 2008; Öker and Adigüzel, 2010; Dalci *et al.*, 2010; Giannetti *et al.*, 2011; Balakrishnan *et al.*, 2012a; Hoozée *et al.*, 2012; Basuki and Riediansyaf, 2014; Campanale *et al.*, 2014). The capacity cost rate is the ratio between the cost of capacity supplied and the practical capacity of the resources supplied, as shown in the equation below:

$$\textit{Capacity cost rate} = \frac{\textit{Cost of capacity supplied}}{\textit{Practical capacity of the resources supplied}} \quad (1)$$

The cost of the capacity supplied refers to the resources used to perform the activity (Reddy *et al.*, 2012). On the other hand, the denominator of the fraction is an estimate of the time that workers actually spend doing their work activities with the resources available in a particular cost centre (Stout and Propri, 2011; Kee, 2012; Tanis and Ozypici, 2012; Campanale *et al.*, 2014). This means that it is not the theoretical amount of time available for a given activity but the actual amount of time dedicated to doing it (Dalci *et al.*, 2010; Reddy *et al.*, 2012).

For the second parameter, the general idea is to determine the time it takes to perform one unit of each type of activity (Tanis and Ozypici, 2012) by means of direct observation, questioning staff and management teams or analysing the organisation's historical data (Kaplan and Anderson, 2004, 2007a, 2007b; Reddy *et al.*, 2012).

With these two parameters determined, they should be multiplied to assign the costs to the cost objects (Kaplan and Anderson, 2007a, 2007b; Dalci *et al.*, 2010; Reddy *et al.*, 2012). This multiplication represents the simplest form of a time equation, and is called cost-driver rate (Kaplan and Anderson, 2004; Reddy *et al.*, 2012). These equations, one novelty compared to ABC, allow the model to reflect how the activities' characteristics lead to variations in the time spent (Kaplan and Anderson, 2004, 2007a, 2007b), including multiple drivers of time if required (Dalci *et al.*, 2010). As a result, time equations lead to a smaller and more flexible model because its size only increases linearly with the complexity, while in ABC, it increases exponentially (Kaplan and Anderson, 2007a; Reddy *et al.*, 2012).

However, the perceived advantages of TDABC do not stop here. TDABC costs less to implement than ABC, because the processes are very simple and easier to apply (Tse and Gong, 2009; Reddy *et al.*, 2012). TDABC represents unused capacity more accurately, as employee surveys tend to overestimate the time spent on activities (Lambino, 2007; Stout and Propri, 2011). Furthermore, TDABC captures the business complexity much more easily than traditional ABC (Kaplan and Anderson, 2004), as the detail depends on the disaggregation of the time equations (Balakrishnan *et al.*, 2012b). Unlike ABC, this new model does not need to be updated regularly, so it is much easier to maintain (Kaplan and Anderson, 2007a). It is also more straightforward to update when improvements must be made that reflect circumstances more accurately.

2.2 Research focus: Is TDABC right for all companies?

All these features and benefits described have allowed Kaplan and Anderson (2007a, 2007b) to assert that TDABC can be applied in most organisations regardless of the complexity of customers, products, channels, segments or processes. And, later on, Everaert *et al.* (2012) underlined this idea by expressing that TDABC has wide applicability, given the number of applications done so far. In fact, and although we must recognise that the TDABC model has been little explored in the literature (Gervais *et al.*, 2010), there are a few studies presented by its creators and analyses of the applicability and benefits of TDABC in some sectors. More specifically, previous studies have implemented TDABC in companies in the hotel sector (Dalci *et al.*, 2010; Basuki and Riediansyaf, 2014), in handling services (Giannetti *et al.*, 2011), in libraries (Pernot *et al.*, 2007; Kont and Jantson, 2011), in restaurants (Everaert *et al.*, 2012), in healthcare (Demeere *et al.*, 2009; Tanis and Ozypici, 2012; Campanale *et al.*, 2014; Kaplan *et al.*, 2014), in logistics and distribution (Everaert *et al.*, 2008a; Hoozée and Bruggeman, 2010; Gervais *et al.*, 2010; Somapa *et al.*, 2012) and in financial services (Kaplan and Norton, 2008). Nonetheless, all these studies have in common the fact that they are based in service companies and there seems to be a lack of studies on TDABC models in production environments.

To the best of our knowledge, only the study by Öker and Adigüzel (2010) deals with the production process of a manufacturing company. The authors concluded that the two types of resources (human labour work and machine work) used in such companies make it necessary to calculate two different practical capacities, thus entailing additional work. In fact, the studies on TDABC in service companies show that for this type of company, it is only necessary to resort to human labour resources to express the practical capacities of companies (Demeere *et al.*, 2009; Dalci *et al.*, 2010; Giannetti *et al.*, 2011; Somapa *et al.*, 2012; Everaert *et al.*, 2012; Kaplan *et al.*, 2014; Basuki and Riediansyaf, 2014; Campanale *et al.*, 2014). As a result, Öker and Adigüzel (2010) believe TDABC is a more appropriate costing system for service companies than for manufacturing. Furthermore, Souza *et al.* (2010) concluded that the unstable and unpredictable production environment in make-to-order companies complicates the definition of time equations, and TDABC is therefore unsuitable. Finally, the study by Stout and Propri (2011), although based on an electronic components manufacturing company, deals only with the support areas and not the production areas. The lack of studies and these conclusions are even more curious when taking into account that the predecessor to TDABC was not only developed based on the experience of its creators in production companies in the USA, but was indeed used in production.

As Stratton *et al.* (2009) reported, their statistical study showed that ABC was one of the three most widely used systems to treat production costs. Moreover, the accounting literature also includes studies that address ABC in manufacturing companies. As an example, see Anderson *et al.* (2002), Liu and Pan (2007) or the seminal work by Cooper and Kaplan (1992), who report that ABC was used in Hewlett-Packard to monitor production performance. Furthermore, Kaplan and Cooper (1998) also make use of an academic example of a pen factory to explain the fundamentals of ABC. In fact, Everaert *et al.* (2008a) already recognised that it was worthwhile to examine if TDABC could provide opportunities for modelling production operations. Also, Everaert *et al.* (2008a) emphasised that TDABC provides a good opportunity to design a cost model for complex operations, and demonstrate it to logistical operations. Specifically, TDABC does not require reductions like ABC, and cost designers have the power to include in the time equations, the various time drivers to represent each subtask of an activity (Everaert *et al.*, 2008a). As the production environments in most of the cases are complex operations, this conclusion is of special importance and shows some promise for TDABC in this type of environment.

However, and although little explored and with a body of research more focused on technical issues, TDABC has raised some criticisms that should also be noted. Cardinals and Labro (2008) indicated some issues regarding measurement errors in time estimates. Assuming that the time estimates are subject to errors, the authors concluded that the breakdown of activities results in larger errors and the estimation of the time for tasks in minutes generates a large overestimation. Based on Cardinaels and Labro's (2008) study, Schuhmacher and Burkert (2013) conducted experimental research on the accuracy of TDABC and ABC. They concluded that when the estimations of TDABC are not corrected for consistent bias, the duration of activity times is heavily underestimated, which results in significantly less accurate estimates than ABC. Hoozée *et al.* (2012) reported that accuracy of TDABC could be affected by errors in estimating times, when the estimation is made using transactional data or by questioning employees. Estimation derived from interviews can lead to erroneous data and some identification mistakes when designing the time equations. Estimations supplied from transactional data can make use of erroneous data (Hoozée *et al.*, 2012). In this context, Gervais *et al.* (2010) also expressed some reservations about the accuracy of estimates. They also stated that the TDABC initially needs elaborate analyses, making it a time-consuming and expensive stage. Moreover, as already identified by Kaplan and Anderson (2007a), Gervais *et al.* (2010) stated that any significant change in practices and tasks requires an update in the model, which means the controller must be careful and work in proximity with the operational level.

Against this background, further information is needed to understand why there are so few examples of industries in the literature. Therefore, this study sought to extend our current understanding on the technical viability and complexity of TDABC for manufacturing companies when compared to service ones.

3. Research approach and the case organisation

3.1 Research approach

This paper adopts an interventionist research approach. Interventionist research is typically a case study in which the researcher is an actor and intervenes in the flow of events, instead of just acting as an observer of the facts (Jönsson and Lukka, 2007; Suomala *et al.*, 2010; Lukka and Suomala, 2014). In this specific case, the intervention of the researchers started as early as the proposal to analyse a TDABC costing model. Taking advantage of the need felt by GP's management team for a more accurate and meticulous costing system, the researchers seized the opportunity to propose them to analyse a change in the existing model to one based on a TDABC methodology. GP's management team showed interest in the proposal and the researchers were commissioned to develop and design a pilot TDABC model that could best represent their internal formation of costs. Thus, this mandate not only guaranteed access to a manufacturing research field to address our aim but also to experience first-hand the process of designing a TDABC model in this setting. As Suomala *et al.* (2010) outlined, these aspects are important justifications for interventionist research. Specifically, in this type of research approach, the intervention of the researcher constitutes an asset to gain access to a field site and to an insider perspective (emic) that allows for collecting more detailed and rich empirical data, extremely grounded in a practical context that otherwise would be inaccessible (Jönsson and Lukka, 2007; Dumay, 2010; Suomala *et al.*, 2014; Lukka and Suomala, 2014). More specifically, this insider perspective (emic) refers to studying human behaviour from inside the system and should be complemented with incursions from an outsider (etic) viewpoint (Jönsson and Lukka, 2007; Suomala *et al.*, 2014). That is, researchers must also assume an etic viewpoint to link the findings with the relevant literature and thus make a theoretical contribution (Jönsson and Lukka, 2007; Suomala *et al.*, 2014). Essentially, it is expected that researchers take an interactive approach, alternating between a balanced use of the etic and emic viewpoints (Jönsson and Lukka, 2007; Dumay, 2010; Suomala *et al.*, 2010; Suomala *et al.*, 2014).

Alternating between an emic and an etic viewpoint, data were collected between September 2013 and April 2014. As Jönsson and Lukka (2007) pointed out, the first task after arriving in the field is to gain an understanding of the situation. To this end, we conducted two interviews that also allowed for confirming the company's viability for the purposes of this research. After presenting the general characteristics of the model and confirming the company's availability in the first interview, information was then obtained about the company's cost accounting practices. Parallel to this, documents such as the company's financial report, magazine articles about the company and sectorial studies were examined. In addition, the company provided their organisation chart, which allowed for a deeper analysis of the internal structure. In this phase, the researchers acted as outsiders adopting an etic perspective (Jönsson and Lukka, 2007; Campanale *et al.*, 2014; Lukka and Suomala, 2014).

The next step was to gather all the data necessary for the model. At this point, the researchers assumed an emic viewpoint, trying to be "immersed" in the company. To achieve this, a number of interviews were conducted (Table AII) and visits were made to directly observe procedures and tasks (Table AIII). Including the initial two interviews, a total of eight interviews were conducted with members of departments involved in the ordering process, each of which lasted, on average, one and a half hours. The interviews took place informally, at the workplace of the interviewed, and the respondents were put at ease to perform any task that was emerging. The latter aspect enabled us to see how the tasks were evolving. These individuals were also asked to specify their tasks and the time spent on them. As suggested by Jönsson (2010), open-ended questions were included to allow the interviewed members to introduce their own observations. Once again, for reasons of confidentiality, the interviews were not taped. However, notes were taken during the interviews and detailed reports were written up immediately afterwards for subsequent analysis. We also composed a diary of the research, as recommended by Jönsson and Lukka (2007). Visits were also made to collect data by means of direct observation in the latter part of the research when the production lines were observed and the time taken for each task was examined (Table AIII). These visits allowed the researchers to interact with the employees by asking them to give explanations as if the researchers were apprentices or trainees. Following each visit, the information collected was summarised in written reports and Excel spreadsheets. Throughout this phase, it was also possible to interact and have one informal meeting with the person responsible for monitoring the project to discuss the progress and the observations and perceptions of the processes, explaining the variations perceived and why certain decisions relating to the model were taken. In other words, the meetings permitted discussing preliminary results. This multiplicity of data sources allowed all the information obtained to be triangulated, leading to stronger construct validity (Jönsson and Lukka, 2007; Yin, 2009).

Therefore, the role of researchers throughout this research work was what Jönsson and Lukka (2007) defined as experts. The researchers acted as resource persons, able to bring new knowledge into the organisation to propose options and solutions to the problems, and in which the main decisions were their responsibility (Jönsson and Lukka, 2007).

3.2 The case study organisation

The host organisation is one of the largest Portuguese players operating in the frozen food sector, which we call GP. GP is a medium-sized family company that has operated in the Portuguese market for over 35 years. Its core business is the transformation of frozen fish. However, GP has a wide range of products that represents 800 reference products. Structurally, GP employs approximately 150 workers distributed across its various departments (Figure 1). The organisational chart (Figure 1) shows the four business units: modern distribution business, traditional retail, wholesale distribution and exporting business. The first mainly involves large supermarket clients, while traditional retail refers to fishmongers, mini-markets and all small-scale retailers. As the names suggest, the other two units are dedicated to wholesale and export activities. In terms of production, GP packs 11,000 tons of fish annually, and it has cold storage facilities for 5,000 pallets. Production takes place in two operation rooms for the processing and packing of fish products, seafood and shellfish. All other products are outsourced. In the two rooms, 12 production lines operate (lines A, B, C, D, E, F, G1, G2, second line skin, glue line, perishable line and multi-head line).

4. The TDABC model designed

4.1 Previous considerations

We decided to take advantage of GP's well-structured internal division to establish the resource pools, in line with Kaplan and Anderson (2004, 2007a, 2007b). All the departments

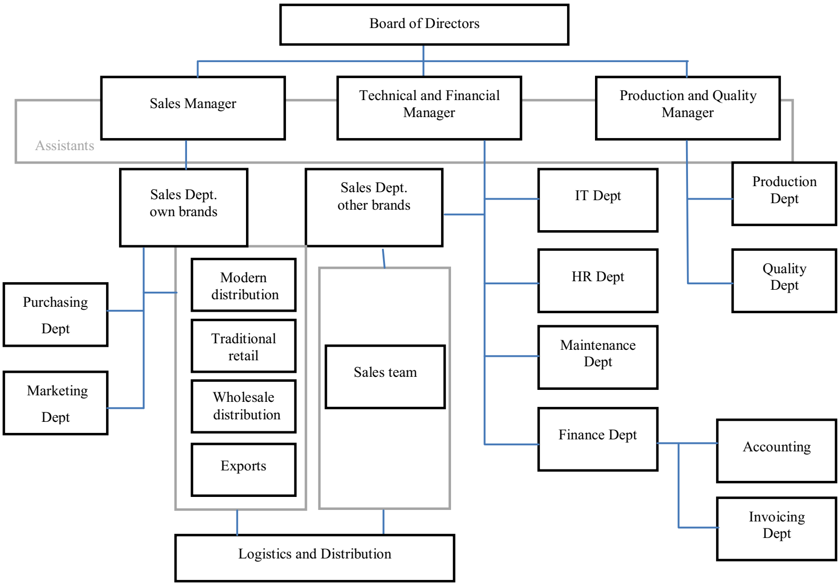

Figure 1.
GP organizational chart

were subdivided according to the hierarchy of corporate-sustaining expenses, support departments and operating departments (Kaplan and Anderson, 2007a; Balakrishnan *et al.*, 2012b). Operating departments are those dealing directly with the products/services and customers. The support departments provide the infrastructure necessary for the company to function well (Kaplan and Anderson, 2007a; Öker and Adigüzel, 2010). The classifications of support and operating departments are depicted in Figure 2. All departments not in Figure 2 were considered corporate-sustaining expenses, i.e. costs incurred irrespective of the size of the company's business that should not be imputed to operational departments (Kaplan and Anderson, 2007a; Balakrishnan *et al.*, 2012b).

In general, Figure 2 represents the flow of resource expenses up to the costing objects, in accordance with the approaches proposed by Kaplan and Anderson (2007a) and Somapa *et al.* (2012). It should also be noted that this model does not cover the maintenance department, the sales departments or the transport area within the logistics and distribution department; this does not mean the model is not feasible for these areas, but that the company does not yet have databases that allow them to be incorporated in the model. This will be addressed later.

However, a list of tasks was required that encompassed all the activities of the organisation for the delivery of its products or services, so that the time equations could be built and the resource consumption assigned to each costing object (Adeoti and Valverde, 2014). To that end, the services provided by each department were listed and then divided into tasks (Adeoti and Valverde, 2014). Wegmann (2007) notes that the TDABC approach, using measures of time, entails dividing the activities performed in a company into tasks. Sixteen processes were identified in the departments covered by this model. Nine of these comprised macro process of production, three in the macro process of logistics and four others in the macro processes of invoicing, export, purchasing and quality control (Table AIV).

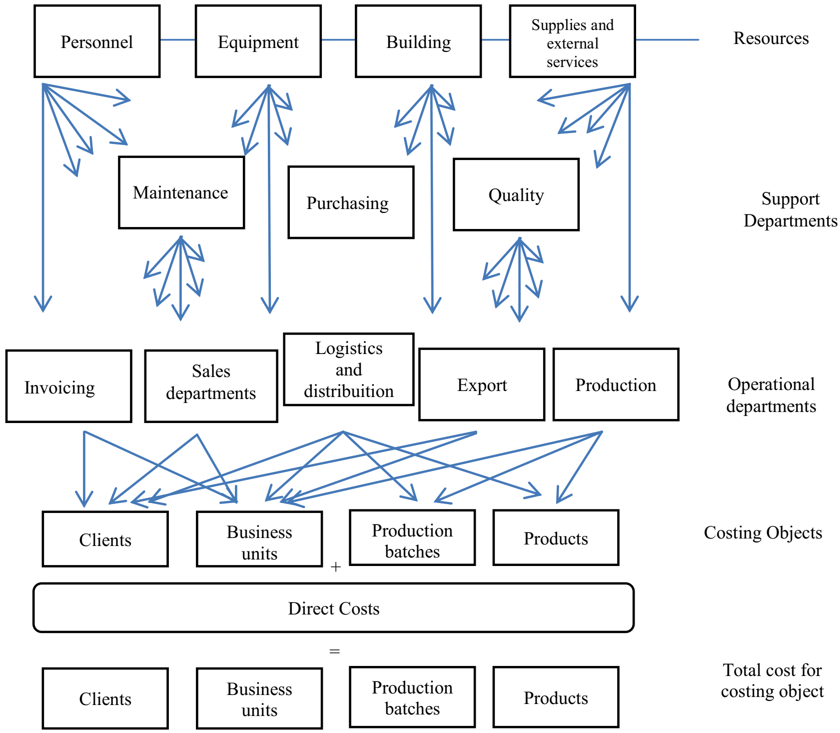

Figure 2.
TDABC procedure

4.2 Practical capacity

The capacity of the various macro processes was calculated using Kaplan and Anderson's (2004, 2007a) approach of estimating the theoretical capacity as a percentage (Appendix 1). This theoretical capacity was obtained by using the number of work hours per employee. Thus, with the exception of the production and storage processes, the theoretical capacity was calculated by multiplying the daily working hours by the total number of employees in each area and the number of working days per year (Somapa *et al.*, 2012; Kaplan and Anderson, 2007a). To determine the amount of practical capacity, Kaplan and Anderson (2004) suggest using a percentage of the theoretical capacity. They propose considering 80-85 per cent of the total theoretical capacity as a rule of thumb, with the rest being for non-productive time such as breaks, trainings or meetings (Kaplan and Anderson, 2004; Reddy *et al.*, 2012; Everaert *et al.*, 2012; Adeoti and Valverde, 2014). Subsequently, we followed a conservative approach in this matter using the lower percentage proposed, i.e. 80 per cent. Conversely, Kaplan and Anderson (2007a) stated that the storage process is one of the rare examples in which time should not be used to measure the process capability, recommending the use of available space instead, i.e. 5,000 pallets in the case of GP. In relation to the macro process of production, it was not considered appropriate to use only the total time of employees. It is not sufficient to calculate just one capacity cost rate, as the resources provided are not the same for all tasks. Some tasks consume machine hours, others human hours and some consume both (Öker and Adigüzel, 2010). The number of machines therefore had to be taken into account for the production department. The practical capacity of equipment was calculated as 80 per cent of theoretical capacity. However, the working hours considered for the theoretical capacity were 8.4 hours per day (42 hours per week), worked every day of the year except weekends.

As for the capacity cost rates, it should be noted that GP chose not to disclose information on their internal costs for reasons of confidentiality.

4.3 Time equations

According to Somapa *et al.* (2012), the first step when building time equations is to map the different internal business processes with as much detail as possible. Linear models were used to develop an equation for each process, as proposed by Everaert and Bruggeman (2007) (Table AIV). Therefore, each of these equations reflects the time required for a specific event in that process, which obviously depends on its intrinsic characteristics (Everaert and Bruggeman, 2007). For that reason, the equations have an absolute value that represents the standard time observed for that event and then has terms that represent the characteristics of that event. Then, the final result of the equation should be multiplied by the cost rate of the process to which it relates. Everaert and Bruggeman (2007) noted that the resulting equations should have a mix of continuous, discrete and indicative variables. We should also note that the time measure used in the equations is in seconds because the tasks of the production process, without exception, only take seconds to result in the final product.

Furthermore, the question of time equations becomes more complicated when we are talking about processes associated with production. As mentioned previously, production process tasks can consume machinery time, human labour time or both. As different cost rates must be calculated, two time equations must be built for some of these processes.

5. Insights from the designing process

With the experience gained from designing a TDABC model for GP, it was possible to gain rich insights into what it means to have a TDABC model in a production environment. Firstly, the achieved model demonstrates that the TDABC is more than viable for this company in the frozen food industry and can handle the variability of the production methods by allowing for the inclusion of a large number of subtasks represented by multiple drivers in the time equations. This is particularly relevant because some production processes, as in GP's case, are typically guided by dynamism, flexibility and a high degree of variability in the flow of tasks. As a consequence, a costing system able to reflect and accommodate these variations is required, a characteristic that is associated with the time equations promoted by TDABC. Especially, the use of the notation (indicative, continuous and discrete variables) proposed by Everaert and Bruggeman (2007) allows for time equations to be constructed that reflect the particular characteristics of the production lines, following its complexity. Similar results were obtained by Everaert *et al.* (2008a) for logistic operations. Everaert *et al.* (2008a) asserted that time equations were able to capture the variability of the activities that the authors considered a complex logistics operation, which this study has extended to the production processes. In other words, TDABC is also able to capture the variability of the production operations.

However, despite this major point, some drawbacks arose. Due to the very nature of the industrial processes, GP's model had to take some complexity into account when compared with the models of service companies presented in the literature. Before going any further, we must mention that most of the models for service companies presented in the literature represent simple environments or reductions for academic purposes. GP is, however, a complex manufacturing operation with multiple production lines acting simultaneously and with a lot of possible variations depending on the product being produced. For that reason, we resort to the example provided by Everaert *et al.* (2008), as it also represents a complex service company operation. The differences are noteworthy. First of all, the principal difference between the models lies in the calculation of the practical capacity. As Öker and Adigüzel (2010) have already noted, as service companies use only one resource, namely, human labour, it is only necessary to calculate one practical capacity for each cost pool. The situation is not as straightforward in production processes; two types of resources are used, i.e. human labour work and machine work, which means two different practical capacities must be calculated (Öker and Adigüzel, 2010). Furthermore, as there are two practical capacities, tasks in the productive areas must be divided between each of them and, based on that separation, two time equations for each process must be created. This could in some ways be an intricate job, as some tasks require both types of resources, and should appear in both equations. As a result, the model loses some of its simplicity and linearity. When we look at the example that Everaert *et al.* (2008) provided, their model is able to represent all the variations of a complex activity with a single time equation. This additional work clearly eliminates some of the simplicity advocated by the creators of TDABC, in the case of complex manufacturing settings.

Another complication that we perceived with creating GP's TDABC model is the difficulty to individualise the duration of some automated tasks in the production processes. For example, some raw materials in GP's production process have to pass through a freezing tunnel; multiple raw materials arrive by conveyor belt and they are pushed into the freezing tunnel in large and always different quantities. At one point, the raw materials may be placed in 10 final packages, but in another, the raw materials may be placed in 40 packages. Although it is possible to determine the time it takes from the entrance of a piece of raw material until it leaves the tunnel, it is not possible to know precisely how many units of the final product were processed each time that the process occurred. In cases like these, estimating the specific time for the processing of each raw material unit is difficult, hindering the time allocation process for each final package. This problem was overcome by making an assumption about the number of units passing simultaneously through the tunnel, as considering the duration that it took for a piece of raw material to cross the tunnel would cause a huge overestimation bias. Even though the overestimation may not have been completely put aside, it is always possible to correct this assumption when GP starts running the model. Thus, this impossibility of precisely estimating the time for the type of processes as the one described represents a possible source of estimation errors to add to the ones reported by Hoozée *et al.* (2012). On the other hand, this situation does not arise in models for service companies. Given the type of tasks that these companies engage in, it is believed that the model designer is able to individualise the duration of the tasks either through the initial surveying process or through existing databases. Take for example the study by Campanale *et al.* (2014) in the area of healthcare or Dalci *et al.* (2010) in hospitality. Both studies show no need to resort to assumptions to individualise the times for the various tasks.

At the same time, the increased complexity associated with the model of the production environment can also limit the simplicity of maintenance described in the cases of service companies. If the model is more complex, with more variables, more replication of these variables and more equations, the updating process reflecting any improvement in daily tasks is likely to be more difficult, time-consuming and error-prone. In some cases, this may be sufficient to withdraw the model from use, which is what happened with its predecessor, ABC.

Apart from these situations, the design and future maintenance of the model for the support areas was simple. Overall, we believe the costing practices delineated were better than the ones in use when we arrived. As a secondary result, we also note that there were some difficulties with collecting information. TDABC requires extensive details about daily operations, obtained by questioning employees and sometimes by actually timing how long the different tasks and their variations take. When speaking to the employees, we tried to obtain a general map indicating the route/flow of tasks and to understand situations in which these tasks would vary. Although apparently a simple exercise, the vast majority of employees found it hard to map the different tasks of the outputs of their services. They also expressed similar difficulty when subsequently asked to quantify the time spent on each task unit and were reluctant to provide a precise figure. In fact, certain tasks in some departments are not performed continually from start to finish, which makes time measurement problematic. Although we did not ask specifically about the reasons for this reluctance to avoid constraints, the idea that transpired is that people were afraid to disclose what they were doing in the course of their duties or the eventual future implications.

6. Conclusions and directions for further research

Previous studies have shown that TDABC is a model of great applicability in various activities (Demeere *et al.*, 2009; Dalci *et al.*, 2010; Giannetti *et al.*, 2011; Somapa *et al.*, 2012; Everaert *et al.*, 2012; Kaplan *et al.*, 2014; Basuki and Riediansyaf, 2014; Campanale *et al.*, 2014). While the vast majority of studies have analysed TDABC models in service companies, there has been less interest in how this costing model works for manufacturing companies, and the study by Öker and Adigüzel (2010) attributes some complexity to this type of model. To shed some light on these matters, the aim of this research work was to examine the technical suitability and the complexity of TDABC in a manufacturing setting. We adopted an interventionist research that allowed us to investigate these matters with greater richness and depth. The host organisation was GP, a Portuguese company in the frozen food sector, with whom we agreed to help improve their costing practices by building a pilot TDABC model. In this way, we were able to experience every aspect of the process and collect insights, otherwise inaccessible, to respond to our theoretical aims.

At the end, our results showed that the TDABC model is feasible and suitable for production environments and able to deal with the variability of the processes. Specifically, the time equations can accommodate the different tasks performed and their specific drivers. Therefore, like Everaert *et al.* (2008a), who explored logistics processes, this capacity to deal with the variability of the production processes is also true. Nevertheless, our experience compared with the published service examples also lets us conclude that TDABC is less complex for a service company than for manufacturing. Stopping short of Öker and Adigüzel's (2010) claim that this is more appropriate for service companies, this study provides two motives for extended complexity in manufacturing settings. First, as production processes use human labour and mechanical work, it is necessary to make a distinction between these two resources because the cost of their provision is different. This differentiation, in turn, entails dividing the processes and two time equations must be created; as a result, besides greater complexity, the model loses some of the simplicity in models for service companies. Second, given the high level of automation of certain processes, those processes always entail different amounts of time, rendering the individualisation of the duration for each final product a challenge. As expected, this situation could make the model error-prone and lead to inaccurate estimates, which also allows us to add one more possible source of error to the literature that has questioned the accuracy of the TDABC.

As in all research works, some limitations of this study should be acknowledged. First, the authors only had first-hand experience of designing a TDABC model in a manufacturing company. The comparison that we made is based on the studies in the literature that report cases of companies in multiple geographical locations, none of which is the same as in this research. Second, the study reports only a pilot model, which may have suffered modifications prior to implementation. Third, the lack of historical data and practices did not allow the times for tasks in some departments to be clearly recorded, and therefore, this pilot model was unable to cover transportation, maintenance and sales departments.

Our study also shows that there are many avenues for further research. The focus of this study was on the building process of a TDABC model, so it would be interesting to examine its implementation and the related difficulties in manufacturing companies in future research. On the other hand, our results point to a more complex model in production environments which may cause difficulties in updating the model and consequently lead to it being abandoned. Thus, future research could examine whether TDABC models in production companies have managed to prosper and, if so, under what circumstances. Furthermore, as many companies chose to stop using ABC (Kaplan and Anderson, 2007a, 2007b; Tse and Gong, 2009; Stratton *et al.*, 2009; Stout and Propri, 2011), it would be interesting to know if this new model is more resilient. Complementary to this idea, Balakrishnan *et al.* (2012a) reported that, at the time, there was no published evidence about the extended use of TDABC and, to the best of our knowledge, this remains to be addressed. Finally, the accuracy of time estimates provided by employees is yet another avenue for future research. Most GP employees were reluctant to map and quantify the time taken to perform tasks when asked to do so. This casts some doubt as to whether the subjectivity that was criticised in ABC has been completely solved in TDABC.

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Appendix

Macro processes	No. of employees or equipment	Normal working hours per day	Working days per year	Capacity per year (h)	Capacity per year seconds	Practical capacity
Invoicing	3	8	261	6,264	22,550,400	18,040,320
Purchase	2	8	239	3,824	13,766,400	11,013,120
Export	1	8	239	1,912	6,883,200	5,506,560
Quality control	2	8	239	3,824	13,766,400	11,013,120
Production						
Labour	70	8	239	133,840	481,824,000	385,459,200
Machinery	49	8.4	261	107,428	386,739,360	309,391,488
Logistics and distribution						
Inbound and outbound logistics	15	8	239	28,680	103,248,000	82,598,400
Storage						5,000 pallets

Table AI. Practical capacity calculations

No.	Date	Time	Position
1	24-10-2013	1 h	Head of the Commercial Department and Head of Accounting
2	17-12-2013	1 h 10 min	Head of Accounting
3	22-01-2014	2 h 40 min	Head of Accounting, Head of the Commercial Department and Invoicing Department employee
4	30-01-2014	3 h 10 min	Head of Logistics Department and some employees
5	14-02-2014	1 h 50 min	Employees of the Purchasing and Export Department
6	25-02-2014	1 h 55 min	Head of Production, Room 1 and Head of Quality Department
7	03-03-2014	45 min	Head of Production, Room 2
8	20-03-2014	1 h 05 min	Head of Commercial Department and Head of Production

Table AII. GP interviews

Date	Time	Type of information collected
05-03-2014	3 h 35 min	Time spent on the tasks associated with production lines A, B, C, D and G2 as well as more detailed view of the process
10-03-2014	3 h 05 min	Times of tasks in the fresh products production line, and E and G1 line. Glean a greater understanding of how these lines operated
20-03-2014	1 h 55 min	More rigorous assessment of time of the blast freezers and cutting processes. Analysis and timing of the vacuum package process
25-03-2014	1 h 55 min	View product unloading procedures and measure the time spent on each task
31-03-2014	3 h 20 min	Timing the glue line tasks. Detailed analysis of the disaggregation processes and clarification of F line tasks

Table AIII. Visits to GP to conduct direct observations of processes

Processes and activities	Time equations and variables
Invoicing	$$T_1 = (60 + 20X_1)X_2 + \frac{60\,(1-X_2)}{X_3} + (30 + 300X_6)\,X_5 + (120 + 120X_8)X_7 + 15 + 585X_9$$
	X_1 = number of lines per order X_2 = 1 (If manual entry request); 0 (otherwise) X_3 = number of orders in the EDI or PDA X_5 = 1 (If client failed credit analysis); 0 (otherwise) X_6 = 1 (If a deeper credit analysis required); 0 (otherwise) X_7 = 1 (If there is lack of stock); 0 (otherwise) X_8 = 1 (If there is no stock in the Warehouse 2); 0 (otherwise) X_9 = 1 (If wholesale customer); 0 (otherwise)
Purchasing	$$T_2 = 120 + 20\,X_{10} + (3620 + 900X_{12})X_{11}$$
	X_{10} = number of product lines ordered from the supplier X_{11} = 1 (If importing process); 0 (otherwise) X_{12} = 1 (If supplier based within European Union); 0 (otherwise)
Export	$$T_3 = 1{,}560 + 2{,}100X_{13} + 120\,X_{14} + (8{,}400 + 900X_{15} + 600X_{16} + 600X_{17} + 300X_{18})(1 - X_{14})$$
	X_{13} = 1 (If used container); 0 (otherwise) X_{14} = 1 (European union client); 0 (otherwise) X_{15} = 1 (If order includes fish products); 0 (otherwise) X_{16} = 1 (If order includes vegetables products); 0 (otherwise) X_{17} = 1 (If order includes meat products); 0 (otherwise) X_{18} = number of licenses requested
Inbound logistics	$$T_4 = 626.58X_{20} + (14.4 + 21.6X_{22})(1 - X_{20})$$
	X_{19} = number of products ordered by the customer X_{20} = 1 (If raw materials or own brand products); 0 (otherwise) X_{22} = 1 (winter period); 0 (otherwise)
Outbound logistics	$$T_5 = \left[\frac{180}{X_{26}} + \left(\frac{900}{X_{26}} + 180(1 - X_{27}) + 60X_{27} + 240X_{27}X_{28}\right)(X_{23} + X_{29}) + 3{,}600X_{24} + (1{,}800 + 9{,}000X_{29})(X_{24} + X_{25}) + 1{,}800\left(\frac{X_{23} + X_{24} + X_{14}X_{25} + X_9}{X_{21}}\right) + (10{,}800 + 3{,}600X_{30})X_{13}\right]X_{20} + 60(1 - X_{20})$$
	X_{21} = number of orders to be delivered X_{23} = 1 (If traditional distribution); 0 (otherwise) X_{24} = 1 (If modern distribution client); 0 (otherwise) X_{25} = 1 (If export client); 0 (otherwise) X_{26} = number of boxes per pallet of finished product X_{27} = 1 (If fixed weight product); 0 (otherwise) X_{28} = 1 (If product is on 3rd floor); 0 (otherwise) X_{29} = 1 (If delivery to a specific distribution group); 0 (otherwise) X_{30} = 1 (If 40-foot container); 0 (otherwise)
Storage	$$T_6 = \frac{X_{31}}{X_{26}}$$
	X_{31} = number of days in warehouse

(*continued*)

Table AIV.
Time equation of processes

Processes and activities	Time equations and variables
Quality control	$T_7 = (36,000 + 18,000X_{33})X_{32}$
	X_{32} = number of boxes analysed per order
	X_{33} = 1 (If glaze product); 0 (otherwise)
Disaggregation	$T_{H8} = \dfrac{6.38+4.75(X_{48} + X_{50} + X_{52} + X_{40} + X_{53})+14.98X_{34} + 79.31X_{35} + 48.11X_{36} + 14.41(X_{45} + X_{46} + X_{47} + X_{49})}{(1-X_{38})X_{37} / X_{57}}$
	X_{34} = 1 (If fish wrapped in protective film); 0 (otherwise)
	X_{35} = 1 (If fish comes bundled); 0 (otherwise)
	X_{36} = 1 (If large fish); 0 (otherwise)
	X_{37} = product quantity in grams per box of raw material
	X_{38} = percentage of loss of raw material per box
	X_{57} = amount in grams per package
Cut	$T_{HM9} = [(0.99 + 0.39\,X_{39})X_{58} + 4.09X_{40}]X_{56}$
	X_{39} = 1 (If hake fillets); 0 (otherwise)
	X_{40} = 1 (If Perishables line); 0 (otherwise)
	X_{56} = 1 (If product needs to be cut); 0 (otherwise)
	X_{58} = number of units per package
Glazing	$T_{M10} = \dfrac{X_{41}}{40+40X_{51}} + 2.46$
	X_{41}= time of passage through the freezing tunnel in seconds
Batching	$T_{H11} = 0.80X_{44} + 6.62(X_{45} + X_{49}) + 12.66(X_{40} + X_{48})$
	$T_{M12} = 0.80X_{44} + 1{,}257(X_{42} + X_{43}) + 0.36X_{47} + 2.81X_{46} + 340X_{45}$
	X_{42} = 1 (If line A); 0 (otherwise)
	X_{43} = 1 (If line B); 0 (otherwise)
	X_{44} = 1 (If line C); 0 (otherwise)
	X_{45} = 1 (If line E); 0 (otherwise)
	X_{46} = 1 (If line G1 – Box packing); 0 (otherwise)
	X_{47} = 1 (If line G2); 0 (otherwise)
	X_{48} = 1 (If line F-seafood); 0 (otherwise)
Packing	$T_{H13} = 1.97X_{42} + 3.40\,(X_{45} + X_{49}) + 14.98X_{40} + 44.80X_{50} + 15.71X_{53} + 12.04X_{53}X_{59}$
	$T_{M14} = 10.01(X_{42} + X_{53} + X_{40}) + 1.22(X_{43} + X_{44} + X_{47}) + 17.12(X_{51} + X_{52}) + 22.36(X_{45} + X_{48}) + 50.94X_{46} + 44.80X_{50} + 12.04X_{53}X_{59}$
	X_{49} = 1 (If line G1-packing in bag or by multi head); 0 (otherwise)
	X_{50} = 1 (If Glue line); 0 (otherwise)
	X_{51} = 1 (If D line); 0 (otherwise)
	X_{52} = 1 (If line second skin); 0 (otherwise)
	X_{53} = 1 (If F line-packing in bag); 0 (otherwise)
	X_{59} = 1 (if F line-vacuum packaging); 0(otherwise)
Labelling	$T_{H15} = 2.81(1 - X_{51} - X_{52})X_{54}$
	$T_{M16} = 3.13(X_{51} + X_{52})X_{54}$
	X_{54} = 1 (If packaging requires labelling); 0 (otherwise)

(*continued*)

Table AIV.

Table AIV.

Processes and activities	Time equations and variables
Weight and metal certification	$T_{H17} = 2.06X_{46}$ $T_{M18} = 2,53 + 4,18X_{46}$
Boxing	$T_{H19} = 9.41 + 3.02X_{45} + 22.88X_{45} + [0.53 + 0.84\,(X_{46} + X_{50} + X_{45})]X_{55}$ X_{55} = number of packs per box of finished product
Palletising	$T_{H20} = 3.25\,X_{26} + 190$

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