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WORKING PAPER

Modeling Logistics Costs using Time-Driven ABC: A Case in a Distribution Company

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September 2005

2005/332

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D/2005/7012/50

Abstract

Purpose: The purpose of this paper is to study whether time-driven Activity-based Costing (ABC) is more appropriate to capture the complexity of logistics transactions than traditional ABC.

Methodology: This paper explores the method of time-driven ABC and presents the results of a case study at a distribution company.

Findings: The case shows that a traditional ABC was not appropriate. Almost 60% of the activities contained more than one subtask, with different time drivers. Ignoring this complexity resulted in a misallocation of 54% of costs. Splitting-up all the subtasks resulted in a traditional ABC model that was too complex. Contrary, the time-driven ABC model captured the full complexity of the logistics transactions through time equations that employ multiple time drivers.

Research implications: This paper formulates the underlying mathematical model of time-driven ABC, leading to a better understanding of the time equations. Different types of complexities in logistics were identified in the case.

Practical implications: The study explains the technique of time-driven ABC and provides some real company examples of time equations in logistics.

Value of the paper: This is one of the first papers on time-driven ABC in a European context. The mathematical representation allows to a better understanding of this new costing technique and provides a new methodology to model complexity of logistics activities.

Keywords: Logistics, Time-driven Activity-based Costing, time equations, mathematical model, complexity

Classification: Conceptual Paper and Case Study

1 Introduction

While supply chains have existed ever since businesses have been organized to bring products and services to customers, the notion of their competitive advantage, and consequently supply chain management (SCM), is a relatively recent thinking in management literature (Chen & Paulraj, 2004). In the relationships between suppliers and their retail customers cost knowledge is identified as essential for two main reasons. First, it can establish a competitive advantage by focusing on the most profitable customers (Foster et al., 1996). Second, managers must know the unit cost of products as well as of customer service levels, to use during negotiations with other members of the supply chain in order to realize fair exchanges and equitable partnerships (Norek & Pohlen, 2001; Lin et al., 2001; Themido et al., 2000). Many suppliers contend there is an increasing amount of pressure placed on them to perform an increasing number of functions previously performed by their retail customer (such as special packaging requirements) (Norek & Pohlen, 2001). Without knowing the cost-to-serve, suppliers have little evidence to demonstrate how shifting functions in the supply chain effects their profitability and long-term survival (Cokins, 1999).

In reporting profitability of orders and customers, *traditional* cost systems treat logistics costs as overhead costs and allocate these costs to products/customers on the basis of volume-drivers such as direct labor hours, units or turnover (Cooper, 1988a). Using volume-based allocation rules for logistic costs might lead to distortions in cost and profitability. The ever-increasing range of products and services offered and the wide variety of channels and customers make it difficult for logistics costs to be modeled by time-drivers alone (Pohlen & La Londe, 1994). Since more than two decades, many companies have successfully developed *activity-based cost* (ABC) systems for logistics activities (Pohlen & La Londe, 1994; Lin et al., 2001; Themido et al., 2000). ABC directly links the costs of performing organizational activities to the products, customers or distribution channels. These links are usually unknown in advance and have to be identified at the level of the individual activities in the different overhead departments (Cooper & Kaplan, 1998). In complex and dynamic environments many companies abandoned activity-based costing because it often failed to capture the complexity of actual operations, it took too long to implement and was too expensive to build and maintain (Kaplan and Anderson, 2004). To solve these problems Kaplan and Anderson introduced the concept of *time-driven activity-based costing.* Time-driven ABC provides the ability to identify and report *complex* and specialized transactions in a *simple* way by using time equations that can employ multiple drivers.

The concept of time-driven ABC is *relatively new and unexplored* in current research (2004). Because logistics activities are expected to be complex, the purpose of this paper is to study whether time-driven ABC is more appropriate to capture the complexity of logistics transactions than traditional ABC. We collected data from a case study at a distribution company. This company deals with many different products and types of customers, asking for a variety of service in an intensely competitive environment. During the case study the following specific research questions were considered. (1) Why does this company need a time-driven ABC system? (2) What kind of activity complexity needs to be captured to provide accurate cost and profitability information about orders and customers? (3) Why was traditional ABC not able to fully capture the identified complexities? (4) How could the identified complexities be incorporated in the time-driven ABC model?

There are several goals of this paper. The first objective of this paper is to review the shortcomings of traditional ABC systems with the opportunities of time-driven ABC, both from a conceptual and empirical point of view. The second objective lies in a clear definition of the underlying mathematical model of the technique of time-driven ABC and the concept of time equations. By utilizing multiple time drivers and interaction terms, we witnessed time-driven ABC's unique way to describe the complexity of logistics activities. Third, this is the first study (as far as we know), describing and exploring a time-driven ABC model at an European company. Finally, this study shows how innovative cost management techniques can be successfully applied in supply chain management.

The paper is organized as follows. First, we address the technique of traditional ABC and the difficulties encountered in applying ABC. Then, we discuss the technique of time-driven ABC. Next we develop a mathematical model underlying time-driven ABC to explore whether time-driven ABC can solve the shortcomings of a traditional ABC system in complex environments. Further on, we describe the case study and analyze the time equations used in this distribution company. Finally, we give a summary of the type of complexities we could identify in the logistics cost model of this company.

2 Activity-based Costing and its reported Shortcomings

2.1 Technique of ABC

Activity-Based Costing is a costing method that first assigns overhead costs to activities and then to products, orders or customers, based on how much each of these cost objects uses the individual activities (Cooper, 1988a, 1988b, 1989a, 1989b; Cooper & Kaplan, 1988; Kaplan & Cooper, 1998). ABC typically involves the following steps, as shown in Figure 1:

Step 1: Identify the different overhead activities.

Step 2: Assign the overhead costs to the different activities by a resource driver.

Step 3: Identify the activity driver for each activity.

Step 4: Determine the activity driver rate by dividing the total activity costs by the normal volume of the activity driver.

Step 5: Multiply the activity driver rate by the activity driver consumption to trace costs to cost objects.

Insert Figure 1 about here

For example, consider the activity "Sales Order Processing". Assume that for this activity the total cost (payroll, depreciation and other supplies) is equal to €50.000. When the number of orders is the activity driver and 1.000 orders can be processed, ABC will come up with an activity driver rate of 50.000/1.000 or €50 per order. In calculating order profitability each order will be assigned €50 per order for sales order processing costs, independent of the number of units that the customer is ordering.

Previous research illustrated successful implementations of ABC in logistics (Pohlen & La Londe 1994; Cokins, 1999; Themido et al. 2000; Lin et al. 2001). In the general ABC literature, many studies have focused on measuring the success of ABC and discovering its determinants (see Foster & Swenson 1997 for a review). We will focus in this literature review on the difficulties encountered when applying ABC. Afterwards, when we discuss the technique of time-driven ABC, we will evaluate whether these difficulties still apply under time-driven ABC.

2.2 Difficulties encountered in applying ABC

Measurement errors leading to less accurate cost information

ABC systems are set up to reduce specification errors. These errors arise when a volume-based allocation is used, while in reality costs are often driven by non-volume related activities. ABC systems are also intended to reduce aggregation errors, since more accuracy occurs as more activity cost centers and cost drivers are used to assign costs to products (Datar & Gupta, 1994). But the refinements of cost systems to reduce these errors might come at the cost of higher measurement errors (Datar & Gupta, 1994). Information on the exact cost or the nature of resource usage at less aggregate cost pools are often difficult to obtain (Foster & Gupta, 1990; Lin et al., 2001). Because of these measurement problems, companies might shift to a less detailed ABC system.

Measurement of costs or units of activity drivers are further complicated when variables to be measured are not supported by well-defined measurement guidelines or measurement techniques. For example, consider the activity “Order Processing”. Computing total costs incurred in order processing requires estimates of the percentage of time spent by various staff functions such as sales representatives, credit controllers and planners. The firm typically estimates the time spent on the basis of *questionnaires and interviews* (Cooper et al. 1992) and these estimates are subject to measurement error (Datar and Gupta, 1994).

Enterprise-wide ABC models are becoming too complex

Anderson et al. (2002) found more complex ABC models for companies facing a great deal of competitive pressure. In a highly competitive environment, the need to focus on developing accurate product costs increases, because plant managers need more data on the cost of operations and opportunities for improvement. More accurate product costs are obtained in ABC as overhead support activities are broken down into finer components (Kaplan & Cooper, 1998). Also Kaplan & Anderson (2004) argue that when the activities become more advanced, ABC requires that activities have to be split into smaller activities leading to an *inflation of the number of activities*. For example when the costs of order processing not only depend on the number of orders but also on the type of customer, accurate costing should use different order processing cost rates for every type of customer. An overproliferation of activities and activity drivers are frequently found for staff functions (such as logistics and distribution), since these employees face less repetitive tasks than on the shop floor (Innes et al.,1992; Armstrong, 2002).

Kaplan and Anderson (2004) argue that as the activity dictionary expands either to reflect more accuracy and detail or to expand the scope of the model to the entire enterprise, the demands on the computer model used to store and process the data escalate dramatically. For example, a company using activities in its enterprise ABC model, and applying the costs in these 150 activities to 600.000 cost objects (SKUs and customers) and running the model monthly for two years requires data estimates, calculations and storage for more than 2 billion items (Kaplan & Anderson, 2004, 132). To reduce the difficulties of operating an enterprise-wide ABC model, companies often build separate ABC models for each of their sites or start with one product group, one time period and one type of distribution channel (Themido et al., 2000). Trying to coordinate cost estimates for products/customers traversing multiple ABC models then becomes almost impossible.

Time-consuming to build a complex ABC model

Many ABC models languish when they are too complex, which in turn leads to long development time (Anderson et al., 2002). Survey research in different countries show that the amount of work is experienced as one of the biggest problems for the team designing the ABC system as well as for the accountants implementing it (Cobb et al., 1994; Pohlen & La Londe, 1994). The analysis of activities involves many interviews, typically requiring about three people working full-time for between four and six months (Cooper, 1990). Very often activities are crossing departmental boundaries and this means coordination of information from many interviews to determine the major activities, again very time-consuming (Cobb et al., 1994).

Difficult to update a complex ABC model

Armstrong (2002) argues that since an ABC model is extensive in staff time to install, it will be even more expensive to update. Kaplan and Anderson (2004) observe that in dynamic environments, where activities, processes, products and customers frequently change, ABC might lead to a high cost of continually updating the model, out-of-date activity driver rates, and inaccurate estimates of product, process and customer costs. Consider the following example in the activity "ship order to customer", taken from Kaplan and Anderson (2004). Rather than assuming a constant cost per order shipped, a company might wish to recognize the cost differences when an order is shipped in a full truck, in a less than truckload shipment

Remark that the breakthrough of time-driven ABC lies in the *time estimates* (see step 5 above). Kaplan & Cooper (1998, 294) earlier suggested in a traditional ABC system to use the capacity of the resources supplied for assigning resource expenses to activities (see step 3 and 4 above). New in time-driven ABC is that the time required for performing the activity is now estimated for each event based on different characteristics, the so-called time-drivers. The basic methodology of time-driven ABC is shown in Figure 2.

Insert Figure 2 about here

Again consider the example of the sales order processing activity. Assume a total resource cost of €57.600 (payroll, depreciation, other supplies) per week related to a practical time capacity of 5.760 minutes (80% of the theoretical capacity of 40 hours per week for 3 employees). So, the cost per minute for this group of resources is 10 euro. The time required to process a standard order is estimated to be 3 minutes. Order processing for new customers requires a subtask of registration, taking an additional 15 minutes. So the event of order processing for a new customer takes 18 minutes, while the event of order processing for an existing customer takes 3 minutes. Hence, in the time-driven approach, the cost per order equals €30 for existing customers and €180 for new customers. By no longer using a transaction driver (number of orders) but the time required to perform the order processing activity, the cost per order can be made *fully situation dependent*, without rebuilding the whole model. Based on the order processing characteristics, event 1 of order processing might take 3 minutes because it is an existing customer, event 2 might consume 18 minutes because it is a new customer, while event 3 might require again 3 minutes, etc. Hence, the time-driven ABC uses *duration* drivers (such as set-up hours, material handling time, order processing time) instead of *transaction* drivers (such as the number of set-ups, the number of material moves, the number of orders). The reason is that in complex environments a particular activity does not always consume the same quantity of resources in every situation. Rather than defining a separate activity for every possible combination of order processing characteristics, the time-driven approach estimates the resource demand by a *time equation* (Kaplan & Anderson, 2004). The time equation for the simple example above is:

Order processing time per order = $3 + 15_{\text{if new customer}}$

4 Our Mathematical Model of Time-driven ABC

As mentioned above, the cost of an activity is generated by the *time* required for the activity multiplied by the *cost per time unit*. Remember from the example in the previous paragraph that the time required for the order processing activity is calculated for each specific event of order processing, depending on the characteristics of that specific event k. We represent this in the following mathematical way:

depend on the characteristics of that specific order.

$$\text{Cost of an individual event k of Activity J} = t_{j,k} \cdot c_i$$

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

The total cost over all events of all activities is then calculated by summing up all activity costs. The total cost of a cost object (e.g. customer, order, product) can be calculated by:

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

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 activity j is performed (or the number of events of a particular activity j)

By using time equations, the time consumed by the event of an activity ($t_{j,k}$) can be expressed in function of different characteristics, the so-called time drivers. The following general time equation describes the time needed for an event k of activity j, with p possible time drivers X. β_0 represents the constant time, independent of the characteristics of the activity. B_1 indicates the increase in time for one unit increase in X_1 (when X_2, …, X_p are held constant).

$$t_{j,k} = \beta_0 + \beta_1.X_1 + \beta_2.X_2 + \beta_3.X_3 + ... + \beta_p.X_p$$

with: $t_{j,k}$ = time required to perform event k of activity j
β_0 = constant amount of time for activity j, independent of the characteristics of event k
β_l = time consumption for one unit of time driver 1
X_1 = time driver l, X_2= time driver 2, … , X_p = time driver p,
p = the number of time drivers that determine the time needed to perform activity j

5 Exploring the Time Equations in Time-Driven ABC

5.1 Different type of Time Drivers

Time drivers are essential in time-driven ABC. As defined above, time drivers are variables (characteristics) that determine the time needed to perform an activity. They can take the form of a *continuous*, *discrete* or *indicator* variable. We took the following examples of the case (as described later) to illustrate the difference.

- Continuous variables: e.g., the weight of a pallet, distance in kilometers.

- Discrete variables: e.g., the number of orders, the number of order lines, the number of credit checks.
- Indicator (or dummy or 0-1) variables: e.g., the type of customer (old versus new), the type of order (normal versus rush), the order reception characteristic (EDI versus fax). The additional time is then added up in the equation when the characteristic is present (X_3 = 1 for an order received by fax) and no additional time is added up when the characteristic is not present (X_3 = 0 for an EDI received order).

5.2 Multiple time drivers

The major advantage of time-driven ABC is that *multiple* drivers can be taken into consideration to define the cost of an activity. In traditional ABC only one activity driver can be considered for each activity. If many activity drivers are necessary for accurate costing, different activities are needed in ABC (e.g. "order line entry" driven by the number of order lines, "new customer registration" driven by the number of new customers). In time-driven ABC the number of time drivers (or terms in the time equation) is not limited as long as the employees performing the tasks are belonging to the same resource pool (i.e. consuming the same c_i).

5.3 Interaction of time drivers

Also time equations might take into account *interactions* between drivers (e.g., the time required for registering a new customer might differ whether the customer is on the phone or whether the data are coming from a sales representative). The general time equation including the main effects and the two-way interactions for two time drivers can be written in the following general time equation:

$$t_{j,k} = \beta_0 + \beta_1.X_1 + \beta_2.X_2 + \beta_3.X_1.X_2$$

In the following sections, we provide some examples, taken from our experience with the company from the case study (as will be discussed on page 19).

5.4 Example of discrete and indicator time drivers

Let's elaborate the introductory example. The order processing might now depend on three time drivers: the type of customer (new or existing customer), the number of line items and the order type (normal or rush order). Order entry of the basic order information involves 3 minutes, each line item requires 2 minutes data input, input of new customer data takes 15 minutes and 10 additional minutes are required for expediting when the order is a rush order. We have now one discrete time driver (i.e. the number of order lines, represented by X_1) and two indicator time drivers, i.e. X_2 (new versus existing customer) and X_3 (normal versus rush order). The indicator variable X_2 takes the value of 1 when the customer is new and 0 for an existing customer. The same applies to indicator variable X_3: the additional time is only required for a rush order, assuming a "1" for a rush order, and a "0" for a normal order. The estimated order processing time is calculated by the following time equation:

Order processing time per order = $3 + 2 * X_1 + 15 * X_2 + 10 * X_3$ [1]

with: X_1 = number of order lines
X_2 = New customer (1) versus existing customer (0)
X_3 = Rush order (1) versus normal order (0)

The order processing time of a rush order with 5 order lines for a new customer will generate the following time equation:

Order processing time $t_k = 3 + 2 * 5 + 15 * 1 + 10 * 1 = 38$ minutes

5.5 Example of a two-way interaction in time drivers

Let's elaborate the example with one more characteristic. The order processing time now also depends on the type of customer. Because of the advanced technical specifications present in the order line descriptions, the time per order line for customer XYZ does not take 2 minutes but 10 minutes (so 8 more minutes than the base time per order line). In this case also the type of customer should be included in the time equation as an indicator variable. In this example the type of customer affects only the time per order line and hence it should be included in the time equation as an interaction term, with a time estimate of 8 minutes. If customer XYZ places the order, activity driver X_4 gets a value of 1. Remark that in this example there is no main effect of customer XYZ, since the time estimate for X_4 is zero.

$$\text{Order processing time per order} = 3 + 2 * X_1 + 8 * X_1 * X_4 + 15 * X_2 + 10 * X_3 + 0 * X_4$$

with: X_1 = number of order lines
X_2 = New customer (1) versus existing customer (0)
X_3 = Rush order (1) versus normal order (0)
X_4 = Customer XYZ (1) versus all other customers (0)

Using this information the time consumption of a normal order with 5 order lines placed by existing customer XYZ can be calculated as:

$$\text{Order processing time } t_k = 3 + 2 * 5 + 8 * 5 * 1 + 15 * 0 + 10 * 0 + 0 * 1 = 53 \text{ minutes}$$

5.6 Example of a three-way interaction in time drivers

Assume that in the previous example the additional time to process technically sophisticated order line descriptions depend on the technical knowledge of the person processing the order. Suppose the additional time is 8 minutes when the order processing is performed by a sales administrative person and only 3 minutes when a technical person does the work. Also assume that the cost of both resources (administrative and technicians) is the same. In this case order lines of an order placed by customer XYZ still generates 8 more minutes per order line, except when the order is processed by a technical person. Such a person spends 5 minutes less per order line than an administrative person. To include this time effect into the time equation a fifth variable has to be defined: the type of order intake person, X_5, being an indicator time driver. In this modeling problem, we now face a three-way interaction between the number of order lines (a discrete variable), the type of customer and the order intake person (both indicator variables). This is the general time equation:

$$\text{Order processing time per order} = 3 + 2 * X_1 + 15 * X_2 + 10 * X_3 + 3 * X_1 * X_4 + 5 * X_1 * X_4 * X_5$$

with: X_1 = number of order lines
X_2 = New customer (1) versus existing customer (0)
X_3 = Rush order (1) versus normal order (0)
X_4 = Customer XYZ (1) versus all other customers (0)
X_5 = Order intake by sales (1) versus order intake by technical department (0)

The calculation of the time to process a normal order with 4 order lines, placed by customer XYZ and processed by a technical person involves 23 minutes, as indicated in the following equation:

$$\text{Order processing time } t_k = 3 + 2 * 4 + 15 * 0 + 10 * 0 + 3 * 4 * 1 + 5 * 4 * 1 * 0 = 23 \text{ minutes}$$

5.7 <u>Example of changing time drivers</u>

We return to the example with three time drivers (see [1]). Suppose the finance department urges sales administration to do a credit check, from now on, before accepting and processing a customer order. Because the credit check is going to be executed by the same resources, we don't need to change the cost system and add a new activity. The requirement of doing a credit check each time an order comes in, will only increase the time per order of the order processing activity. Assume that a credit check will take 10 minutes, the constant term will increase from 3 to 13 minutes and the time equation becomes now:

$$\text{Order processing time per order} = 13 + 2 * X_1 + 15 * X_2 + 10 * X_3$$

with: X_1 = number of order lines
X_2 = New customer (1) versus existing customer (0)
X_3 = Rush order (1) versus normal order (0)

5.8 Conclusion: Can Time-driven ABC solve the ABC shortcomings?

These examples illustrate that time-driven ABC can solve some of the earlier mentioned difficulties encountered with traditional ABC. (1) The measurement of time in minutes (or hours) on a specific activity as a function of different characteristics (time drivers) can reduce *measurement errors*. Staff people can be more specific on estimating the time of a broad activity (with all its variants) than to estimate the total time spent for a whole year on each of the variants of the activities. (2) The use of time equations allows companies to design time-driven enterprise wide systems with a limited number of activities. As Anderson & Kaplan have shown through the inclusion of multiple time drivers, *complex activities* can be modeled without expanding the number of activities. Hence, time-driven ABC provides apparently many opportunities to design ABC models in environments with complex activities, such as in logistics and distribution companies, hospitals, and servicing companies in general. The second part of this paper will further explore these opportunities for the logistics activities in a distribution company. (3) The time equations also allow easily *updating* the cost system when products or service offerings change or when production and service processes are redesigned. This characteristic makes time-driven ABC suitable for fast changing environments and makes it a candidate for corporate agility. Furthermore, the unit cost per resource pool can be easily updated when wages, ICT usage or tooling changes within the resource pool, without recalculating the whole model. (4) Finally, based on their experience with more than 100 clients, Kaplan & Anderson (2004) believe that time-driven ABC systems can be estimated and installed quickly.

Future research on time-driven ABC applications is needed to confirm whether the above-mentioned opportunities of time-driven ABC will counteract the reported problems with ABC in practice. The technique of time-driven ABC looks promising, but more case studies are needed to reinforce our knowledge on this innovative topic (Ryan et al., 2003). In this study, we did a case study to further explore the opportunities of time-driven ABC to design a cost model for *complex activities*.

6 Case Study

6.1 Methodology

In order to explore real-world implementation of a time-driven ABC, we conducted case study research at a distribution company, during May-June 2004. A case study is the most appropriate research method to explore the reasons for a particular accounting practice (Scapens, 1990; Otley & Berry, 1994). As such, this case study represents a preliminary investigation of an innovative practice, which is intended to generate ideas for testing at a later stage.

Data was collected using various sources. Interviews were conducted with the managing director, the controller and the consultant who had installed the time-driven ABC system. Since the purpose of our study was to learn from practice, we conducted open-ended interviews. Rather than assuming that the existing literature had covered all aspects of time-driven ABC, we tried to uncover new concerns as much as possible. Therefore, the direction that every interview took was unique. Other documents such as annual reports, internal reports, promotional brochures, a video and power point presentations were studied. Complete access was given to the activity database and the time equations.

The authors approached this company because of a business contact between one of the authors and the consultant. In a sense, this site selection was not ad random, although it helped tremendously to overcome one of the biggest practical difficulties of conducting case study research, i.e. gaining access to field sites (Baxter & Gua, 1998). This company was attractive on a priori, objective grounds, and would have been a top candidate in a purposive sampling approach, because it implemented the time-driven approach company-wide and was already using the time-driven cost information for almost one year at the time of the interviews. We admit that the method of access might be a source of bias and a threat to internal and external validity of the qualitative case results (e.g. need for time-driven ABC or reported benefits), while we do not expect any bias towards the more quantitative case results (e.g. time equations or complexity of the ABC model).

The goal of this study is to *explore* the time-driven approach of ABC in practice. In particular we wanted to discover why the company was using time-driven ABC to contrast with the academic literature's assumptions regarding the need for time-driven ABC. Secondly, we want to explore whether time-driven ABC can capture the complexity of the logistics operations. Third, we want to find out why traditional ABC was not able to capture the complexity in the logistics operations. Finally, we wanted to find out how this company translated the complexity of the activities into the time equations.

6.2 Research Site

Facts

Sanac is a distributor of plant-care products in Belgium with total sales of 62 million euro, an own transportation fleet of 25 trucks and a warehouse of 22 500 pallets. Sanac neither produces nor sells any of its products under its own name. It only retails well-known brand products to four different types of customer groups: farmers, growers, public sector companies & landscapers, and large and small consumer shops. Sanac has about 7.000 customers, 7.000 products, and 298.000 order lines per year. Sanac employs 129 people; 40 of whom are employed as sales technicians and 57 in the logistics department. Sanac is in continuous expansion and in the last ten years its sales has increased by 10% per year.

Competitive Strategy

There are three very important elements of the *competitive strategy*. The first one is advice. Sanac sells not only items related to planting and growing (especially the plant-care products) but also indirectly, advice. They consider it as essential to provide technical support for the sale of these products. Technical skills and the services and advice from technicians on the products together with solutions to technical problems, lead to sales as part of a working partnership that in the long-term ensures a reliable and trusting relationship with its professional clients. Advice for the small and large consumer shops are realized by offering a display, as shops do not usually have either the structure or the time to deal with technical products or to give advice to customers. Sanac, in fact, runs a sales area for one store ensuring its profitability without any or with very little investment in time or training for the supermarket employees. Profitability per square meter is very important for supermarkets and hypermarkets. The second element of the competitive strategy is marketing and knowledge of the market. The markets where Sanac is present have a seasonal-based activity and are subject to trends. Therefore, feedback from the technicians and sales people as well as from the truck drivers is essential as it is a precious source of information and helps to maintain contact with clients in order not to have any unsold items. Third, Sanac is also an expert in logistics. Logistics are important, as the company is either having to deal with professionals within supermarkets and hypermarkets for whom any delay means a loss of sales or with professionals for whom speed of delivery is an essential asset in order not to prejudice their crop.

Market Evolution

In the nineties the company was very sales driven, without any insight into the profitability of the different customers. At the end of the nineties competition increased, profit margins became under pressure and customers asked more services. The company also experienced a faster changing market situation, strong seasonal fluctuation in its activities and a growing complexity and diversity of its products and its customers. These changes in the environment forced the company to change from a growth strategy to a *profitability enhancing strategy*.

Marketing policy was focused on the consumer shops, which was a new segment. But nobody knew the true cost of this new activity or the resources invested in it (the logistics, terms of payment). Despite an important increase in sales (from 37 to 62 million euros in four years) and stable gross profit margins, a decrease in the overall result was noticed. In order to solve what was considered a paradox, Sanac tried to calculate profitability by sector. The existing cost accounting system only enabled a contribution margin (gross margin minus logistics and commercial costs) to be calculated. There remained however unallocated indirect overheads (2.5 million euros in 2000) and these costs, considered in principle as fixed, were increasing each year. Even with incomplete data, Sanac saw that the consumer segment was making a big loss, that the agriculture was profitable and that the horticultural sector was loss making. In fact, the sector where there was most growth and where Sanac wanted to re-orientate itself was the least profitable. Sanac was changing its business but this new business was not understood financially.

6.3 The Need for a Time-Driven ABC model at Sanac

The need for a more accurate cost system came from reduced profitability. Sanac's aim was to recover its profitability, to shift its focus from growth (a focus forcing the company to have a wide range of products with large stocks and to deliver any order to any client in the shortest possible time and in whatever quantity was needed at a single price) to profitability. The firm wanted to know what its costs were per product, per customer, per delivery, per order line and per supplier (see Figure 3). All this effort was meant to lead to improvement in services and to privilege clients who generate value, that is to say margins and profit for Sanac, even if this meant discarding certain clients and/or products or even markets. For this to occur, there had to be a reliable system for measuring costs and performance before there could be any changes in strategy.

Insert Figure 3 about here.

Sanac started with a traditional ABC, but soon realized that this ABC cost system would not work out. Several reasons were mentioned. (1) The CEO wanted monthly profitability data at the level of business unit, products, orders and customers. This required that the model be *updated monthly* with actual data. This was not possible without hiring 10 controllers. (2) The rapidly growing market of consumer shops required Sanac to take immediate actions on customer's requests. These clients are very demanding in terms of price and resources. In such a dynamic environment the *maintainability of the cost model* was very important. Again without 10 controllers, keeping the ABC model up to data was impossible. (3) *Strong seasonal trends* in the sales made it difficult to define the "normal capacity" of the activity cost drivers (80% of the sales are achieved in four months with an idle capacity in winter). During winter periods the company cannot charge all unused capacity to that one customer that is coming in November. Working with averages was not working out in this company, because the CEO wanted to know each month what departments were having overcapacity and what departments were running under capacity. (4) *High diversity of customers and products* required too many activities to keep track off. Sanac has 7,000 clients, a portfolio of 7,000 products in stock and 20,000 in catalogue. It receives 298,000 orders a year and issues 69,000 invoices. But more important, clients have important and varied demands in services and in logistics. This wide diversity in the consumption of resources makes it difficult to trace and analyze costs. For instance, there is a wide difference in unit costs according to the products (packaging, type of product) and the clients (delivery terms, advice, terms of payment). A small farmer does not generate the same gross profit margins or the same costs as the DIY store of a large chain. A traditional ABC system required here too many activities. (5) Last, but not least, the *strong diversity in resource consumption* by the various cost objects could not be captured by a traditional ABC model. During the activity analysis preparing for the implementation of a traditional ABC, they experienced that many logistics activities were too complex and that cost rates, such as the cost per drop, the cost per order etc. were too average and did not mean very much to the people interpreting the profitability reports. The examples in the next paragraph illustrate the kind of complexities this company was dealing with in its logistic activities.

6.4 Time Equations of some Complex Activities

Supplier-related activity: Reception of incoming goods

Interview data reveal that reception of incoming goods is a process in itself, composed by many subtasks, each with different time drivers. The interviewee described the task as follows: "When the truck arrives the driver is assigned a dock (1 minute). Next the warehouse employee enters the delivery voucher into the computer. Input of the general order information takes 1 minute and input of each purchase order line takes 10 seconds per purchase order line. Unloading of pallets takes 2,5 minute per pallet. Each order delivery requires also 1 minute of administration (communicating information about reusable containers or signalling of specific problems). When reusable containers are returned to the supplier employees need to spend 10 minutes per pallet for sorting, counting and blistering. Sometimes pallets have to be returned to the supplier. In this case pallets are transported in staples of 15 from the warehouse and loaded on the truck. This operation needs 3 minutes per staple of 15 pallets. When the truck is unloaded the delivered goods need to be checked, prepared and stored in the warehouse. This operation takes 1 minute per homogeneous pallet and 15 minutes per heterogeneous pallet. Finally a warehouse employee signs off the voucher (1 minute)."

Analysis of these data shows that this activity is not homogeneous and can be subdivided in different tasks, each having its own specific time driver and time consumption per unit time driver (see Table 1).

Insert Table 1 here.

The activity reception of incoming goods is not solely driven by the number of purchase orders as would be used in a traditional ABC model. The activity can be considered as a "multiple driver" activity, because multiple time drivers influence the activity time. The following time equation is capturing the time drivers[5]:

Reception time per delivery = $4 + 0{,}17 * X_1 + 2{,}5 * X_2 + 10 * X_3 + 3 * X_4/15 + 1 * X_5 + 15 * X_6$

With: X_1 = number of order lines
X_2 = number of pallets received
X_3 = Number of pallets to return with reusable containers
X_4 = Number of pallets to return
X_5 = Number of homogeneous pallets received
X_6 = Number of heterogeneous pallets received

Using the time equation we can calculate the cost per delivery in different situations. For instance a reception of incoming goods with 10 order lines, 10 (homogeneous) pallets, no reusable containers or pallets to be returned requires 41 minutes. A reception of incoming goods with 10 order lines, 10 pallets, 5 pallets with reusable containers and 2 staples of 15 (homogeneous) pallets to be returned ask for 97 minutes. The examples show that activity times per order might significantly differ from each other.

Customer-related activities: drop off with the customer

In the traditional ABC model the identified activity driver was the number of drops. Traditional ABC could only come up with an average cost per drop. But in reality the cost per drop depends on many variables. The following interview data picture the complex reality

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[5] In the Acorn time-driven ABC software, this time equation was written as follows: 1 + 1 + 0.17 * [Line Items] + 2.5 * [ReceivedPallets] + 1 + 10 * [PalletsReusableContainers] + 3 * [EmptyPallets] / 15 + 1 * [HomogeneousPallets] + 15 * [HeterogeneousPallets] + 1

of the dropping activity: "Farmer routing: An order dropped at a farmer's premises normally takes 5 minutes per order, except when it is a first delivery. In this case the drop takes 10 minutes. When the truck driver also has to take back returned goods, he needs an additional 5 minutes to check the goods and to finish the necessary administration. When reusable containers have to be taken back the truck driver needs 10 minutes to check the labels. Delivery under cash payment requires an extra 20 minutes per drop delivered to farmers and growers, and 5 minutes for all other customers. Non-farmer routing: When the customer is not a farmer the time per drop is 2 minutes per pallet when the goods are delivered on pallets, and 1 minute per pack when delivery is in packs. With some customers there are important waiting times. In garden centres the waiting time is 15 minutes, in large distribution companies the waiting time is 30 minutes per drop. However when the delivery goes to Makro or Leroy Merlin the driver has to wait 60 minutes. Non-farmer customers might also have goods to take back. When an appointment has been made, the goods are ready to load and have been assigned a return code. In this case loading of returned goods only takes 3 minutes. When no appointment has been made the driver has to call Sanac to ask a return code. This inquiry takes 30 minutes. In case of non-farmer customers loading and checking empty pallets takes 2 minutes. Cash payment for non-farmers requires 10 minutes."

The interview data show that the time per drop depends on the type of customer (farmer or non-farmer), the type of non-farmer customer (large distribution company or not, garden center or not, Makro/Leroy Merlin or not), the type of delivery (first delivery or not), the availability of a return code (yes or no), the need to take back goods (yes or no), the need to take back reusable containers (yes or no), the mode of payment (cash or non-cash), the number of pallets and the number of packs, as shown in Table 2.

Insert Table 2 here.

The time drivers affect the time of the drop-off activity in different ways. Some factors determine an additional *subtask* during the delivery process (e.g. first time delivery needs more time to talk with the farmer), some factors determine the *type of time driver* (e.g. a farmer drop off takes 5 minutes per drop, a non-farmer drop off depends on the number of pallets and the number of packs), and some factors determine the *time per unit time driver* (e.g. return of goods ask 3 minutes for a non-farmer and 5 minutes for a farmer). The example also illustrates how the time spent in a certain activity might *depend on the event of other activities*: the subtask "taking back returned goods" takes more time when no appointment has been made. Using time equations in time-driven ABC allows for modeling interdependencies between activities. The following time equation was set up for this logistics activity.

Delivery time per drop[6] $= 5 * X_1 + 5 * X_1 . X_2 + 5 * X_1 X_3 + 10 * X_1 X_4 + 5 * X_1 X_5 + 15 * X_1 X_5 X_6 + 2 * X_7 . X_8 + 1 * X_7 . X_9 . + 15 * X_{10} + 30 * X_{11} + 60 * X_{11} + 30 * X_7 X_3 X_{13} + 3 * X_7 X_3 + 2 * X_7 X_{14} + 10 * X_7 X_5$

with: X_1 = farmer routing (1) versus non-farmer routing (0)
X_2 = first delivery: yes (1) versus no (0)
X_3 = returned goods: yes (1) versus no (0)
X_4 = returned reusable containers: yes (1) versus no (0)
X_5 = cash payment: yes (1) or not (0)
X_6 = customer is farmer or grower: yes (1) or no (0)
X_7 = non-farmer (1) versus farmer (0)
X_8 = number of pallets
X_9 = number of packs
X_{10} = garden center: yes (1) or no (0)
X_{11} = large distribution center: yes (1) or no (0)
X_{12} = hypermarket Makro or Leroy Merlin: yes (1) or no (0)
X_{13} = appointment is made, so return code is known: no (1) or yes (0)

[6] In programming language of Acorn this equation was written as: IF([CustomerType] = "Farmer", 5 + IF([FirstOrder] = "Yes", 5, 0) + IF([Returns] <> 0, 5, 0) + IF([ReusableContainers] <> 0, 10, 0), 2 * [Pallets] + 1 * [Packs] + LOOKUP([CustomerType], "DIY", IF([Customer] = "Makro" OR [Customer] = "Leroy Merlin", 60, 30), "Garden Centre", 15, 0) + IF([Returns] <> 0, IF([Appointment] = "Yes", 3, 30), 0) + 2 * [EmptyPallets]) + IF([CashPayment] = "Yes", IF([Customer Type] = "Farmer" OR [CustomerType] = "Grower", 20, 5), 0)

X_{14} = empty pallets to return: yes (1) versus no (0)

The time equation fully captures the complicated structure of this activity. Many time drivers affect the time for this activity. Some of them (X_{10}, X_{11} and X_{12}) only have a *main effect* on the activity time (garden centers, large distribution centers, Makro or Leroy Merlin requiring large waiting times). Most drivers have an *interaction effect* on the activity time. This means that the time effect of the driver depends on the value of one or more other drivers. For example: The time of a drop is not always 5 minutes per order in the farmers routing. When this is a first delivery, an additional 5 minutes time is needed (two way interaction $X_1.X_2$ between "farmer versus non-farmers routing" (X_1) and "first delivery" (X_2). When no appointment was made for the non-farmers, who have goods to return, the additional time can be modeled by a three way interaction $X_7.X_3.X_{13}$ between the three indicator variables "non-farmer versus farmer" (X_7), "goods to return versus no goods to return" (X_3) and "no return code versus return code" (X_{13}).

Also for this activity, sensitivity analysis shows that the activity time per drop significantly differs depending on the characteristics of the delivery. For example an order shipped to a farmer, no return of goods or reusable containers, no cash payment requires 5 minutes time per drop. An order shipped to a farmer, normal delivery, goods and reusable containers to be returned, cash payment requires 40 minutes time per drop. An order shipped on pallets to a garden center, 10 pallets, goods to be returned but appointment has been made, no pallets to return, no cash payment requires 38 minutes per drop. An order shipped on pallets to a garden center, 10 pallets, goods to be returned, no appointment has been made, no goods to return, cash payment requires 78 minutes per drop.

6.5 Analysis of Model Complexity at Sanac

Studying the activities as described above (among others) in the time-driven ABC system of Sanac reveals that logistics activities show different types of complexities.

1. Activities are not homogeneous and contain *different subtasks*, each having their own *different time driver*. For instance, different drivers influence the time for unloading, waiting, loading goods to return.
2. *Necessity of different subtasks* depends on the characteristics of the order, the customer, etc. For instance, the commercial talk to the farmer (subtask) is only done for a first time delivery in the farming routing (characteristic of the order) .
3. *Time drivers of subtasks* depend on the characteristics of the customers, the orders, etc. For instance, unloading for farmers is depending on the number of drops, whereas for non-farmer it depends on the number of pallets, or packs.
4. The *required time per unit time driver* depend on the characteristics of the customer, the order, etc. For instance, time for cash payment is depending on the type of customer (garden center, farmer, grower).
5. Activities (or subtasks within activities) are *interdependent*. For instance, calling for a return code is needed when no appointment was made.

These complexities are translated in the time equations by including multiple time drivers and interactions of time drivers, what will be discussed in paragraph 6.7. But first, we discuss why the traditional ABC system could not capture these kinds of complexities.

6.6 Why was traditional ABC not able to capture the identified complexities?

There are two ways to deal with the identified complexities in a traditional ABC model: (1) simply ignoring the multiple time drivers per activity; or (2) creating a separate activity for each subtask. We describe why none of these solutions was working out at Sanac. When *ignoring the multiple time drivers*, the traditional ABC model worked with an activity driver rate for each of the 106 identified activities, without including time drivers. For instance, for the order entry activity, in traditional ABC method a cost per order entry is calculated without considering the specific characteristics of that order. The same applies for the delivery cost per drop, the reception cost per incoming delivery, the planning cost per trip, the administration cost per product, the meeting cost per supplier, etc. This solution is still keeping in mind the hierarchy of activities (unit, batch, product, customer, supplier), which is much better than a traditional cost system with only volume drivers (such as turn over). However, considering only an "average" activity driver rate (without time equation) resulted for Sanac in *distorted product cost information*, because of the high diversity in orders, customers, suppliers, routings, drop-offs and order lines. For instance, taking an average cost per drop-off in traditional ABC is "*undercosting*" the deliveries that are consuming a lot of resources (because of long waiting time, cash payments, many goods to return) and is "*overcosting*" the deliveries that are not consuming a lot of resources (because of no waiting time, no cash payments, no goods to return). As will be explained further (see Table 4), this traditional ABC method created distortions for about 54% of the total activity costs by not including multiple time-drivers.

The company then tried for the second solution, i.e. *splitting-up* the 106 logistics activities into smaller activities representing the different subtasks. This resulted in 330 activities (subtasks), as shown in Table 3. This large number of activities in the activity database made resource assignment to the activities extremely difficult. Taking the example of receiving incoming goods, under the traditional ABC method Sanac needed to calculate the unloading cost per pallet received, the checking cost per order line on the pallet received, the loading cost per pallet to return, the loading cost per pallet to return with reusable containers, the storing cost for one homogeneous pallet, the storing cost for one heterogeneous pallet. For each of these activities the normal volume of the activity drivers needed to be estimated, which was impossible. As you can see in Table 3, the proliferation of activities under the traditional ABC model is mainly caused by the order, route and drop-off related activities. The high increase in supplier-related activities is caused by a lot of subtasks that model the negotiation style of the many suppliers.

Insert Table 3 about here.

6.7 Incorporation of the Complexities in the Time-Driven ABC model at Sanac

In order to explore whether the time-driven ABC model was able to capture the different kind of complexities at Sanac, we wrote each of the 106 time equations in mathematical representation as explained in paragraph 4. A summary is provided in Table 4. You see that one time driver drives about 45% of the total resources. Around 54% of all resources needed more than one time driver to explain the reality of the logistic operations. Table 5 shows that about 30% of the activities contain 2 different time drivers and 31% contain more than 3 time drivers. These *multiple time drivers* were needed because the activities were not homogeneous.

Insert Table 4 about here.

Insert Table 5 about here.

Table 6 provides an overview of the *number of subtasks* that were included in the time-driven ABC model at Sanac. The strength of time-driven ABC is to include more than one variable (constant or time driver) in the time equations. Two, three and four terms seem to be most commonly used at Sanac, consuming respectively 15%, 9% and 15% of the resources. In terms of the number of activities 31% contain two terms, whereas 4% contain 3 terms and 11% contain 4 terms. Remarkable is that 9% of the time equations contain 10 or more terms. By including more than two terms, Sanac was able to cope with complex operations, containing different subtasks with different unit time requirements.

Insert Table 6 about here.

Subtasks with different type of time drivers, *depending on the characteristics of the event*, ask for two-way or three-way interaction terms. As shown in Table 7, 23% of the equations contained a two-way interaction effect and 8% contained a three-way interaction effect. This represented together 21% of the resource costs.

Insert Table 7 about here.

In sum, the time-driven ABC model at Sanac contained 106 time equations, 31% of the time equations contained interaction terms (representing 21% of total costs), 61% of the time equations contained multiple drivers (representing 54% of total costs). About 74% of the time equations included more than one term in the equation. These type of complexities could easily be modeled in the time-driven ABC model at Sanac.

7 Conclusions

The case study shows that a time-driven ABC system was needed for this company. Similar to the literature, this company found it too complex to include the high diversity of order-related activities in a traditional ABC model and too time consuming for maintaining and running the model on a monthly basis. Specific to this company was the seasonal trend in the sales, asking for capacity utilization reports for the different departments. Additionally, this company faced a strong diversity in resource consumptions by the various suppliers, customers, orders, drops and routes that could not be captured in a traditional ABC model.

The examples of time equations for the reception of incoming goods and the delivery of goods to customers showed that different kind of complexities were found in the logistics operation. (1) Activities are not homogeneous and contain different subtasks, each having their own different time driver. (2) The necessity of different subtasks depends on the characteristics of the order, the type of customer, etc. (3) Time drivers of subtasks depend on the characteristics of the order, the type of customer, etc. (4) The required time per unit time driver is a function of the characteristics of the order, the type of customer, etc. (5) Subtasks of activities are depending on the outcome of other activities (interdependency).

When using traditional ABC it was difficult to take these types of complexities into account. The problem of different subtasks with different time drivers, situation dependent tasks, drivers and costs per unit time driver can be solved by activity splitting. Also interdependencies could be solved this way, but this method leads to a large number of activities in the activity database, which makes resource assignment to the activities extremely difficult, less accurate and almost impossible to update. For Sanac this would lead to 330 different activities, compared to 106 in the time-driven ABC approach.

Time-Driven ABC was able to capture the different types of complexities at Sanac. When analyzing the time equations, we found that 64% of all activities contained more than one term in the time equation, consuming 54% of all costs. Almost one third of the activities asked for interaction terms, representing 21% of all resources. These quantifications show that the time-driven ABC approach was needed at Sanac to provide accurate cost information. Because of the high competitive pressure they could not tolerate to have 50% of their resources misallocated to the different cost objects.

Many research opportunities are available for future studies.

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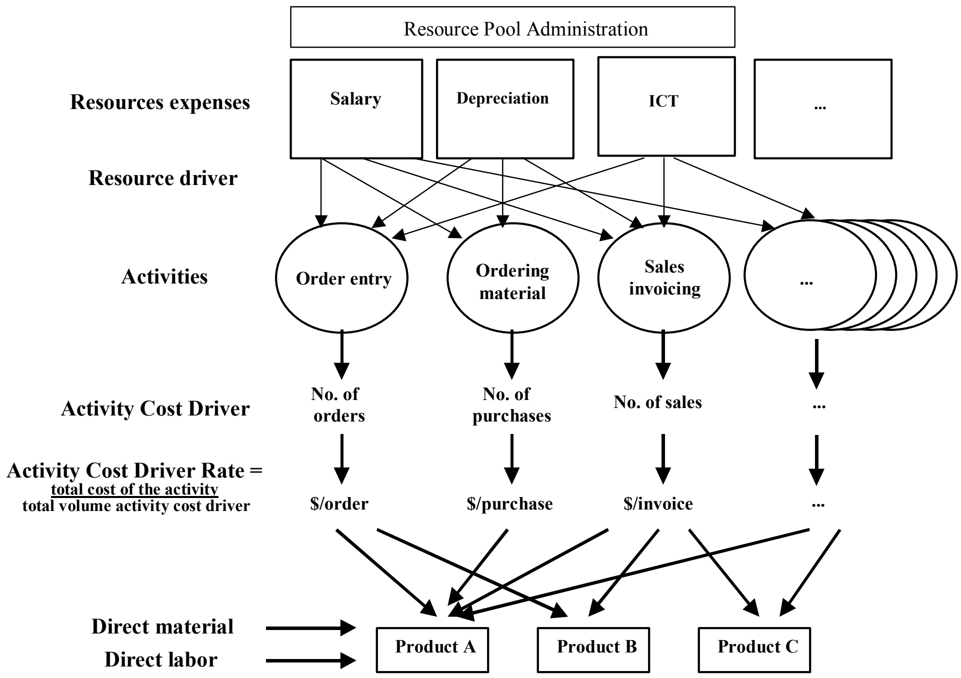
Figure 1: Traditional Activity-Based Costing

Activity-Based Cost Systems trace resource expenses to activities and use activity cost drivers for tracing activity costs to objects.



Source: Based on Kaplan & Cooper (1998)

Figure 2: Time-Driven Activity-Based Costing

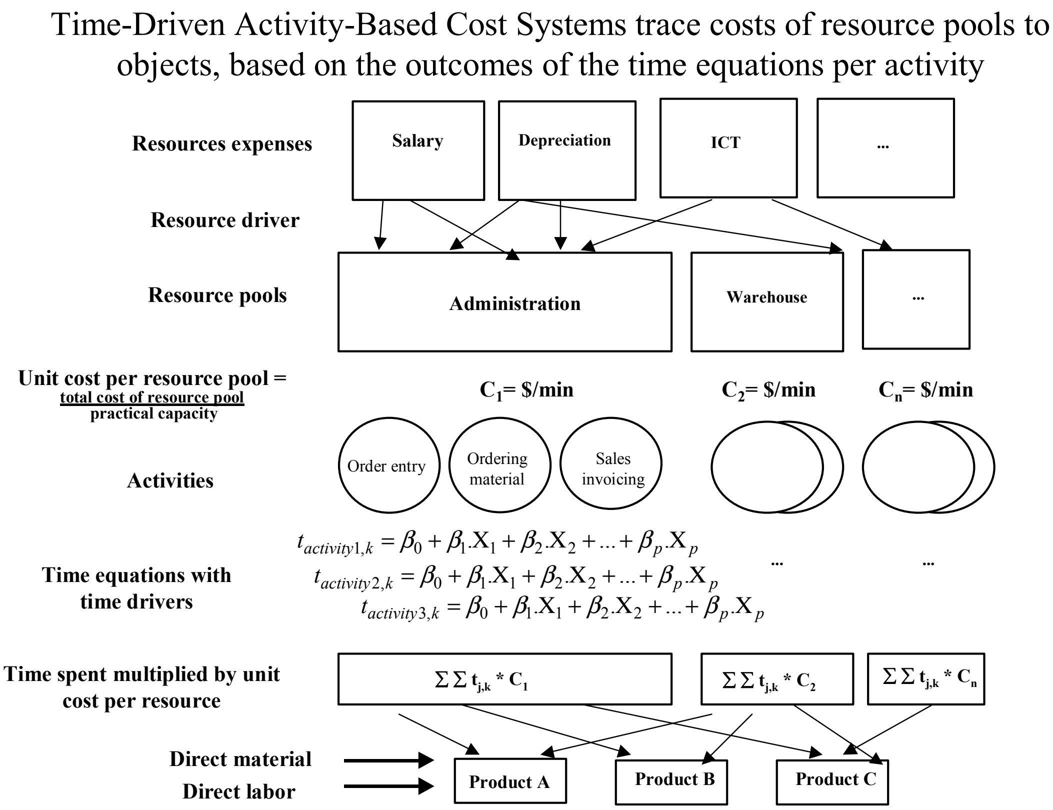
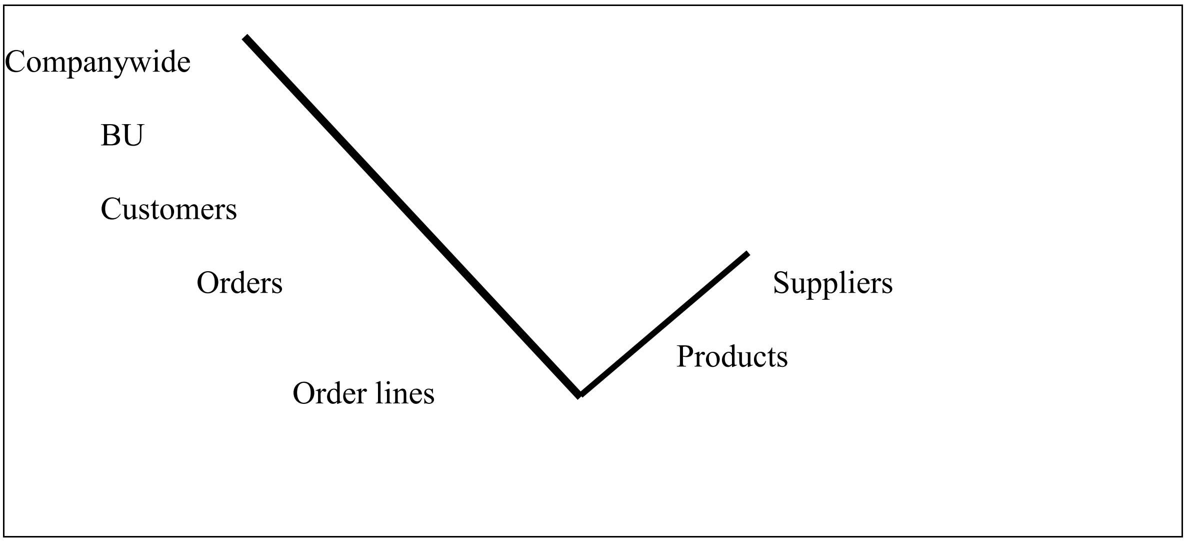


Figure 3: Profitability Analysis for the different Cost Objects



Source: Internal Documents at Ranger

Table 1: Time Drivers for the Activity "Reception of Incoming Goods"

Subtask	Time Driver	Time consumption per unit time driver
Dock assignment	Number of deliveries	1 minute per delivery
Input general information	Number of deliveries	1 minute per delivery
Input order line information	Number of purchase order lines per delivery	10 seconds per order line
Unloading truck	Number of pallets per delivery	2,5 minute per pallet
Communicating information	Number of deliveries	1 minute per delivery
Returning reusable containers	Number of pallets with containers per delivery	10 minutes per pallet with containers
Returning pallets	Number of staples of returned pallets per delivery	3 minutes per staple pallets to return
Checking and storing	Number of homogeneous pallets per delivery	1 minute per homogeneous pallet
Checking and storing	Number of heterogeneous pallets per delivery	15 minutes per heterogeneous pallet
Signing off the voucher	Number of deliveries	1 minute per delivery

Table 2: Time Drivers for the Activity "Drop off goods to customers"

Subtask	Time driver	Time consumption per unit time driver
Dropping the goods	• Farmer or non-farmers' routing: o Number of *drops*, in case of delivery to farmers o Number of *pallets*, in case of delivery on pallets to non-farmers o Number of *collies*, in case of delivery in collies to non-farmers • First delivery or not, in case of delivery to farmers	• 5 minutes per *drop* for farmers • 2 minutes per *pallet* for drop to non-farmers • 1 minute per *pack* for drop to non-farmer • 10 minutes per drop to a *new* farmer.
Take back returned goods	• Returned goods or not: o Number of drops o Appointment being made or not, in case of returns from non-farmers	• 5 minutes per drop for *farmers* • 3 minutes per drop for a *non-farmer* • 30 minutes per drop to non-farmer if no appointment was made
Take back reusable containers	• Reusable containers to take back or not: o Number of drops, in case of returns from farmers	• 10 minutes per drop to farmer
Waiting	• For non-farmers: type of customer: o Garden centre or not o Large distributor or not o Leroy Merlin, Makro or not	• 15 minutes per drop to garden centre • 30 minutes per drop to large distributor • 60 minutes per drop to Makro or Leroy Merlin
Take back pallets	• Pallets to take back or not: o Only for non-farmers: the number of drops	• 2 minutes per drop to non-farmer
Cash payment	• Cash payment or not: o For farmer's routing, type of customer: • Farmer • Grower • Other o For non-farmer's routing:	• 15 minutes per drop • 15 minutes per drop • 5 minutes per drop • 10 minutes per drop

Table 3: Number of Activities in the Time-Driven ABC Model at Sanac

Time equations for each …	**Resources in % of total**	**Number of activities in Time-Driven ABC (1)**	**Activities in % of total for Time-Driven ABC**	**Number of activities as-if traditional ABC (2)**	**% Increase in activities** (2) – (1)/(2)
Supplier	10%	28	26%	133	+ 375%
Product	4%	14	13%	20	+ 43%
Customer	9%	29	27%	45	+ 55%
Order	48%	23	22%	87	+ 278%
Route	12%	4	4%	13	+225%
Drop-off	10%	5	5%	23	+360%
Order line	7%	3	3%	9	+ 200%
	100%	**106**	100%	**330**	**+ 211%**

Table 4: Summary of the Time Equations found at Sanac

Time Equation Specifications	Resources in % of total	# of activities	Activities in % of total
$t_{j,k} = \beta_0$	1%	5	5%
$t_{j,k} = \beta_1.X_1$	45%	33	31%
$t_{j,k} = \beta_0 + \beta_1.X_1$	0%	3	3%
$t_{j,k} = \beta_1.X_1 + \beta_2.X_2$	10%	15	14%
$t_{j,k} = \beta_1.X_1 + \beta_2.X_1X_2$	5%	5	14%
$t_{j,k} = \beta_0 + \beta_1.X_1 + \beta_2.X_2$	5%	2	2%
$t_{j,k} = \beta_1.X_1 + \beta_2.X_2 + \beta_3.X_3$	4%	2	2%
$t_{j,k} = \beta_0 + \beta_1.X_1 + \beta_2.X_2 + \beta_3.X_3$	8%	4	4%
$t_{j,k} = \beta_1.X_1 + \beta_2.X_1X_2 + \beta_3.X_1X_3 + \beta_4.X_1X_4$	1%	3	3%
$t_{j,k} = \beta_1.X_1X_2 + \beta_2.X_1X_2X_3 + \beta_3.X_1X_2X_4 + \beta_4.X_1X_2X_5$	4%	3	3%
$t_{j,k} = \beta_1.X_1X_2 + \beta_2.X_1X_2X_3 + \beta_3.X_4 + \beta_4.X_5$	2%	1	1%
$t_{j,k} = \beta_1.X_1 + \beta_2.X_2 + \beta_3.X_3 + \beta_4.X_4 + \beta_5.X_5$	1%	2	2%
Time equations with more than 5 time drivers and more than 5 terms, on average 3,2 two-way interactions and 0,9 three-way interaction per equation	15%	18	17%
	100%	106	100%

Table 5: Summary of the Number of Time Drivers in the Time Equations at Sanac

Time equations with	**Resources in % of total**	**# of Activities**	**Activities in % of total**
Only $ß_0$	1%	5	5%
1 time driver (with or without $ß_0$)	46%	36	34%
2 time drivers (with or without $ß_0$)	20%	32	30%
3 time drivers (with or without $ß_0$)	12%	6	6%
4 time drivers (with or without $ß_0$)	1%	3	3%
5 time drivers (with or without $ß_0$)	6%	6	6%
7 time drivers (with or without $ß_0$)	6%	8	7%
More than 7 time drivers (with or without $ß_0$)	8%	10	9%
	100%	106	100%

Table 6: Summary of the Number of Terms in the Time Equations at Sanac

Time equations with	**Resources in % of total**	**# of Activities**	**Activities in % of total**
1 term in the time equation	46%	38	36%
2 terms in the time equation	15%	33	31%
3 terms in the time equation	9%	4	4%
4 terms in the time equation	15%	11	11%
5 terms in the time equation	1%	4	4%
7 terms in the time equation	3%	3	3%
9 terms in the time equation	3%	3	3%
10 terms or more in the time equation	8%	10	9%
	100%	106	100%

Table 7: Summary of the Type of Interactions in the Time Equations at Sanac

Time equations with	**Resources in % of total**	**# of Activities**	**Activities in % of total**
No interactions	79%	73	69%
Two-way interactions: 1 or more	9%	25	23%
Three-way interactions: 1 or more	12%	8	8%
Higher order interactions	0%	0	0%
	100%	106	100%

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