TECHNOLOGICAL AND ECONOMIC DEVELOPMENT OF ECONOMY
ISSN 2029-4913 / eISSN 2029-4921

2016 Volume 22(4): 512–531
doi: 10.3846/20294913.2016.1190420

ABC MODEL FOR ECONOMIC DEVELOPMENT OF A FIRM

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Received 14 August 2015; accepted 12 May 2016

Abstract. The activity-based costing (ABC) in service companies is considered for minimization companies expenses modeling the uncertainty of service demand in the statistical probabilistic way. The two-stage stochastic programming model is formulated and implemented obtaining the deterministic model as a particular case of the stochastic one. The model takes into account the relation among activities better as compared with other known ones, namely, coherently with the ABC system. The model involves a stochastic demand and a relative minimum level to be satisfied. A modified L-shaped algorithm is developed in order to solve this stochastic optimization model. The applications of the model developed to the hospital service and the Crown prosecution service are considered, too.

Keywords: activity-based costing, economic development, strategic planning, financial management, mathematical programming, two-stage stochastic programming.

JEL Classification: C02, C15, C61, G29.

Introduction

Under the conditions of high competition a low cost of production is becoming one of the main advantages of the firms. The motive of this research is to develop a model for proper calculation of service costs. Wrong calculation of the cost may lead to wrong management decisions, because cost-effective production can be refused, or, vice versa, unpromising production can be even increased (Ríos-Manríquez *et al.* 2014). Application of ABC (Activity-Based Costing) allows the head of a firm to more accurately determine the value of a product, especially in such a situation where indirect costs exceed direct ones (Kolosowski, Chwastyk 2014; Schulze *et al.* 2012; Shapiro 1999).

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Taylor & Francis Group

The Resource-Based View of the firm (RBV) (Bowman, Toms 2010; Kozlenkova *et al.* 2014) is often applied to resource analysis and taxonomy. RBV is an abstract discipline for studying how the firm can create and maintain resources that will provide it with a sustained competitive advantage. ABC and mathematical programming (MP) are approaches for creating data-driven models to analyze decisions on acquiring, adjusting, allocating, and divesting the firm's resources (Giuliani, Meloni 2015). To accurately calculate the cost of production in many firms it suffices to restore the order in the account. When restoring of the order is over, you can refer to more "subtle" tools, one of which is the method of ABC. This method is suitable for cost calculation, when all simpler tools are exhausted. Service industries such as banks, hospitals, insurance companies, and real estate agencies have all had success with ABC. Usually as a result of introduction of this method it is possible to identify 30–40% of the costs in total costs that can be avoided (Lysenko 2008). That allows getting more profit.

Activity-based costing is a costing methodology that identifies activities in an organization and assigns the cost of each activity with resources to all products and services according to the actual consumption by each. This method is based on the fact that the costs are generated by performing certain operations and it assigns manufacturing overhead costs to products in a more logical manner than the traditional approach of simply allocating costs on the basis of machine hours. First ABC assigns costs to the activities that are the real cause of overheads. It then assigns the cost of those activities only to the products that are actually demanding the activities.

Activity-based costing recognizes that the special engineering, special testing, machine setups, etc. are activities that cause costs, – they compel the company to consume resources. Under ABC, the company will calculate the cost of the resources used in each of these activities. Next, the costs of each of these activities are assigned only to the products that demanded the activities.

This method has grown in importance in recent decades. Several reasons have contributed to that. The first one is that manufacturing overhead costs has considerably increased. The second one is that manufacturing overhead costs no longer correlate with the productive machine hours or direct labour hours. The third reason is that the diversity of products as well as customers' demands have grown. The last one is that some products are produced in large batches, while others are produced in small batches.

The ABC model has been considered in detail by (Atkinson *et al.* 2004), where the concepts of activities, cost drivers, activity cost rates, and differences from traditional cost accounting are described. ABC has been extended to mathematical programming in (Giuliani, Meloni 2015), concerning resources and developing forecasts of how costs will vary as functions of the cost drivers. The cost driver is assumed as a resource that may be scarce and therefore may constrain the optimal strategy, and that for which the cost driver is merely an accounting device and not a resource that will constrain the strategy. The former functions are referred as cost/resource functions, and the latter ones as cost/accounting functions. Resources in the former category are called as sustaining resources, while that in the latter category are called as accounting resources.

In this paper, the two-stage ABC stochastic programming model is developed, following to the concepts of (Shapiro 1999), who described a model for supply chain decisions, concerning a particular facility in a deterministic environment, and extending this model to stochastic environment (Giuliani, Meloni 2015). Note, that early ABC concepts (Shapiro 1999) focused their analysis on manufacturing companies. In contrast, this article focuses on service companies, which correspond more to the ABC methodology, even more than the first ones: their justification of this statement is that most of the costs are indirect. A modified L-shaped method, based on Birge's decomposition algorithm (Birge, Louveaux 2011) is also described, but there are a few new changes. The modified L-shaped method is applied to the developed two-stage ABC stochastic programming model, where the statement of ABC is given according to (Giuliani 2009). Software realization and calculations of the model are performed by using Microsoft Visual Studio 2010 with CPLEX Studio 126. The applications to the Hospital Service model and the Crown Prosecution Service model are considered, too.

1. ABC methodology

We can define ABC as a methodology of assigning the organization's resource costs during activities to the products and services provided for its customers, with a view to analyze services, products, customer cost and profitability. It belongs to a broader area of management accounting for identifying, measuring, reporting, and analyzing information on the economic events.

The main differences from the traditional financial accounting are as follows: not historical, but forward-looking, focused on the needs of management rather than on external reports, and pragmatically computed instead of complying with the accounting standards.

The traditional model of activity-based costing is widely described in literature: we can identify two main stages (Siegel, Shim 2010) when implementing the ABC model. In the first stage, costs are assigned to cost pools within an activity center, based on a cost driver. There is no equivalent step in the traditional costing approach. In the second stage, costs are allocated from the cost pools to a product, based on the product's consumption of the activities. This stage is similar to the traditional costing approach except that the traditional approach uses solely volume related characteristics of the product without consideration of non-volume related characteristics. Some examples of cost drivers, not related to volume, include setup hours, number of setups, ordering hours, and number of orders. Allocation of non-volume related costs, using volume-based methods, distorts the product costs.

In the ABC model, overhead expense categories such as administration, rent, transportation, and insurance are identified. These cost data can be usually obtained from accounting. Such expense categories, referred to the traditional way in which a company divides overheads from the general ledger, allow us to identify resources: how to turn from expense categories to resources can be a job of reclassification of expenses in order to have a meaningful classification of our scopes of analysis ("Stage 0" in Fig. 1). At this step, it can be useful to inherit some concepts and ideas from the resource-based view of the firm.

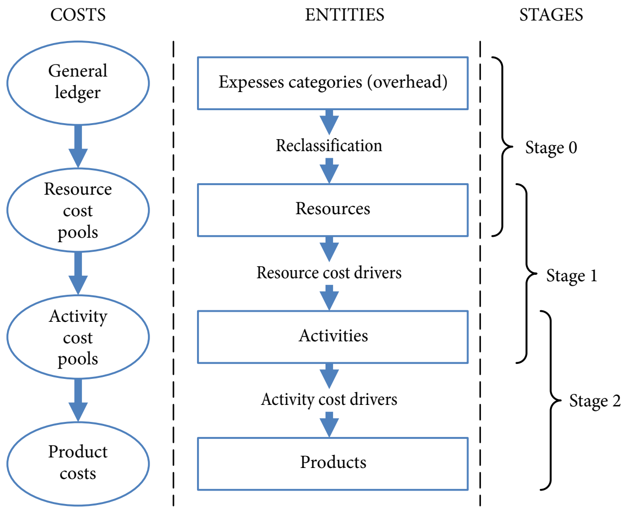

Fig. 1. ABC methodology

The next step is to determine the main activities that simplify the tracing of cost information. It can be accomplished by grouping actions into activities and activities (or cost pools) into activity centers, using the ABC approach. A flowchart of the process or Integrated Definition IDEF0 modeling methods (Colquhoun *et al.* 1993) are commonly used tools for identifying the main activities. Thus, in order to establish the needed activities, homogeneous processes must be grouped together: i.e., product-driven activities and customer-driven activities must be divided into different groups. Some examples of activities for a manufacturing company are: receiving a customer inquiry, customer quotes, production supervision and shipping products. Resources will be assigned to the previously defined activities via the (first stage) resource cost drivers.

In the second stage, activity cost drivers are meant for allocating the overheads to individual products. Figure 1 illustrates the hierarchical relationship among resources, activities, and products. This information will assist the company in validating that the total overhead, calculated at the beginning of the process, matches the total, obtained when summing the overhead assigned to each individual product using ABC.

As a result of ABC the company receives objective information on: the performance and cost of the operations of business processes and divisions; the actual (not calculated according to accounting) cost of the final cost of objects (products, services, customers, suppliers); the degree of loading structural units, officials, and equipment.

In literature connections among mathematical programming and ABC are analyzed in (Shapiro 1999) and ABC implications for operations management in (Gupta, Galloway 2003). Some models which make use of ABC are presented in literature: in (Takakuwa 1997) a model for flexible manufacturing systems in a simulation framework, models for procurement in (Degraeve *et al.* 2005) and for sourcing strategies in (Degraeve, Roodhooft 2000), a model for best product mix in (Gurses 1999) and for logistic process and tactical production planning in (Comelli *et al.* 2008), a viable instrument for small and medium enterprises (Ríos-Manríquez *et al.* 2014) and for financial cost management in (Qingge 2012), for the cost of carbon in (Tsai *et al.* 2012), for life cycle assessment in green building projects in (Tsai *et al.* 2012). Direct Costing and Activity based Costing in a Farm Management System are explored in (Carli, Canavari 2013). ABC and its application in medicine has been described in (Goldberg, Kosinski 2011; Yereli 2009), etc. The integration of activity-based costing and the theory of constraints, as well as the application of a mixed-integer programming model, able to assist in making decisions about product-mix using green manufacturing technologies has been studied in (Tsai *et al.* 2013, 2014). Thus, activity-based costing and process improvement techniques can be utilized together. This fact allows outcomes, i.e, cost and quality, to be simultaneously evaluated.

2. Two-stage ABC stochastic programming model

The stochastic programming model is a means for strategic planning of resources to face stochastic demand, having a net revenue objective function and a minimum level of potential demand to be satisfied. The model has two stages. The first stage is the only pure investment that must have the basic capital. The main income is received after the second stage.

The RBV theory was used for resource analysis and taxonomy. The model consists of raw materials, transformation activities, accounting resources, sustaining resources, fixed resources, design, and policy. Let us define indices, parameters, functions, and decision variables, underlying the deterministic and stochastic ones.

The indices are as follows:
$i \in I$ – raw materials,
$j \in J$ – transformation activities,
$k \in K$ – accounting resources,
$s \in S$ – sustaining resources,
$l \in L$ – fixed resources,
$m \in M$ – design and policy constraints,
$z \in Z$ – output products.

Deterministic parameters and functions are defined as well:
a_{ij} – raw material i units to produce one activity j, $i \in I$, $j \in J$,
a_{kj} – accounting resource k units to produce one activity j, $j \in J$,
a_{sj} – sustaining resource s units to produce one activity j, $s \in S$, $j \in J$,
a_{lj} – fixed resource l units to produce one activity j, $l \in L$, $j \in J$,
a_{mj} – design and policy resource m units to produce one activity j, $m \in M$, $j \in J$
a_{jz} – activity j units to produce one product z, $j \in J$, $z \in Z$,
ρ_l – fixed level of resource l, $l \in L$,
b_m – design or policy parameter concerning m, $m \in M$,
U_j – upper bound on activity j, $j \in J$,
C – facility throughput capacity,
c_z – revenue of product z, $z \in Z$,
c_z^- – cost of penalty for product z, where $c_z^- > c_z$, $z \in Z$,
υ_i – raw material i unit cost, $i \in I$,

υ_i^+ – raw material i inventory unit cost, $i \in I$,
u_k – accounting resource k unit cost, $k \in K$,
u_k^+ – accounting resource k inventory unit cost, $k \in K$,
q_s – sustaining resource s unit cost, $s \in S$,
q_s^+ – sustaining resource s inventory unit cost, $s \in S$,
e_z – minimum rate of satisfied demand for product z, $z \in Z$,
W – budget of raw materials I,
R – budget of accounting resources K,
H_s – maximum of sustaining resource s, $s \in S$,

The connection with ABC, after a subdivision of resources into accounting and sustaining suggested from RBV, is given by the parameters a_{ij}, a_{kj}, a_{sj} and a_{jz}.

The first stage decision variables are denoted as follows:
w_i – quantity of raw material i to be acquired by facility, $i \in I$,
r_k – quantity of accounting resource k, $k \in K$,
h_s – quantity of sustaining resource s, $s \in S$,
The second stage decision variables are as follows:
x_j – level of activity j, $j \in J$,
y_z – quantity of output of product z produced by facility, $z \in Z$,
y_z^- – penalty for product z, $z \in Z$,
w_i^+ – raw material i inventory level, $i \in I$,
r_k^+ – accounting resource k inventory level, $k \in K$,
h_s^+ – sustaining resource s inventory level, $s \in S$.

Following these definitions, the facility model is created according to the concepts considered in (Shapiro 1999).

The first step constraints (denoted by the first stage feasible set D) are as follows:

$\sum_{i \in I} \upsilon_i w_i - W \le 0$ – raw materials budget,

$\sum_{k \in K} u_k r_k - R \le 0$ – accounting resources budget,

$h_s - H_s \le 0$ – sustaining resources maximum.

The second step constraints (second stage feasible set D^+) are following:

$\sum_{j \in J} a_{ij} x_j - w_i + w_i^+ = 0,\ i \in I$ – raw material balance equations,

$\sum_{j \in J} a_{kj} x_j - r_k + r_k^+ = 0,\ k \in K$ – accounting resource balances,

$\sum_{j \in J} a_{sj} x_j - h_s + h_s^+ = 0,\ s \in S$ – sustaining resource constraints,

$\sum_{j \in J} a_{lj} x_j - \rho_l \le 0,\ l \in L$ – fixed resource constraints,

$\sum_{j \in J} a_{mj} x_j - b_m \le 0,\ m \in M$ – design and policy constraints,

$\sum_{z \in Z} a_{jz} y_z - x_j = 0,\ j \in J$ – output product balance equations,

$x_j - U_j \le 0,\ j \in J$ – production bounds,

$\sum_{z \in Z} y_z - C \le 0$ – facility throughput constraint,

$y_z + y_z^- \ge e_z \cdot \tilde{d}_z,\ z \in Z$ – unsatisfied demand constraints.

$y_z \le \tilde{d}_z,\ z \in Z$ – maximum of demand constraints,

where $x_j, y_z, y_z^-, w_i^+, r_k^+, h_s^+ \ge 0$.

Assume the demand d_z of the product z to be distributed normally $N(\bar{d}_z, \delta_z)$, $\bar{d}_z$ is the mean, δ_z is the standard deviation, $z \in Z$.

Let us introduce the first stage function of costs of raw materials, accounting resource, and sustaining resource:

$$\varphi(w,r,h) = \sum_{i \in I} \nu_i \cdot w_i + \sum_{k \in K} u_k \cdot r_k + \sum_{s \in S} q_s \cdot h_s .$$

Denote the function:

$$g(x,y,y^-,w^+,r^+,h^+) = -\sum_{z \in Z} c_z \cdot y_z + \sum_{z \in Z} c_z^- \cdot y_z^- + \sum_{i \in I} \upsilon_i^+ \cdot w_i^+ + \sum_{k \in K} u_k^+ \cdot r_k^+ + \sum_{s \in S} q_s^+ \cdot h_s^+.$$

The first component of this sum defines income and has a minus sign, all other components define costs. The goal is to minimize costs of the first and second stages, so the two-stage stochastic programming problem is as follows:

$$F(w,r,h) = \min_{w,r,h \in D} \left[\varphi(w,r,h) + E_{\tilde{d}} \left(\min_{x,y,y^-,w^+,r^+,h^+ \in D^+} g(x,y,y^-,w^+,r^+,h^+) \right) \right].$$

The negative value of the objective function after two stages will mean expected profits, and positive – expected losses.

3. Modified L-shaped decomposition algorithm

Many practical problems, formulated as multi-stage or dynamic linear programs, require that optimal decisions be made periodically over time. The resulting programs have a staircase structure (Birge, Louveaux 2011). Difficulties may arise in implementing solutions of these programs in the case of uncertainty about some parameters of the model. In these cases, random coefficients are sometimes replaced by their expected values, thus, decisions of the second stage are the same for all scenarios. Note, that received the respective Expected Value Solution (EVS) obtainet in this way may not be optimal for the stochastic program, and the difference between the values of objective functions of EVS and the optimal solution yields us the value of a stochastic solution (Birge, Louveaux 2011). In fact, no linear program which allows for only one solution for each scenario may lead to the optimal solution (Birge, Louveaux 2011). In such a case, a stochastic model must be solved to obtain the optimal solution (King, Wallace 2012). The deterministic equivalent of the linear program is usually very large, and the standard solution procedures may prove very costly. The decomposition method allows solving this problem. It splits the original problem into a master problem and a subproblem which decomposes into a series of independent subproblems.

The standard decomposition L-shaped algorithm requires that the master problem solution should exist, while the second stage solution is zero. Namely, the classic L-shaped two-step algorithm gives the stochastic problem solution, which is obtained specifying the master solution received including only the objective function and constraints of the first stage. But judging ABC challenges, the investor only invests in the first stage, thus, all the coefficients of the objective function at the first stage are negative and, hence, the optimal solution of the first stage does not exist, because it is unbounded, although the solution of the stochastic two-stage problem exists.

In order to adjust the L-shaped to ABC challenges, a modified L-shaped method algorithm was developed, where a master problem is constructed by including the second phase of restrictions. The algorithm is iterative and consists of several steps. The iteration is repeated until the required accuracy is obtained. The algorithm is based on the described decomposition method (Birge, Louveaux 2011). However, several changes have been made.

Before the first iteration we need to define the initial values: $r = s = \nu = 0$, where r is the number of feasibility constraints, s is the number of optimality constraints, and ν is the number of iterations.

In the first step, we solve the linear program (master):

$$\min z = c^T x + q_k^T y + \theta \tag{1}$$

$$\text{s.t. } Ax = b; \tag{2}$$

$$D_l x \geq d_l, \quad l = 1,\ldots,r; \tag{3}$$

$$E_l x + \theta \geq e_l, \quad l = 1,\ldots,s; \tag{4}$$

$$Tx + Wy = h, \tag{5}$$

where $x, y \geq 0, \quad \theta \in \Re$.

There are no constraints (3), (4) in the first iteration and θ is not considered in the computation of x^ν.

Thus, in the first iteration we have:

$$\min c^T x \big| Ax = b, x \geq 0. \tag{6}$$

By solving this program, the initial solution is obtained: $\bar{x}^\nu = x^*$. In a separate case, the initial solution can be selected in other ways, for example, by solving the expected value problems or selecting any solution that satisfies the requirements. In the second step we solve the linear program:

$$\begin{aligned} &\min w' = e^T \upsilon^+ + e^T \upsilon^- \\ &\text{s.t. } Wy + I\upsilon^+ - I\upsilon^- = h_k - T_k x^\nu, \\ &\quad y,\ \upsilon^+, \upsilon^- \geq 0, \end{aligned} \tag{7}$$

where $e^T = (1, ..., 1)$, until, for some scenarios $k = 1, ..., K$, the optimal value $w' > 0$. In this case, let σ^ν be the associated simplex multipliers and define

$$D_{r+1} = (\sigma^\nu)^T T_k, \; d_{r+1} = (\sigma^\nu)^T h_k, \tag{8}$$

to generate feasibility cut constraint (3). Set $r = r + 1$, add to the constraint set (3) and return to the first step. If, for all k, $w' = 0$, go to the third step.

In the third step we solve the second stage linear program

$$\min \omega = q_k^T y \middle| Wy = h_k - T_k x^\nu, y \geq 0, \ k = 1, ..., K. \tag{9}$$

for all scenarios. Let π_k^ν be simplex multipliers associated with the optimal solution of the problem k of type (9). Define

$$E_{r+1} = \sum_{k=1}^{K} p_k (\pi_k^\nu)^T T_k \, , d_{r+1} = \sum_{k=1}^{K} p_k (\pi_k^\nu)^T h_k. \tag{10}$$

Let $\omega^\nu = e_{r+1} - E_{r+1} x$. If $\theta^\nu \geq \omega^\nu$, stop; x^ν is the optimal solution. Otherwise, set $s = s + 1$, add to the constraint set (4), and return to the first step.

Thus, the first termination condition is: $\theta^\nu \geq \omega^\nu$ or $x^\nu - x^{\nu-1} = 0$, i.e. when the solution values also do not change.

4. Hospital service model

"Resource management in hospitals is of increasing importance in today's global economy because traditional accounting systems have become inadequate for managing hospital resources and accurately determining service costs. Conversely, the activity-based costing approach to hospital accounting is an effective cost management model that determines costs and evaluates financial performance across departments. Obtaining costs that are more accurate can enable hospitals to analyze and interpret costing decisions and make more accurate budgeting decisions" (Yereli 2009). Note, that hospitals are a considerable economic factor in many countries. Remarkable investment needs arise from the preservation of this economic factor. A reduction of the operational costs and an improvement of the operating procedures in treatment and care within the hospital are very important as an option for financing the necessary investments (Fellmann 2006).

Let us consider a specific healthcare application of the above described two-stage ABC stochastic programming model. To this end, the "Casa Sollievo della Sofferenza" (i.e., house for relief of the suffering) hospital case was chosen. This hospital, founded by Saint Pio from Pietrelcina in 1956, is one of the National Institutes for Scientific Research (IRCCS) located in the south of Italy (San Giovanni Rotondo) and its research activity is focused on medical genetics; other areas of research are endocrinology, gastroenterology, gerontology, oncology and thrombosis and haemostasis.

It has 7 research laboratories and approximately 150 researchers. Receptivity of the hospital is approximately 1000 beds subdivided among 26 wards: it delivers 50 inpatient specialties and more than 4300 outpatient services, some of which are characterized by a profile of high specialization and, therefore, delayed only in few other hospitals at a national and international level.

The hospital started implementing ABC about ten years ago. The applied methodology and instruments are described in detail in (Crupi *et al.* 2008): the focus of the approach is on finding the cost for each inpatient episode. The data taken from ABC were transformed in a way suitable for a stochastic programming model.

As we can see in Table 1, hospital resources are divided into three groups: raw materials, sustaining and accounting. Drugs and devices are subdivided into different typologies, relevant from a medical and economical point of view. Doctors are subdivided according to their specialty and/or level and the same is done with the other personnel.

Concerning the resource drivers, the total amount of labour hours, identified by the information systems, is split among the activities according to percentages, elaborated within the software, after interviews with managers. The activities, provided in Table 2, have been identified in the ABC system of the hospital and they are mainly focused on the inpatient activity that is a big portion of the managed processes. The difference between the ordinary inpatient care and the day hospital is that the latter requires a stay in the hospital for one or half a day without the need to use a bed. The activity drivers are split for the services: according to a single inpatient care episode and, considering the major diagnosis (even if further diagnoses can be present), we can allocate the inpatient days or surgical operations or interventions or examinations/consulting.

Table 1. Hospital resources

Raw Materials	**Description**	**Driver**
w1	Drugs	Unit number of value 100
w2	Devices	Unit number of value 100
Sustaining	**Description**	**Driver**
h1	Doctors	Labour hours
h2	Depreciation and others	Unit number of value 10000

Accounting	**Description**	**Driver**
r1	Nurses	Labour hours
r2	Auxiliaries	Labour hours
r3	Technicians	Labour hours
r4	Other graduated	Labour hours
r5	Administrative	Labour hours

Table 2. Hospital activities

Acti-vities	**Description**	**Driver**
x1	Ordinary inpatient care	Inpatient days
x2	Day Hospital	Inpatient days
x3	Intensive care	Inpatient days
x4	Surgery	Surgical operations
x5	Invasive Cardiology	Interventions

Acti-vities	**Description**	**Driver**
x6	Medical guard	Inpatient days
x7	Examination and consulting for inpatient care	Examinations/ consultings
x8	Emergency	Treatments
x9	Outpatients care	Examinations
x10	Research	Impact factor score

Hospital services are provided in Table 3. The first eighteen services were given from the international Clinical Classification Software (CCS) (Elixhauser *et al.* 2008): patient diagnoses and procedures are clustered into a manageable number of clinically meaningful categories rather than economically meaningful. The last two services are obtained in an aggregated way, as they are not managed into the ABC system.

Table 3. Hospital services

Servi-ces	Description	Metric	Servi-ces	Description	Metric
y1	Infectious and parasitic diseases	Inpatient days	y11	Neoplasms	Inpatient days
y2	Diseases of the genitourinary system	Inpatient days	y12	Endocrine	Inpatient days
y3	Complications of pregnancy	Inpatient days	y13	Diseases of the blood and blood-forming organs	Inpatient days
y4	Diseases of the skin and subcutaneous tissue	Inpatient days	y14	Mental illness	Inpatient days
y5	Diseases of the musculoskeletal system and connective tissue	Inpatient days	y15	Diseases of the nervous system and sense organs	Inpatient days
y6	Congenital anomalies	Inpatient days	y16	Diseases of the circulatory system	Inpatient days
y7	Certain conditions originating in the perinatal period	Inpatient days	y17	Diseases of the respiratory system	Inpatient days
y8	Injury and poisoning	Inpatient days	y18	Diseases of the digestive system	Inpatient days
y9	Symptoms	Inpatient days	y19	Medical services without inpatient admission	Examinations
y10	Residual codes	Inpatient days	y20	Research products	Impact factor score

5. Crown Prosecution Service model

Next we consider a specific justice application of the ABC model. To this end, the Crown Prosecution service (CPS) case was chosen. CPS is a UK government agency that undertakes legal justice services related to criminal acts in England and Wales. The agency structure was created in the Government Policy Act of 1985 and operations by the agency commenced in 1986.

The original structure of CPS consisted of 14 operational units. Each unit covered a number of cities, urban and rural counties and was geographically linked with several police force boundaries. The nature of CPS work naturally requires the maintenance of close links with the police force and two court systems (i.e. the Magistrates' Courts and the Crown Court). In order to increase cost effectiveness and accountability, CPS was re-organized in April, 1999. This are replaced a 14-operational-unit structure with one consisting of 42 area offices (Areas). Each Area was aligned with individual police force boundaries, apart from CPS's London Area, which was aligned with both the City of London Police and the Metropolitan Police.

CPS has implemented the ABC system since 1995. The intention to extend ABC into resource planning was raised during the re-organization in 1999: time-based ABC information was used in a resource planning system (ABP). CPS has formally adopted the ABP system since 2000 as the only tool for resource allocation across 42 Areas. When adopting ABC, CPS has followed the footsteps of two other government agencies (National Insurance and the Employment Agency) in the UK: the system was driven primarily by time, i.e. the length of time in undertaking an activity, a time-driven ABC approach (Kaplan, Anderson 2004). It was initially implemented in 1995 and revalidated and extended in 2002, so as to capture more than 90 per cent of CPS activities and processes, as well as to provide measures on activity timings, caseload, workload, and resource utilization. Three elements of timings for each every activity are measured: timings of activities directly related to the above prosecuting processes; relaxation allowance timing on the basis of a 5-min break in each working hour; travelling time, which refers to the length of time required by legal staff to travel to the courts and police stations.

The mission of CPS is to face demand for minimizing costs. Anyway, resources are scarce and demand can be not faced at all. It means we have to identify some priorities, fixed at a political level, and that we expect to be positively correlated with the most serious offence categories. The way to satisfy demand taking into account the priorities, is to translate them into incentives: we do that after considering the cost of services, identified by the ABC system that is a sort of revenue/reimbursement delivered by the Treasury to CPS for the services provided.

The first step consists in the definition of resources that are illustrated in Table 4, where it is evident a higher level of details reserved for personnel that are subdivided according to grades, as it accounts the majority of costs.

An ad hoc voice is reserved for training and external personnel that are barristers. A minor portion of costs is subdivided into raw materials and other costs, which are comprehensive, among others, of accommodation, depreciations connected to investments and residual voices. We have chosen higher grades of personnel as sustaining resources that are more difficult to acquire and are directly linked to the strategy: the voice concerning other costs has been chosen because of the presence of depreciation connected to possible investments. Among the accounting resources we find, apart from lower grades, external barristers because they are usually not scarce: training is an accounting resource because its acquisition rate is quite linear and it cannot be considered as a scarce resource. In the end, raw materials are clearly classified, even if not split into analytical clusters: anyway, for our research purposes such a level of detail will be sufficient.

Resource drivers connected with personnel are labour minutes. For other resources the measure "amount of unit value 100" is a monetary one, where 100 is referred to pounds,

Table 4. CPS resources

Raw Materials	Description	Driver
w1	Expenses, travel, stationery, utility costs	Unit number of value 100
Sustaining	**Description**	**Driver**
h1	Managers – Grade D	Labour minutes
h2	Lawyers – Grade C	Labour minutes
h3	Lawyers – Grade B2	Labour minutes
h4	Capital expenditures (accommodation, etc)	Unit number of value 100

Accounting	Description	Driver
r1	Administrative – Grade B1	Labour minutes
r2	Administrative – Grade A2	Labour minutes
r3	Administrative – Grade A1	Labour minutes
r4	Payments to external barristers	Unit number of value 100
r5	Training	Unit number of value 100

chosen because of multiple drivers for raw materials and other costs. In order to make easy the interpretation of variables, a monetary driver has also been chosen for training, where we have different drivers, but of the same measure, and for costs of external barristers, whose driver is given by defendants, concerning the only activities where they are involved.

The activities of the CPS ABC system are shown in Table 5, where the first subdivision is among Magistrates' Court activities, starting from MC, and Crown Court's activities, beginning with CC: the former treat a large majority of records, but the latter treat the most severe cases. A further subgroup among the MC activities is given by the Pre Charge Decisions, in Table 5 starting from PCD.

Crown Prosecution model services are provided in Table 6. All the services have the same metrics – number of defendants.

Table 5. CPS activities

Acti-vities	Description	Driver
x1	MC Advice only	Number of activities/ defendants
x2	MC Other proceedings	Number of activities/ defendants
x3	MC Prosecution dropped	Number of activities/ defendants

Acti-vities	Description	Driver
x12	MC Pre Charge Decision – No Further Action (NFA)	Number of activities/ defendants
x13	MC Pre Charge Decision – Administrative Finalisation	Number of activities/ defendants
x14	CC Committal for sentence	Number of activities/ defendants

End of Table 5

Activities	Description	Driver
x4	MC Write off	Number of activities/ defendants
x5	MC Guilty Either way	Number of activities/ defendants
x6	MC Guilty Summary	Number of activities/ defendants
x7	MC Trial – Either Way	Number of activities/ defendants
x8	MC Trial – Summary	Number of activities/ defendants
x9	MC Discharged Committal	Number of activities/ defendants
x10	MC Pre Charge Decision – Charge	Number of activities/ defendants
x11	MC Pre Charge Decision – Caution	Number of activities/ defendants
x15	CC Appeals	Number of activities/ defendants
x16	CC Write off	Number of activities/ defendants
x17	CC Prosecution dropped	Number of activities/ defendants
x18	CC Timeous guilty	Number of activities/ defendants
x19	CC Late guilty	Number of activities/ defendants
x20	CC Guilty / Not guilty contest	Number of activities/ defendants
x21	CC All not guilty	Number of activities/ defendants

Table 6. CPS services

Services	Description	Metric
y1	Homicide	Number of defendants
y2	Offences against person	Number of defendants
y3	Sexual offences	Number of defendants
y4	Burglary	Number of defendants
y5	Robbery	Number of defendants
y6	Theft and handling	Number of defendants
y7	Fraud and Forgery	Number of defendants
y8	Criminal Damage	Number of defendants
y9	Drugs offences	Number of defendants
y10	Public Order Offences	Number of defendants
y11	All other offences exc Motoring	Number of defendants
y12	Motoring offences	Number of defendants
y13	Pre Charge Services and advices	Number of defendants

6. Calculation results

Results of the Hospital service model are as follows:

Since the most important special case in practical applications arises due to a random right-hand side having a nondegenerate multivariate normal distribution (Birge, Louveaux 2011), the stochastic values in the model considered have a Gaussian distribution, where the variation coefficient was taken 10%. Thus, the model has 127 variables and 78 constraints finally: 13 variables and 4 constraints in the first stage and 114 variables and 74 constraints in the second one. The deterministic solution (i.e. obtained when all stochastic values of the model are fixed and replaced by mean values) has been used as the starting one for the stochastic optimization by a modified L-shaped decomposition method.

500 scenarios were generated for simulations. The optimal solution was obtained after 88 iterations. Deterministic and stochastic solution values are shown in Table 7.

Termination conditions have been satisfied after 88 iterations and the resulting solution was taken as optimal. The program has been stopped when the optimality gap $\omega^{\nu} - \theta^{\nu}$ was equal to zero.

Table 7. Deterministic and stochastic solution values for the Hospital model

Resources	Deterministic solution	Stochastic solution
	Raw Materials	
w1	$1.5 \cdot 10^5$	$1.51 \cdot 10^5$
w2	$2.43 \cdot 10^5$	$2.4 \cdot 10^5$
	Accounting	
r1	$1.76 \cdot 10^6$	$1.76 \cdot 10^6$
r2	$2.5 \cdot 10^5$	$2.47 \cdot 10^5$
r3	$3.56 \cdot 10^5$	$3.71 \cdot 10^5$
r4	$1.95 \cdot 10^4$	$2.1 \cdot 10^4$
r5	$5.97 \cdot 10^3$	$5.99 \cdot 10^3$
	Sustaining	
h1	$8.7 \cdot 10^5$	$8.89 \cdot 10^5$
h2	$2.44 \cdot 10^3$	$2.49 \cdot 10^3$

The expected losses during the iterations of the Hospital model are shown in Figure 2 (A). The corresponding values of optimality gap $\omega^{\nu} - \theta^{\nu}$ are shown in Figure 2 (B) during the iteration ν. These figures illustrate the dynamics of the expected objective function and optimality gap during the optimization process. Although intermediate values can be large, finally the objective function converges to the optimal value and the gap converges to zero.

The minimal expected costs are $6.59 \cdot 10^8$, so the value of stochastic solution is $1.07 \cdot 10^8$. Thus, if one does not take into account the stochasticity of scenarios and takes the same deterministic solution at the second stage, the costs will increase by 14%.

Results of the Crown prosecution service model are as follows:

Similarly as in the previous section, stochastic variables in the Crown Prosecution service model are also taken multivariate normal with the variation coefficient 15%. The

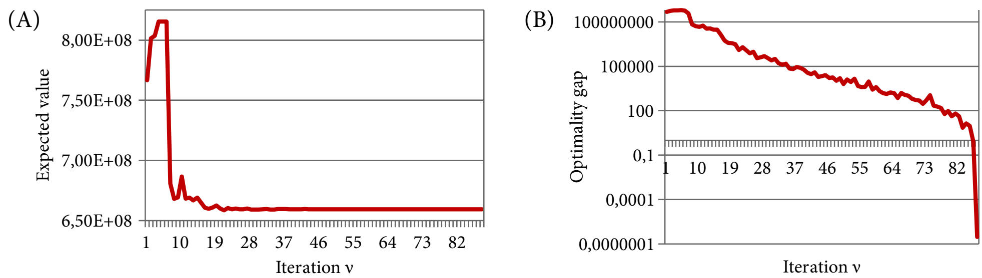

Fig. 2. Stochastic solution values during the iterations

model has 121 variable and 85 constraints: 16 variables and 6 constraints in the first stage and 105 variables and 79 constraints in the second one. The deterministic solution given below has been used as the starting one for the stochastic optimization by a modified L-shaped decomposition method.

500 scenarios were generated for simulations. Termination conditions have been satisfied after 32 iterations and the resulting solution was taken as optimal. The program has been stopped when the optimality gap $\omega^{\nu} - \theta^{\nu}$ was equal to zero. Deterministic and stochastic solution values for the Crown Prosecution model are shown in Table 8.

Table 8. Deterministic and stochastic solution values for the Crown Prosecution Service model

Resources	**Deterministic solution**	**Stochastic solution**
	Raw Materials	
w1	$7.42{\cdot}10^5$	$6.72{\cdot}10^5$
	Accounting	
r1	$1.11{\cdot}10^8$	$1.03{\cdot}10^8$
r2	$8.59{\cdot}10^7$	$7.95{\cdot}10^7$
r3	$6.03{\cdot}10^7$	$5.59{\cdot}10^7$
r4	$1.18{\cdot}10^6$	$1.09{\cdot}10^6$
r5	$2.57{\cdot}10^4$	$2.36{\cdot}10^4$
	Sustaining	
h1	$2.86{\cdot}10^7$	$2.62{\cdot}10^7$
h2	$1.92{\cdot}10^8$	$1.75{\cdot}10^8$
h3	$3.35{\cdot}10^7$	$3.09{\cdot}10^7$
h4	$5.15 \cdot 10^4$	$4.71{\cdot}10^4$

The expected losses during the iterations of the Crown prosecution service model are shown in Figure 3 (A). The optimality gap $\omega^{\nu} - \theta^{\nu}$ values are shown in Figure 3 (B) during the iteration ν.

As we can see in Figure 3, the objective function converges to the optimal value and the gap converges to zero. The minimal expected costs are $3.99{\cdot}10^8$, the value of stochastic solution is $2.68{\cdot}10^7$, i.e. 6.29%.

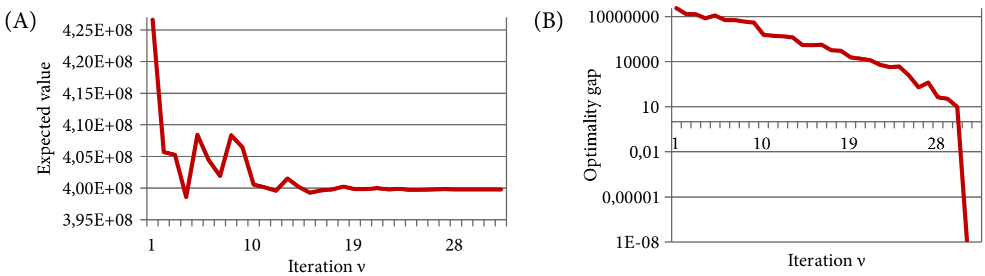

Fig. 3. Stochastic solution values during the iterations

Conclusions

The economic development is closely related to strategic planning. The main goal of the Strategic Planning is an effective use of the limited resources (financial, material, human, and others): goals and methods for the coming periods are determined; resources to achieve these objectives are attracted. An effective use of the resources allows saving and thus increases the profit. The cost reduction to the rational level will ensure the growth of the economic efficiency and increase the competitiveness of the firm.

From the formulation and application of the proposed approach we have seen that it is possible to formulate stochastic programming models which use the data coming from the ABC system and a taxonomy of resources from the RBV theory. The models can be used to face situations, where the strategic planning of resources is required, when the demand is uncertain: the usefulness of the stochastic approach is showed by two applications in the service sector: both in the hospital and the Crown Prosecution Service, we obtain a positive value of the stochastic solution. In fact, such value measures gain from using the stochastic approach with respect to a deterministic one, which ignores the variability of demand. The interpretation of the results has been made according to RBV that furnishes a framework for the analysis of resources according to their strategic value, which is extremely important in order to identify the competitiveness of a firm.

One of the main peculiarities of the models is that they are based on data coming from the ABC system that is an accounting technique quite widespread among both manufacturing and service companies. Thus data availability, accuracy and updating should be ensured to guarantee a possible implementation of the models, without an extensive effort in estimating difficult and expensive ad-hoc parameters and variables. In fact, the two case studies organizations, as both had already implemented the ABC methodology, have not required a strong effort in data gathering. Anyway, more detailed analyses, i.e., more disaggregated activities or resources or services, can require an adequacy of the ABC accounting system to the optimization purposes: this is not a negative aspect but a better use of the existing accounting system. Application of the model is limited by the necessity to collect and save data of resources, activities and services.

The formulated stochastic programming model is two-stage: the deterministic model has been obtained as a particular case of the stochastic one and it differs from that proposed in literature in order to better take into account the relation among activities, coherently with the ABC system. The model has been implemented in our two case studies.

The connections among stochastic programming, ABC and RBV, have shown a multiplicative positive effect in order to use the potential of mathematical modeling and, anyway, a further research can amplify such a potential. In general, future directions could be oriented towards the introduction of further details in the models (suppliers, markets, etc.) or solutions with nonlinear sustaining functions and continuous distributions (e.g., Monte Carlo approximation, Sakalauskas 2004; Sakalauskas, Zilinskas 2010). Moreover, the introduction of further stochastic variables, beyond demand, can be useful for describing parameters such as prices, revenues, or technical coefficients, in particular, those estimated by the Activity-Based Costing system.

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