# A Model for Cost Deviation Analysis and Prescriptive Analytics

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**Abstract.** A cost variation within an acceptable range is considered an "event under control" and does not require investigation or action. Nevertheless, often, managers investigate cost variations based on historical data and subjective judgments or empirical rules. Both, positive and negative cost variations may represent a problem, for example, if service levels and quality standards are not achieved. This paper presents a model and a methodology that allows establishing the acceptable range for cost analysis towards a predictive analytics approach. Monte Carlo simulation is used to compute the inherent variability in the processes. This methodology was tested in a case study, obtaining, as a result, the range of standard values which serve as a basis for operational and tactical decisions in the organization. Potential applications and opportunities for further developments and research are also discussed. Namely, the use of simulation that allows obtaining results in a short time for day-to-day decisions within the organization.

**Keywords:** Cost deviation · Costing systems · Prescriptive analytics · Monte Carlo simulation

## 1 Introduction

Good cost estimation has a direct bearing on the performance and effectiveness of a firm because overestimation can result in loss of business and goodwill in the market, whereas underestimation may lead toward financial losses to the enterprise. Because of this sensitive and crucial role in an organization, cost estimation and control has been a focal point for the design of operational and strategic plans and a key agenda for managerial policies and business decisions [1].

Prescriptive cost models support optimized decision making going beyond the analysis of ex-ante data. To perform an application of a prescriptive cost models it is necessary to use mathematical cost models, mathematical algorithms or parametric equations which can be used to model and estimate cost behavior in order to optimize certain objectives constrained by a set of relevant conditions. Relationships and patterns within large volumes of data can be used to predict behavior and events. Business analytics can be put into practice through three different phases of analysis:

– descriptive, which uses business intelligence and data mining to ask: "What has happened?",


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– predictive, which uses statistical models and forecasts to ask: "What could happen?" and, finally, the most sophisticated of these approaches,
– prescriptive, which uses optimization and simulation to ask: "What should we do?".

Managers use feedback on cost deviations to initiate corrective actions. A fundamental question is for what level of variation it makes sense to initiate such actions and which variations can be considered normal in production and business processes. Usually, this is done empirically, however, analytical techniques can be used to set such limits considering the inherent characteristics of the process as the expected variability of the production or business system.

To determine these variations, we developed a model based on Activity-Based Costing (ABC), used to calculate more accurately and allocate better indirect costs which are an increasingly important component of the total cost [2]. By focusing on the activities, ABC offers, among others, the following advantages: it identifies the activities that do not add value, identifies expensive or inefficient processes, facilitates continuous improvement, and reduces costs.

## 2 Standard Costing

The standard costing system is a costing system that essentially measures the effectiveness and efficiency of manufacturing. Standard costs are predetermined costs. However, not all predetermined costs are standard costs. In companies, in addition to actual and effective costs, so-called theoretical costs are assumed on a regular basis and with different objectives. These costs are called basic costs or conventional costs. For the basic cost of each resource one can consider its market price, the average cost of previous periods, the cost of reproduction or the standard cost.

The standard costs are obtained based on the results of previous periods and assume a set of conditions that reflect the normal efficiency of the factors. According to [3] standard cost is the base cost of a product, according to current and/or expected operating conditions. It is based on normal or ideal conditions of efficiency and volume mainly related to indirect costs. Direct costs, such as labour and materials, can be calculated taking current conditions into account. In [3] the authors high-light two essential components in a standard cost: the existence of a standard and a cost. By default, we refer to the physical characteristics inherent in a given operation, which in turn necessarily imply a cost. They may be the hours of required work or the quantity of a given material. Basically, it can be said that behind a standard cost there is always a physical standard. Determining this physical standard is an engineering job.

The authors [3] highlight two essential components in a standard cost: the existence of a standard and a cost. By default, we refer to the physical characteristics inherent in a given operation, which in turn necessarily imply a cost. They may be the hours of required work or the quantity of a given material. Basically, it can be said that behind a standard cost there is always a physical standard. Determining this physical standard is an engineering job.

According to [4] standard costs can be of three types: ideal or theoretical, basic (or normal) or current. The ideal standard cost corresponds to the case in which the production is carried out in the best possible conditions. When quantities, prices and degree of utilization are normal, the standard cost is normal. In this situation, information from past experience is considered. The current standard cost is based on the planned production for the period in question and takes into account the current conditions.

The authors [3] distinguish standard costs into only two types: the basic standard cost and the current standard cost. The basic standard cost is the one that reflects the conditions of productive efficiency, so it is also called ideal cost. The current standard cost considers the particular conditions of the period in question and may therefore differ from previous ones.

Standard costs are not calculated on a historical basis, but on the basis of the technological limitations of production and the knowledge of production processes. As predetermined costs, they indicate how much should be spent, thus allowing cost control. The standard cost would be that which would exist if a set of hypotheses in production are fulfilled. It is different from a budgeted cost that is essentially a forecast and a much more high-level governance tool. In this system, costs are calculated the opposite of what is done in process and order costing systems. The costs of each cost center are calculated first and only then the unit costs are obtained. In the standard costing system, first the unit costs are calculated and, at a later stage, the total production costs are computed.

In highly diversified production enterprises, the standard cost system may be the only practical possibility for determining the cost of products. This occurs when, in a cost-benefit analysis of alternative costing systems, it is discovered that it is not economically feasible to use methods based on actual quantities of inputs. In these cases, the criteria of operability and economic rationality are contrasted with the calculation of costs with greater precision.

Methodologically, standard costing is carried out in five stages. In the first stage, the standard costs of the production factors are defined, taking into account the technology used and the history and experience accumulated. In the second phase, standard consumptions are calculated. In the third phase, activity levels are calculated and in the fourth phase, the manufacturing overhead budget is included. Finally, overloads of defective products are taken into account. In other words, first the technological costs are calculated, knowing the normal consumption of inputs (physical standards) and then the respective costs are calculated (standard costs). The standard cost of a product is obtained by multiplying the standard unit consumption by the standard cost per factor. Once the actual costs have been calculated, they can be compared with the standard costs by analysing the deviations. In this sense, standard costs are assumed as efficiency measures. Typically, this is calculated by breaking down the standard cost into its three main components: materials, labour and manufacturing overheads.

The analysis of deviations is done at two levels: price and quantity. In addition to these two types of deviation (quantity deviation and price deviation), the total deviation can also be obtained, which is no more than the sum of the other two as shown in Eqs. 1 to 6.

$$\text{Total Deviation} = \text{Actual Cost} - \text{Standard Cost} \quad (1)$$

$$\text{Total Deviation} = \text{Actual Quant} \cdot \text{Real Price} - \text{Standard Quant} \cdot \text{Standard Price} \quad (2)$$

$$\text{DT} = \text{RQ} \cdot \text{RP} - \text{SQ} \cdot \text{SP} \quad (3)$$

Adding and subtracting RQ · SP, the total deviation must be equal to:

$$\text{DT} = \text{RQ} \cdot (\text{RP} - \text{SP}) + \text{SP} \cdot (\text{RQ} - \text{SQ}) \quad (4)$$

where:

$$\text{Price deviation} = \text{RP} - \text{SP} \quad (5)$$

$$\text{Quantity deviation} = \text{RQ} - \text{SQ} \quad (6)$$

The model adopted in this research is an activity-based cost model and thus it is not necessary to consider the traditional distinction in the aforementioned three types of deviations: materials, labour and manufacturing overheads. The analysis of deviations in direct and indirect costs can always be done at the level of quantity (e.g., kilograms consumed, hours worked) and price (of inputs) or unit cost calculated for the activities (in this case, in the formula, price is replaced by unit cost). Activity-based costing is a full costing system but in our model we may not consider, for the purpose of calculating the standard cost, certain costs (for example, fixed or general costs which can be allocated to the structure). Or, on the other hand, highlight the non-utilization of resources through the accounting of idle capacity (in the logic of Time Driven ABC) or activities without added value associated with inefficiency and waste (in the context of Lean accounting).

Standard costs are especially important for companies with a long production cycle that manufacture a single product or for those that manufacture a small number of different products in series. However, standard costs are also useful in other situations. Using a standard costing system allows us to understand the production cost and its components. On the other hand, also allows for a more detailed analysis of manufacturing processes. They can be used also for the definition and analysis of pricing policies and strategies for the organization and for production management purposes namely, in terms of productivity.

Standard costs are often used as instruments for the decentralization of responsibilities. Because a standard costing system makes it easier to identify the causes of abnormal costs and to identify or indicate causes. And finally, its adoption considerably simplifies the exercises of management control and the different evaluations that the company must carry out periodically.

In [5] list other benefits associated with a standard costing system. First, it is a less costly method than the permanent calculation of actual costs. On the other hand, it allows to define goals at the operational level. It is often a valuable cost control tool. Last but not least, standard costs can support decision-making, particularly, performance analysis.

## 3 Model and Methods

Let, $n$ resources, $m$ activities and/or products. For the estimation of costs, the following matrix model was used, taking into account the following parameters:

$CR := (cr_{ij})_{n\times 1}$ = Cost of resources used,

$AR := (ar_{ij})_{m\times m}$ = Relation activity resource, where $\sum_{i=1}^{m} ar_{ij} = 1\, \forall j$,

$CA := AR \cdot CR = (ca_{ij})_{m\times 1}$ = Cost of each activity,

$PA := (pa_{ij})_{o\times m}$ = Activity products relationship, where $\sum_{i=1}^{o} pa_{ij} = 1\, \forall j$,

$CP := PA \cdot CA = (cp_{ij})_{o\times 1}$ = Cost for each of the products or services.

To build the model that recognized de variability, it is assumed that $ar_{ij}, pa_{ij}$ are uncertain parameters. A sample $ar^{e}_{ij}, pa^{e}_{ij}$ are generated for each input parameter $ar_{ij}, pa_{ij}$ using their probability density function (PDF) Which is derived from the fit analysis of each parameter (i.e. the Anderson-Darling test or The Kolmogórov-Smirnov (K-S) test). The expected result must be calculated for the result or output (the cost of the product or services), the value of $cp^{e}_{ij}$ are the outcome variable, which is calculated considering:

$$cp^{e}_{ij} = f(ar_{ij}, cp_{ij}) \tag{7}$$

The procedure is repeated for s number of iterations. Finally, the outcomes are analyzed using statistic criteria, histograms, confidence intervals, among others statistics. Using the logic of the Decision-analytical modelling (DAM) the proposed model was applied in a real case [6]. One of the methods used to understand and to manage uncertainty is the Monte Carlo Simulation. A Monte Carlo simulation was made and interesting results were obtained. Indeed, probabilistic costing models are tools that can be used to turn costing systems more relevant, contributing to improve decision making. This new model can be used to deal with uncertainty in an extended ABC model (which includes uncertainty) that offers additional and very valuable information for budgeting and cost management. The model was applied in a textile company and allowed to determine the limits for which a deviation in the cost of the product can be considered normal and when a deviation warrants a preventive, corrective or improvement action. The deviations in the production cost of two types of yarn were analysed considering a production process based on 12 resources (including raw material) and 5 main activities.

## 4 Application and Analysis

The model was applied in a textile company that allowed to use it to determine the limits for which a deviation in the cost of the product can be considered normal and when a deviation justifies a preventive, corrective or improvement action. The deviations in the production cost of two types of yarn were analysed by considering a production process based on 12 resources (including raw material) and 5 main activities.

The textile company A is specialised in home textiles, especially in the bedspread subsector. In 10 years, the industrial surface increased from 840 $m^2$ to 11.340 $m^2$, distributed in 3 buildings. The turnover has tripled in 3 years, which reflects the great growth of the company in recent years.

The company exports to 24 countries and the U.S. market accounts for about 70% of sales volume. In terms of human resources, it employs 220 workers in the factory, with an average age of about 35 years, which allows it to present itself as a company with solid, properly updated and capable of achieving high productivity rates. The company produces yarn through its spinning unit. The activity-based costing methodology was used to estimate the production cost of two types of yarns (P1 and P2 products) produced in a given period. The following tables provide information on the costs of the resources employed and on the process. Table 1 represents the consumption of resources by each of the activities required to produce the products. Table 2 represents the consumption of the activities by each one of the products.

**Table 1.** Resource consumption by activity.

| Resources | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading | | 5,05 | | | | 76.431 | | | 15% | 150 | | 76.431 |
| Combining | | 2,00 | 5,18 | 100% | | | | | 15% | 180 | 20% | |
| Twisting | | 2,00 | 51,41 | | 100% | | | | 40% | 270 | 80% | |
| Emplasticize | | | 0,04 | | | | | 1 | 20% | | | |
| Storing | | 4,95 | | | | 75.668 | | | 10% | | | 75.668 |
| Raw materials | 100% | | | | | | | | | | | |
| Cost driver | Direct | Workers | Kw | Direct | Direct | Kg | Direct | % | $m^2$ | $m^2$ | % | Kg |
| Cost | 111.05 | 10.802 | 2.348 | 235 | 2.648 | 265 | 69 | 1.224 | 1.091 | 329 | 191 | 19 |

R1: Raw Materials, R2: Direct Labour, R3: Energy, R4: Combing, R5: Twisting, R6: Forklift, R7: Emplasticizer, R8: Indirect Labour, R9: Air-Conditioner, R10: Building, R11: Compressor, R12: Scale.

**Table 2.** Activities consumption by product.

| Activity | Loading | Combing | Twisting | Emplasticizer | Storing | Raw materials |
|---|---|---|---|---|---|---|
| Yarn 4/2 | 44.389 | 12.682 | 23.040 | 106 | 43.946 | 66.583,49 |
| Yarn 6/2 | 32.042 | 12.588 | 23.040 | 76 | 31.722 | 50.466,75 |
| Idle capacity | | 650 | | | | |
| Cost driver/units | Hours | Hours | Hours | Pallets | Kg | Euros |

The information in Tables 1 and 2 was standardized to produce Tables 3, 4 and 5, which were used in the cost model presented before to compute activity and product costs.

**Table 3.** Resource-activity matrix.

| | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,00 | 0,36 | 0,00 | 0,00 | 0,00 | 0,51 | 0,00 | 0,15 | 0,25 | 0,18 | 0,00 | 0,51 |
| A2 | 0,00 | 0,14 | 0,09 | 1,00 | 0,00 | 0,00 | 0,00 | 0,15 | 0,30 | 0,21 | 0,20 | 0,00 |
| A3 | 0,00 | 0,14 | 0,91 | 0,00 | 1,00 | 0,00 | 0,00 | 0,40 | 0,45 | 0,32 | 0,80 | 0,00 |
| A4 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 | 0,20 | 0,00 | 0,00 | 0,00 | 0,00 |
| A5 | 0,00 | 0,35 | 0,00 | 0,00 | 0,00 | 0,49 | 0,00 | 0,10 | 0,00 | 0,29 | 0,00 | 0,49 |
| A6 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |

**Table 4.** Activity-product matrix.

| | A1 | A2 | A3 | A4 | A5 | A6 |
|---|---|---|---|---|---|---|
| P1 | 0,58 | 0,49 | 0,50 | 0,58 | 0,58 | 0,57 |
| P2 | 0,42 | 0,49 | 0,50 | 0,42 | 0,42 | 0,43 |
| P3 | 0,00 | 0,03 | 0,00 | 0,00 | 0,00 | 0,00 |

**Table 5.** Resource-product matrix.

| | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | 0,57 | 0,56 | 0,50 | 0,49 | 0,50 | 0,58 | 0,58 | 0,53 | 0,52 | 0,54 | 0,50 | 0,58 |
| P2 | 0,43 | 0,44 | 0,50 | 0,49 | 0,50 | 0,42 | 0,42 | 0,46 | 0,48 | 0,46 | 0,50 | 0,42 |
| P3 | 0,00 | 0,00 | 0,00 | 0,03 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,01 | 0,01 | 0,00 |

With this information, using the costing model we obtain the standard cost for each of the activities, their distribution in the products and the cost for each product, as shown in Table 6, allowing also to evaluate the profitability per product.

**Table 6.** Product costs.

| | Yarn 4/2 | Yarn 6/2 | Inactivity | Total |
|---|---|---|---|---|
| Loading | 2,646 | 1,910 | | 4,556.12 |
| Combing | 1,279 | 1,269 | 66 | 2,613.46 |
| Twisting | 3,692 | 3,692 | | 7,384.36 |
| Emplasticize | 184 | 132 | | 361.54 |
| Storing | 2,426 | 1,751 | 66.54 | 4,176.46 |
| | | | | 19,046.94 |
| Raw material | 66,583.49 | 50,466.75 | | 117,050.24 |
| Total | 76,810.37 | 59,221.27 | 65,54 | 136,097.18 |

Once analyzed in the model, it was found that several production factors have variability in the production process, which introduces variability in the cost of the products. Analyzing the production factors, the cost of raw material is the one that most affects the cost of the products and this is in turn related to the twisting activity because the dimension of the yarn spools, which in the deterministic model is 3.5 kg, however by practical experience it is considered that this can vary between 3.1 kg and 3.85 kg. Taking into account this information, it was considered that this parameter could be modeled by a triangular distribution, which is commonly used in cost analysis with uncertainty [7]. For the development of the model we used the software @risk 7.6 and 10,000 simulations of the deterministic model were run. Once the simulations were run, the probability distribution of each of the product costs could be obtained, from which, taking as a reference a tolerance limit of 20% above and below the average, tolerance limits could be obtained as shown in Figs. 1 and 2.

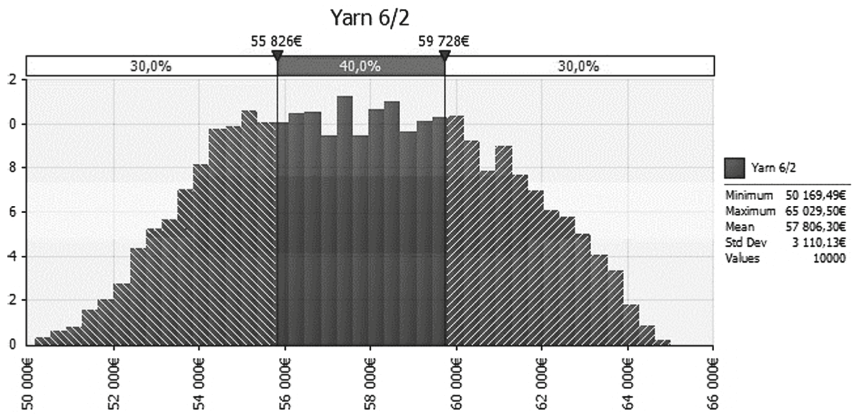


**Fig. 1.** Tolerance limits for yarn 6/2.

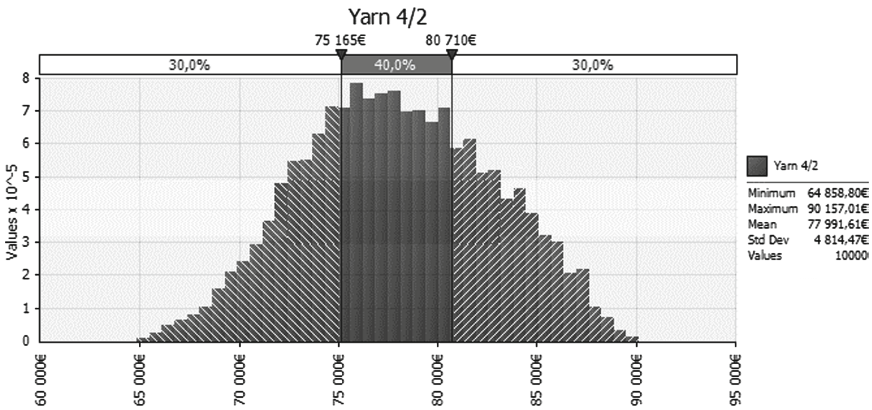


**Fig. 2.** Tolerance limits for yarn 4/2.

As can be seen in each figure the analysis is as follows with the current conditions there is an expected average value of the cost for each product, the company accepts a variation more or less than 20% of its average, any variation that is below or above that value must be investigated, if it is within that value is accepted as within control.

A cost variation within an acceptable range is considered a “controlled event” and does not require investigation or action. However, managers often investigate cost variations based on historical data and subjective judgments or empirical rules. Both positive and negative cost variations can be a problem, for example, if service levels and quality standards are not met. This paper presents a model and methodology for establishing the acceptable range for cost analysis toward a predictive analytical approach. Monte Carlo simulation is used to calculate the variability inherent in the processes. This methodology was tested in a case study, resulting in the range of standard values that serve as the basis for the organization’s operational and tactical decisions. Potential applications and opportunities for future development and research are also discussed.

Decision makers analyze variations to evaluate performance after decisions are implemented, in order to activate the process of learning about the cost behavior of the organization and make continuous improvements. Variations serve as a timely warning system to alert managers to existing problems or potential opportunities. Variation analysis allows managers to evaluate the effectiveness of actions and performance in the current period, and refine strategies to achieve better future performance.

To ensure that managers correctly interpret variations and make appropriate decisions based on them, they need to recognize that variations can have multiple causes, that variations must be quantified, and that not all variations merit corrective action, this will depend on the limits set for a deviation to be considered normal or out of control. In the era of large data, artificial intelligence, automatic learning and business analytics, must be done before costs occur, supporting effective predictive analytics in practice, here Monte Carlo simulation can be considered an effective tool for such analysis.

This article proposes a model that allows these limits to be established taking into account the production process and the factors that generate costs. Simulation allows results to be obtained quickly, at low cost and useful for decision making. The potential of the method presented here is that it can be adapted to any type of organization and the use of simulation allows results to be obtained in a short period of time for daily decisions within the organization.

## 5 Conclusion

An adequate management of the variability in production processes allows companies not only to understand their production processes but also the impact that variability has on production costs and therefore on the profitability of the company. Traditionally, standard costing has been used to analyze the variability in costs. In this article we propose to see the standard as a range of possible values where being within that range is considered normal and outside that range, abnormal. This point of view allows us to really concentrate on analyzing the relevant variations and creates awareness that variability is inherent in most production processes.

This analysis is important. Indeed, decisions makers analyse variations to evaluate performance after decisions are implemented, in order to activate the learning process on the organization’s cost behaviour and make continuous improvements. Variations serve as a timely warning system to alert managers to existing problems or potential opportunities. The analysis of variations allows managers to evaluate the effectiveness of the actions and the performance in the current period, and to refine the strategies for achieving better future performance.

In the era of big data, artificial intelligence, machine learning and business analytics we should do this before costs happens supporting effective predictive analytics in practice. Thus, we propose a model that allows to set those limits taking into account the production process and the drivers that generate costs. Simulation allows to obtain results quickly, at low cost and useful for decision making. The potential of the method presented here is that it can be adjusted to any type of organization and using simulation allows obtaining results in a short time for day-to-day decisions within the organization.

An opportunity for future work is taking advantage of the potential of the Monte Carlo simulation namely, for the analysis of the correlations between the production factors, between the consumption of resources by activities and of the activities by the different products. In traditional standard costing this is not taken into account since only deviations are evaluated whether of price or quantity.

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