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AUTHOR Johnson, Gordon; Baum, Paul
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ABSTRACT

With tighter budget allocations, funding for different university budgets items must be managed more judiciously. Subjective criteria are often used to allocate funds to colleges within a university, with the result that allocation decisions can be based on spending differences that are not statistically significant. A statistically based method of managing spending levels would avoid this problem. A control chart appears to be an appropriate statistical tool if modified to account for size differences among academic departments. This paper proposes a control chart modified in this manner. Such a control chart, modified depending on the level at which it was applied, reduces the impact of political pressures on the budget process since it provides an objective basis for allocating funds and establishing accountability. (Contains 10 references.) (Author/SLD)

Running head: STATISTICALLY BASED BUDGET ALLOCATION PROCESS

A Statistically Based Budget Allocation Process

Gordon Johnson

Paul Baum

California State University, Northridge

Abstract

With tighter budget allocations, funding for different university budget items must be managed more judiciously. Subjective criteria are often used to allocate funds to colleges within a university, with the result that allocation decisions can be based on spending differences that are not statistically significant. A statistically-based method of managing spending levels would avoid this problem. A control chart appears to be an appropriate statistical tool if modified to account for size differences among academic departments. This paper proposes a control chart modified in this manner.

A Statistically Based Budget Allocation Process

In an environment where state funds for university support must be supplemented with private fund arising efforts, university administrators must become more efficient managers of the budget allocation process. In particular, this requires a solution to the problem of allocating funds to different colleges (or schools) within the university in the most efficient manner possible. We focus on one budget area--a college's travel budget. However, the methodology can be readily extended to other budget areas–for example, spending on supplies, copying, and budgets for improving the efficiency of the educational process. An important metric in the latter category is mean time to graduation.

This paper develops a statistically based model to address the issue of allocating scarce resources among competing uses. Additionally, the paper will discuss the implications of the model as a tool for managing a university budget allocation process.

Review of Previous Studies

To what extent have control charts been applied to a university budgeting process in the past? A search of the literature reveals that control charts have rarely been used as a tool for monitoring a university budgeting process. Most articles--for example, Cyert (1981) and Jones (1984)--lack specific applications, data, or analytic tools. By contrast, Kemper (1985) presented an actual budget document in his article on faculty allocation formulas. Dickman (1996) reported the results of a survey of university administrators regarding the process of budget reduction.

Budget cuts were also addressed by Kissler (1985). The only article that applied control charts to a university budgeting problem, in particular, monitoring faculty workloads, was by Lau (1996).

What has been the focus of prior studies on developing metrics that could be used to manage a university budget process? Middaugh and Hollowell (1992) attempted to compare expense ratios among departments. They displayed several budget tables, showing time series trends of such ratios as FTE students/FTE faculty and cost/FTE student, as well as administrative expenses. Additionally, they emphasized that one can not compare expense ratios among departments with different equipment needs. Also, the authors caution that comparisons of ratios should be restricted to similar departments at similar universities. One limitation of their analysis is that it makes no attempt to differentiate between statistically significant differences in expense ratio and differences that merely reflect random variation. One possible explanation for ignoring the statistical significance of their results is the difficulty in performing statistical test when dealing with ratios. It should be noted that their article was written in the environment of budget cuts in the early 1990s, so the focus was on developing metrics to identify programs that should have reduced budgets. However, the general concepts can also be applied to decisions surrounding budget increases.

Smith (1992) expands on the idea of comparing ratios with comparable universities by focusing on similar disciplines. Index numbers are used to compare expenses at one university with the average expense for several universities. First, the cost per student credit hour (SCH) is calculated for each discipline. Next, the Discipline Cost Index (DCI) is obtained by dividing the cost/SCH by the average cost/SCH for the benchmark universities. The DCI is used to determine a standard cost unit for each discipline, which in turn is part of a formula to calculate a budget allocation.

Savenije (1992) explains that university budgets not only allocate funds, but also help achieve goals and promote the accountability process. He identifies two general components of a budget: (1) lump sum, or base component, which does not have direct ties to specific outcomes, and (2) earmark component, which is often for special projects. Faculty expenses are a major example of a base component, while earmarked funds often go to programs to achieve goals specified by management. At many universities applications for earmarked funds are reviewed by management in a competitive process.

Massy (1989) discusses two approaches to decentralized budgeting: (1) responsibility centers, which include both income and expense data, and (2) block budgeting, where only spending decisions are made at the division level.

Use of Control Charts

Based on the above literature review, two vital functions of the budget is to allocate resources and establish accountability for outcomes. A statistical control chart is a very effective tool for accomplishing both of these objectives. The use of control charts provides an objective basis for accomplishing the following objectives: (1) allow the administrator to distinguish between random differences in spending levels among departments within a college and differences that are statistically significant; (2) provide reasonable protection against Type I and Type II errors. A Type I error occurs if a department is falsely accused of over-or under-utilizing resources. A Type II error is committed when failing to detect a department that is under-or over-utilizing resources.

If the control chart reveals that a department's mean expenditure on a given budget item is significantly higher than the mean for the college, an increase in the department's allocation during the next budget period may be justified, depending upon the nature of the assignable cause responsible for the significant difference. Conversely, if a department's mean expenditure on a given budget item is significantly lower than the mean for the college, a decrease in the department's allocation during the next budget period may be justified, depending, once again, on the nature of the underlying assignable cause. The third possible outcome is when a department's mean expenditure on a given budget item is not significantly different from the college mean. In this case, the most efficient use of resources may be to set the department's allocation in the next budget period equal the mean for the college.

A Control Chart for Travel Expenditures

What is the appropriate type of control chart for monitoring a university budgeting process? If the goal is to monitor the use of resources at the department level relative to the college, an X-bar and S chart seems appropriate. To monitor, for example, travel spending among departments within a given college, the center line on the X-bar chart would be the mean spending level of the college. The plotted points would represent each department's mean travel expenditure, or the mean expenditure per faculty member. The S chart plots the department standard deviations to determine if any departments exhibit significantly lower or higher variation in spending levels relative to the college.

Statistical Control

If a department's mean falls within the control limits, the department's mean is not significantly different from the mean travel expenditure for the college. If the means of all departments within a college fall within the control limits, it can be concluded that no department is spending excessively more or appreciably less than any other departments within the college. The differences in the expenditure levels among the departments are due to random variation. The travel budget process within the college is said to be in statistical control. As such, the budget process represents a stable system, and, as a result, its future performance is predictable. Any attempt to change the college mean can only be achieved by changing the system--that is, the policies and procedures that govern the use of travel funds–and not by exerting political pressure on a particular department to utilize its resources more efficiently.

Special Causes

If a department's mean falls above the upper control limit, is can be concluded that the department's mean is significantly higher than the mean for the college. This outcome may be due to one of two underlying special causes: The department is more productive than other departments in the sense that the faculty within this department present more papers at professional meetings, or are actively involved as discussants or session chairs. However, this outcome could alternatively indicate that the department is spending significantly higher amounts on travel because they attend expensive conferences but faculty within the department are not giving papers or serving as session chairs or discussants. In the former case, an efficient allocation of travel funds may result in the department receiving an increase in its travel budget for the next academic year. In the latter case, the opposite might happen–the department's travel budget could be cut and the resulting cuts could provide the source of funds for more efficient departments. When special causes are present, the process is said to be "out of control."

Conversely, if the department's mean falls below the lower control limit, the department's mean travel expenditures are significantly lower than the mean for the college. This in turn could imply that the department is less productive relative to other departments within the college, or that the department is using its travel funds more efficiently. This could happen, for example, if several faculty from this department attend the conferences closer to the university and/or share the same room and airport shuttle. This department could be rewarded by having its travel budget for the next academic year increased, or, alternatively, the college could require that all other departments follow this department's economical travel policy.

Example of a Stable Process

An example of applying a control chart to the travel budget process is developed in this section for a college containing seven academic departments, Accounting, Business Law, Economics, Finance, Management, Marketing and Management Science. The data are hypothetical. The data for the first four faculty in the Accounting department, the first two faculty in the Business Law department, the first three faculty in Economics, and so on are shown in Table 1:

Table 1. Travel Expenditure Data

DEPARTMENT	CODE	TRAVEL
ACCT	1	1687.42
ACCT	1	2906.74
ACCT	1	8115.26
ACCT	1	5551.39
BUSINESS LAW	2	6703.98
BUSINESS LAW	2	4526.99
ECONOMICS	3	5505.11
ECONOMICS	3	1020.82
ECONOMICS	3	1776.06
FINANCE	4	5677.31
FINANCE	4	2126.85
MANAGEMENT	5	4010.86
MANAGEMENT	5	7503.95
MANAGEMENT	5	1503.83
MARKETING	6	4425.18
MARKETING	6	3347.61
MARKETING	6	2859.82
MGMT SCIENCE	7	3090.52
MGMT SCIENCE	7	2972.04

(The column labeled "Code" is a numerical code representing the department.) Each row in the table represents the travel expenditures by a particular faculty member of the indicated department. For example, the entry in the first row indicates that faculty member 1 in the Accounting department spent $1,687.42 on travel during this budget year.

The X-bar and S charts were obtained using "Minitab" and are shown in Figure 1.

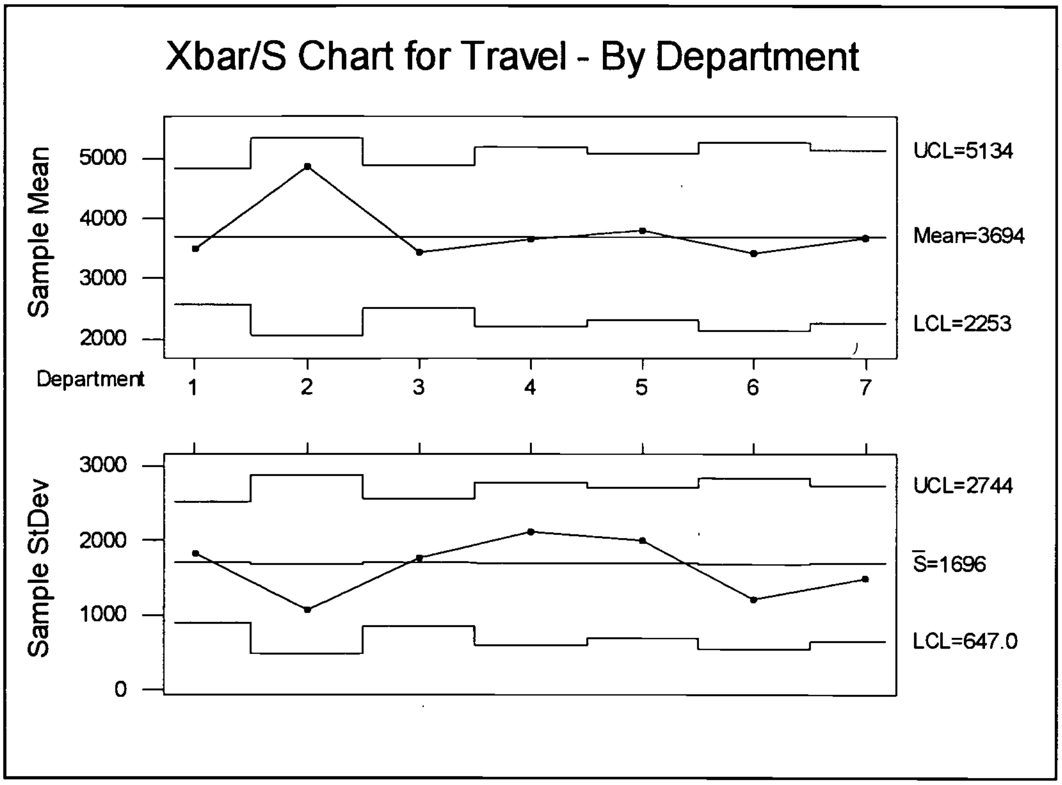

Figure 1: X-bar and S Chart for Travel Spending

The numbers on the horizontal axis represent the different departments within the college, seven in this example. The center line on the X-bar chart, the mean travel expenditure for the college, is \$3,694. The control limits shown on the X-bar chart (UCL = Upper Control Limit = 5134 and LCL = Lower Control Limit = 2253) were computed as the mean of the seven department control limits. The control limits for each department vary due to the different sizes of the departments. Thus, with varying department sizes, each department has its own set of control limits, the upper control limit being three standard deviations above the college mean and the lower control limit established at three standard deviations below the college mean.

To compute the control limits for the X-bar chart, let n_i denote the size of department i

(number of faculty), $n = \Sigma n_i$, the size of the college in which department i is located and $\overline{X}_i$, the mean travel expenditure by department i. We then define the mean travel expenditure for the college and the pooled college standard deviation S_p, respectively, as

$$\overline{\overline{X}} = \frac{\sum n_i \overline{X}_i}{\sum n_i}$$

$$\overline{S} = \sqrt{\frac{\sum (n_i - 1) S_i^2}{\sum (n_i - 1)}} \tag{1}$$

The control limits for the X-bar chart are

$$\overline{\overline{X}} \pm 3\left[\frac{\hat{\sigma}}{\sqrt{n_i}}\right] \tag{2}$$

where $\hat{\sigma}$, the estimated college standard deviation, is

$$\hat{\sigma} = \frac{\overline{S}}{c_4(d)},$$

where

$$d = n - (\text{\# of samples}) \tag{3}$$

$$c_4(d) = \frac{4(d-1)}{4d-3}.$$

Substituting (3) into (2) results in

$$\text{Control Limits for X-bar chart} = \overline{\overline{X}} \pm 3\left[\frac{\overline{S}}{c_4(d)\sqrt{n_i}}\right]. \tag{4}$$

Letting

$$A_3 = \frac{3}{c_4(d)\sqrt{n_i}}, \tag{5}$$

the control limits become

$$\begin{aligned} LCL &= \overline{\overline{X}} - A_3\overline{S} \\ UCL &= \overline{\overline{X}} + A_3\overline{S} \end{aligned} \tag{6}$$

As an example, we calculate the control limits for the Accounting department, where $n_l =$ 21. From the data, we compute

$$\overline{\overline{X}} = 3694$$

$$\overline{S} = 1696$$

$$\begin{aligned} d &= n - (\#\text{of samples}) \\ &= 100 - 7 = 93 \end{aligned}$$

$$c_4(d) = \frac{4(d-1)}{4d-3} = \frac{4(92)}{4(93)-3} = 0.9973$$

$$A_3 = \frac{3}{c_4(d)\sqrt{n_1}} = \frac{3}{(0.9973)\sqrt{21}} = 0.6564$$

Substituting the above results into (6), we obtain the control limits for the Accounting department:

$$LCL = \overline{\overline{X}} - A_3\overline{S} = 3694 - (0.6564)(1696) = 2581$$

$$UCL = \overline{\overline{X}} + A_3\overline{S} = 3694 + (0.6564)(1696) = 4807$$

The control limits represent the limits of random variation. The plotted points are the department means. Since all department means fall within the control limits, the process is in statistical control, implying that there are no significant differences among the department mean expenditure levels. Since the control limits are 3-sigma limits, we predict that 99.73% of the time, the mean travel expenditures by departments within this college will fall between $2,581 and $4,807. However, mean spending levels that fall within these limits do not differ significantly from the college mean.

The *S* chart monitors the process variation. The center line, *S*-bar, is the mean of the department standard deviations of travel spending, $1,696. The control limits were computed using the median department size. The plotted points are the department standard deviations. The *S* chart control limits for the Accounting department were computed as follows:

$$LCL = B_3\overline{S}$$

$$UCL = B_4\overline{S}, \tag{7}$$

where

$$B_3 = 1 - \frac{3}{c_4(d)\sqrt{2n_i - 1}}$$

$$B_4 = 1 + \frac{3}{c_4(d)\sqrt{2n_i - 1}}.$$

Substituting the required values,

$$B_3 = 1 - \frac{3}{c_4(d)\sqrt{2n_i - 1}} = 1 - \frac{3}{(0.9973)\sqrt{2(21)-1}} = 0.5302$$

$$B_4 = 1 + \frac{3}{c_4(d)\sqrt{2n_i - 1}} = 1 + \frac{3}{(0.9973)\sqrt{2(21)-1}} = 1.47$$

$$LCL = B_3\overline{S} = (0.5302)(1696) = 899$$

$$UCL = B_4\overline{S} = (1.47)(1696) = 2493.$$

Since the department standard deviations fall within the control limits, the process variation is in statistical control. (The process variation must be in control for the X-bar chart to have any meaningful interpretation.) It can therefore be concluded that there is no justification for increasing or decreasing any department's travel budget for the following academic year.

A Control Chart for Mean Time to Graduation

A increasingly important performance measure is mean time to graduation at the department level. This performance measure could be tracked using an X-bar/S chart. The center line on the X-bar chart would be the mean time to graduation for all majors within the college. The plotted points would be the mean time to graduation for each department. If a department's mean time to graduation falls above the upper control limit, the mean time to graduation for this department is significantly higher than the mean time college wide. The outcome should be investigated to determine the underlying special causes. If, on the other hand, the mean time to graduation for a department is below the lower control limit, the mean for the department is significantly lower than mean for the college. The case should also be investigated to determine if the special cause is due to, for example, better scheduling of classes, more effective students advising, or restrictions on the number of times students can repeat a course.

Departments that are below the lower control limit are using resources more efficiently in terms of reducing cycle time, the time required to graduate students. Additional budget funds could be allocated to these departments to reward them for being more efficient producers. This could serve as an incentive for other departments to improve their efficiency.

Conclusions

The control chart approach can be used at various levels in a university. However, the chart must be modified appropriately, depending on the level at which it is applied. For example, if an administrator want to compare spending at the college level, the center line on the control chart should be the university mean. Moreover, the control chart approach reduces the impact of political pressures on the budget process, since it provides an objective basis for allocating funds and establishing accountability.

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