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Redesigning variance analysis for problem solving

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This paper is an exploratory study that examines how management accounting can be designed to improve problem solving at an operational level. A case study is used to describe a number of improvements that were made to the problem solving process at a manufacturing company, including changes to the system of variance analysis. After discussing these improvements collectively, the paper focuses on four of the changes to variance analysis and examines their theoretical effect on problem solving. Four propositions are developed and tested using a cross-sectional study and the results indicate that three of the four changes are associated with improved problem solving.

Key words: variance analysis, innovation, change.

Introduction

Organizational performance partly depends on the ability to solve problems and managers can enhance this ability at operational levels by implementing various problem solving improvement programs. Such improvement programs may include changes to the management accounting system as well as other organizational changes and it is important to study the individual contribution changes to management accounting can make to improved problem solving, as well as studying how these changes complement and reinforce one another within an organizational setting.

However, empirical research tends to either focus on measuring the contribution of management accounting in isolation to the organizational context (e.g. Hirst and Luckett, 1992) or focuses on the organizational context without measuring the contribution of management accounting (e.g. Young and Selto, 1993). This paper

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attempts to address both these aspects by using a multiple method approach involving a case study and a cross-sectional study.

The first part of the paper uses a case study to describe, in sequence, the various improvements to problem solving that were introduced at a single manufacturer and a case study is an appropriate research method for describing such organizational processes (Yin, 1989). One of the improvements concerned changes to variance analysis and specifically how the formal system of variance analysis (that was used by superiors at head office for control) was supplemented by an informal system of variance analysis (that was used within the plant for problem solving).[1]

The development of formal and informal systems of variance analysis in the case study reflects the 'different information for different purposes' argument (Howell and Soucy, 1987), which is consistent with the use of multiple management accounting systems that have been observed in Japanese companies (Monden and Hamada, 1991). It is also consistent with the work of Simons (1990) who noted that, although different systems of variance analysis may appear to be similar, they differ significantly in detail, and this detail is important depending on whether variance analysis is designed for control or problem solving (Taylor *et al.*, 1984). For example, all systems of variance analysis may be similar to the extent that they 'regularly compare actual to expected performance' (Drury, 1992). But 'regular' may mean daily or monthly and daily may be more appropriate for problem solving and monthly for control (or vice versa). This literature suggests that where variance analysis is used for problem solving it needs to be designed for that purpose and, together with the findings from the case study, motivates the second part of this paper.

The second part of the paper isolates four aspects of information from variance analysis that were identified as important in the case study and examines them for their theoretical effect on problem solving. A cross-sectional study is then used to empirically test these relationships.

Part 1: Case study

The setting and opportunity

The case study was located at a manufacturing site of a multinational chemical company. Twelve integrated plants were located on the site and each plant operated continuously, 24 hours-a-day, 365 days-a-year. Each plant manager reported to the site manager for site-related matters (such as safety issues) and to head office for profitability.

I visited the site over a period of some eighteen months and, in particular, three plants that manufactured bulk-commodity plastics. I became familiar with operations at these plants by attending meetings, interviewing managers and other employees, as well as gaining access to archival records. While my initial involvement at the company was not research orientated, I soon became aware of

[1] The formal system of variance analysis is defined in this paper as a monthly process of subordinate managers explaining to their superiors the reasons for budget variances (or other organizational goal). The informal system of variance analysis is defined in this paper as the process (not necessarily monthly) where subordinate managers seek to generate information at an operational level about the problems that have caused the variances (either against the budget or some other goal that managers have set). This information is used by subordinate managers to solve those problems but can also be used by them to explain to superiors the reasons for variances as provided by the formal system of variance analysis.

the changes that had occurred in the plants, and were continuing to occur, and the potential research opportunities these changes represented. The case study primarily focuses on events at one of the three plants, although those events were broadly replicated in the other two plants.

The case study is organized in three sections. The first section describes two antecedents that preceded the introduction of new problem solving techniques; namely, (i) increasing employees' awareness that problem solving was important, and (ii) aligning employees' incentives with problem solving. The second section describes the new problem solving techniques that were introduced. The third section describes how these new problem solving techniques led to the formal system of variance analysis being evaluated for its usefulness in problem solving and, in response to the inadequacies of that formal system, how an informal system of variance analysis was developed to facilitate problem solving.

Antecedents to improving problem solving

The first section of the case study describes the two antecedents that preceded the changes to problem solving techniques; namely, (i) increasing employees' awareness that problem solving was important, and (ii) changing employees' incentives to better motivate them to solve problems. These antecedents were believed to be important because they helped to maximize the benefit from the subsequent changes to the problem solving techniques.

Increasing awareness

The first antecedent related to increasing awareness among employees that problem solving was important for the plant's survival. Given the commodity nature of bulk-commodity plastics, the plant's strategy was a typical cost leadership strategy where the long-term profitability depended on continuously reducing the unit cost of production (Porter, 1980). This need to reduce unit costs was becoming more urgent as a significant amount of new and additional capacity was currently being built by foreign competitors that, when completed, would put further pressure on prices. This threat to profitability from globalization has previously been identified as reasons for change (e.g. Chenhall, 1999) and this case study reinforces that literature.

However, the ability to reduce unit costs was limited because bulk-commodity plastics are made in capital intensive plants that are characterized by a high level of committed and fixed cost. Consequently, once such a plant is built, increasing profitability is largely limited to maximizing the utilization of the plant and, while this often means maximizing production output (or throughput), there was also a growing recognition that profitability was also a function of quality through its effect on average prices and margins. Consequently, solving quality and output-related problems were given equal standing as the two main goals at plant level and the plant manager's approach was to produce as much A-1 quality output as possible (i.e. output that meets quality specifications), eliminating problems as and when they occurred. This incremental improvement approach reflected the TQM background of the plant manager who stressed the importance of improving levels of output and quality at every opportunity. These actions raised employees' awareness that problem solving was important. However, the plant manager also believed that the employees needed a greater motivation to get involved in the problem solving process and, consequently, changes were also made to the structure of employees' incentives.

Changes to employees' incentives

Changes to employees' incentives involved changes to employees basic wage and overtime structure. Prior to these changes, employees received a relatively low basic wage that was supplemented by overtime. Overtime was worked to fix a problem where that problem significantly affected quality and/or output, and employees' dependence on overtime motivated them to ensure that there was overtime to be worked. The change to employees' wage structure involved a move to a relatively high and flat wage with the obligation to work *unpaid* overtime to fix any problem that significantly affected output. This change was important as employees were now more motivated to prevent problems *ex ante* than solve them *ex post* because they would effectively receive the equivalent overtime payments (through the higher basic wage) without necessarily having to physically work the overtime.

These antecedent conditions of increasing employees' awareness and aligning their incentives to improved problem solving, arguably, made it more likely that employees would be more willing to solve problems. But the plant manager believed this willingness was, on its own, insufficient to significantly improve problem solving and new problem solving techniques were also needed.

New problem solving techniques

The second section of the case study outlines the new problem solving techniques that were introduced which can be described using Simons' (1990) framework of interactive and diagnostic control systems.

Interactive controls are controls that focus on those aspects of a business a manager needs to manage directly (rather than delegate) which, in this case study, related to output and quality issues. Specifically, interactive controls are structures or forums (e.g. meetings) where output and quality issues are actively debated and discussed. The aim is to develop a better understanding of these issues by 'searching for surprises' (Feldman and March, 1981) and seeking alternative ways to view problems. In contrast, diagnostic controls are feedback controls, such as variance analysis, that measure progress against plans.

Three interactive controls and their relationships with the diagnostic control of variance analysis will be described in this paper. In particular, one of the interactive controls led to considerable debate about the usefulness of the formal system of variance analysis for problem solving. In turn, this led to a number of deficiencies being identified that were overcome by developing an informal system of variance analysis. This informal system of variance analysis was linked to the other two interactive controls because it used information generated from, and validated by, those other interactive controls. This point is important because, rather than viewing interactive and diagnostic control systems as mutually exclusive, they were highly inter-related. These three interactive controls are now described.

(1) The first interactive control involved the daily production meeting. The original purpose of this meeting was to facilitate the hand-over of operations between shifts and it typically focused on the problems that were outstanding at the time of hand-over. The plant manager started to attend these meetings and, rather than just focus on those problems that remained at hand-over, he broadened the purpose of the meeting to focus on <u>all</u> the problems that had occurred during the previous 24 hours. In particular, the meeting sought to clarify

the problems and the circumstances in which the problems had arisen and this involved gaining a consensus between the participants at the meeting. These participants represented different sections of the plant and achieving this consensus generated considerable discussion and debate as the problems were often complicated with no obvious cause.

(2) The second interactive control was the introduction of a weekly meeting for all employees. This meeting presented a summary of the problems (ranked by importance) that had occurred during the previous week, as identified from the daily production meeting. This ranking was useful because often a problem spread across a number of days and the ranking enabled the cumulative effect of the problem to be understood. In addition, the meeting provided the opportunity to update any information about problems that had come to light subsequent to the daily production meeting.

(3) The third interactive control was the introduction of short-term, multidisciplinary problem solving teams. Each team was set up to address a particular problem area in the plant and consisted of employees with knowledge and experience in that area. The teams attempted to analyse and identify the causes of problems where the cause had not been immediately obvious the first time it occurred or where the cause had been misdiagnosed. The team discussed their diagnosis and proposed solutions with the plant manager for implementation. Thereafter, the team would be disbanded and a new one formed to focus on a different problem area.

However, the effectiveness of these problem solving teams was limited by the relatively poor information about problems that meant: (i) it was difficult to know which problem solving teams were most important to set up; and (ii) once a team was set up to address problems in a particular area, the poor information hampered any systematic analysis of those problems.

Consequently, one of these short-term, multidisciplinary teams was set up to examine how information for problem solving could be improved. The management accountant was involved in this team which focused on information from the formal system of variance analysis that, to this point, had traditionally been used by superiors at head office to control the plant manager.

Evaluating the formal system of variance analysis for problem solving

This last section of the case study outlines the work of the short-term, multidisciplinary team that was charged with improving information for problem solving. In particular, this team sought to identify the reasons why the formal system of variance analysis did not generate appropriate information for problem solving at plant level and how this situation could be improved.[2] While some of the following reasons have been identified in the literature before, overcoming these reasons have neither been widely canvassed nor empirically tested.

The following describes the team's four main criticisms of the formal system of variance analysis. Overcoming these criticisms provided the motivation for, and

[2]Note that these reasons were not regarded as problems where the formal system of variance analysis was used as a control tool; only for its use in problem solving.

guided the design of, the informal system of variance analysis. While the design features of the informal system of variance analysis are described below, the theory that explains why they could be expected to improve problem solving is detailed in the subsequent theory development section.

(1) The first criticism of the formal system of variance analysis was that variances were based on cost variances which were less meaningful at plant level than non-financial variances because they did not differentiate between output and quality problems. In addition, cost-based variances were lagging indicators of performance that were only generated when the cost of a problem is recorded and this could be a considerable time after the problem had occurred. Consequently, to resolve both these issues, the first feature of the informal system was to focus on calculating variances against non-financial targets of output and quality and this provided feedback that differentiated between those goals.

(2) The second criticism of the formal system of variance analysis was that it was geared towards explaining variances to superiors at head office where relatively vague reasons for variances could be given (e.g. 'we had problems with suppliers'). This vagueness was possible because superiors at head office often had non-technical backgrounds and did not always understand, or want to know, the technical detail of problems. Furthermore, arguably, superiors did not *need* to understand the detail so long as they were reassured that the plant manager was taking appropriate action to minimize the recurrence of problems. However, solving problems requires information about the specific problems; consequently, the second feature of the information from the informal system of variance analysis centred on identifying the specific problems that had occurred and the circumstances in which they arose. For example, a description of the problem was recorded, together with the time/date it occurred, the shift it occurred on, the product that was being made when the problem occurred, etc.

(3) The third criticism of the formal system of variance analysis was that once explanations for variances had been given to superiors at head office, the information was discarded and this was wasteful for problem solving because it was not used by the problem solving teams. Consequently, to resolve this issue, the third feature of the information from the informal system of variance analysis was the retention of information about specific problems on a database for future analysis by the problem solving teams or any other *ad hoc* analysis.

(4) The fourth criticism of the formal system of variance analysis was that variances were calculated against the budget which was easier to achieve than the targets set within the plant itself. As a result, formal variance analysis only identified a sub-set of the problems that had occurred which, in turn, reduced the opportunities to solve problems. The fourth feature of the information from the informal system of variance analysis involved raising the target closer to the practical capacity of the plant for output and zero defects for quality with the intention of generating more problems.

The management accountant generated the information for the informal system of variance analysis by attending the daily morning production meeting (i.e. the first interactive control described in the previous section). At that meeting, variances against output and quality targets were investigated and specific details about problems were gathered and subsequently documented on a database. Information entered on to the database for the week was validated at the weekly meeting (i.e. the second interactive control described in the previous section). As such, this database represented an informal system of variance analysis that was used within the plant for problem solving while the formal system of variance analysis was maintained for reporting to superiors at head office.[3]

This case study has described the events at one organization that led to improvements in problem solving and, while these events have been put into an organizational context, their effect on performance was not systematically tested. However, performance is one of the most important variables for organizations to manage and, consequently, it is important to measure whether performance improved as a result of these changes to variance analysis. While the case study generates many research issues such as the role of the antecedents and the relationship between interactive and diagnostic controls, it is the changes to variance analysis that are investigated further in this paper because the case study indicated that they were important for improving problem solving.

Consequently, the second part of the paper takes each of the four features of the informal system of variance analysis and theoretically explains how they improve problem solving. This theory development produces four propositions that are subsequently empirically tested in a cross-sectional study.

Part 2: Theory development

The theory development section provides the theoretical links between each of the four aspects of variance analysis and problem solving. The theory is developed from the psychology, management and management accounting literatures and explains why the changes to variance analysis are generalizable to situations beyond the case study.

Information about different goals

The first aspect follows up on the first criticism of formal variance analysis in the case study (outlined in the previous section) that variance analysis needs to differentiate between different goals.

A well established principle in psychology is that feedback affects performance and the mechanism which drives this effect is the dissatisfaction a manager experiences in failing to achieve a desired goal (Gagne, 1985). Such dissatisfaction motivates managers to minimize future dissatisfaction by working harder or by learning how to avoid repeating mistakes (Herold *et al.*, 1987, p. 826). Without such feedback,

[3]Rather than being mutually exclusive, the informal system *complemented* the formal system of traditional variance analysis in two ways: (i) informal variance analysis provided the operational manager with more specific problems than were necessary to explain the budget variances and this enabled the manager to be selective about the problems reported to superiors at head office; and (ii) the manager could report the reasons for variances from the formal system of variance analysis more quickly (because they were already gathered from the informal system) and this enabled the manager to give the impression that he was on top of the problems.

the manager is likely to remain ignorant about any poor performance and the reasons for that poor performance.

This issue is relevant to management accounting research which has described cost-based feedback from variance analysis as incomplete because it does not reflect 'all the relevant dimensions of performance' (Hopwood, 1972, p. 158). Applied to variance analysis, 'all the relevant dimensions of performance' means providing feedback about the important goals of the work unit. Important goals are those that affect overall performance and, in addition to costs, might include output, quality and delivery goals (depending on the situation). To solve problems associated with each of these goals, it is necessary to receive feedback about each goal. Where feedback is not provided about each goal, it becomes more difficult for the manager to know how to make trade-offs between these goals and problem solving is likely to be biased towards those goals where feedback is provided (McGee *et al.*, 1989); (Kopelman, 1986); Locke and Latham, 1990, p. 52). Consequently, overall performance (which takes account of performance on all important goals in the work unit) is likely to be lower than where an appropriate amount of feedback is given about each important goal.

This discussion leads to the following proposition.

> *H1: The ability to solve problems will increase where variance analysis provides feedback about the important goals of the work unit.*

Information about specific problems

The second aspect follows up the second criticism of formal variance analysis in the case study where information from investigating variances needed to identify the specific problems that caused the variances.

Interpreting a variance in terms of specific problems is important because it can reduce the ambiguity or equivocality surrounding the variance and this process has been linked to enhanced learning and performance (Daft and Lengel, 1986). This principle is consistent with the psychology literature that points to the effectiveness of unequivocal feedback about isolatable elements of the control system (Senders and Cruzen, 1952). For example, a study examining electricity consumption in households argued that providing variance information about the total consumption was less effective in reducing consumption than variance information about the consumption of different household appliances (Seligman and Darley, 1977). Householders with variance information about individual appliances were able to minimize their overall consumption of electricity because they were better able to identify the appliances that were accounting for most of the variance in total consumption.

Applying the principle in this example to variance analysis, the 'isolatable elements' are analogous to the specific problems that have caused the unfavourable variance and information that identifies the specific problems can enhance problem solving because it is actionable (Fisher, 1995). For example, identifying the problem that has generated the variance (e.g. incorrect materials used in production) can lead the manager to identifying the cause (e.g. incorrect labelling of materials) which, in turn, can lead to solving the problem (e.g. reviewing the labelling procedures). However, without identifying the specific problem first, these subsequent steps cannot be taken to solve the problem.

This discussion leads to the following proposition.

H2: The ability to solve problems will increase where the information from investigating variances is presented in terms of specific problems.

Once specific problems have been identified, solving them might be relatively straightforward where the cause of the problem is immediately obvious, for example, where a lack of materials has caused production to stop. But often the cause is not obvious and the manager may need to undertake further analysis (such as in the problem solving teams described in the case study). The effectiveness of this analysis relates to the third and fourth aspects of variance analysis in this paper which relate to information that identifies:

— how specific problems are inter-related; and

— greater numbers of specific problems.

Information about how specific problems are inter-related

The third aspect follows up the third criticism of formal variance analysis in the case study about the lack of information about problems and the circumstances in which they occurred. Where this information is retained and analysed, it can identify how problems are inter-related which can help managers to: (i) prioritize problems and (ii) solve problems whose causes are not obvious.

Prioritizing problems

The most obvious way problems are inter-related is where the same problem recurs. However, if information about problems is not retained, the manager is less likely to detect both the recurring nature of the problem and its cumulative effect. This information is important for prioritizing problems because tracking a small problem that recurs over several reporting periods may be cumulatively larger, and thus more important to solve, than a once-off problem.

However, problems may be inter-related in more subtle ways that concern the shared circumstances in which they arise and these may be important for identifying the causes of problems.

Identifying causes where they are not obvious

Where the cause of a problem is *not* obvious, the 'signal' denoting the actual cause does not stand out against the 'noise' of other potential causes. Without knowing what has caused a problem it cannot be solved and, consequently, the problem is likely to recur and may recur several times before the manager can identify the actual cause.

As a problem recurs, the 'signal' relating to the cause will get stronger if the manager can correlate the problem with a potential cause. In these situations, a manager will increasingly treat the potential cause as the actual cause because it produces an increasingly strong 'signal' that isolates the cause from the 'noise' of other potential causes (Ansari, 1979).

For example, if a particular problem occurs when product A is being made, the manager might not draw any conclusion the first time this occurs. But if the problem recurs, and only seems to recur when product A is made (rather than when products B, C and D are made), this knowledge will increasingly lead the manager to investigate what it is about product A (or something correlated to product A) that might be systematically causing the problem.

Such relationships are more likely to be revealed as problems are correlated against an increasing number of different potential causes. That is, while the previous example focused on product A as the potential cause, other potential causes may exist. For example, the potential cause may relate to the shift that was working when each problem occurred (Bruns and McKinnon, 1993), or the different locations in the plant (Ishakawa, 1972), or, indeed, by any other factor appropriate to a given work situation.

While this process of correlating problems with potential causes does not guarantee that the cause is the actual cause, relative to other possibilities, it provides a promising avenue of investigation that can expedite the problem solving process.

This discussion leads to the following proposition.

H3: The ability to solve problems will increase where information from investigating variances identifies how specific problems are inter-related.

Information about the number of specific problems

The fourth aspect of variance analysis follows up on the fourth criticism of formal variance analysis in the case study where only a sub-set of problems were identified and changes were made to identify a greater number of problems for problem solving.

Theoretical support that increasing the number of problems assists in problem solving is provided by Galbraith (1977) and Herold *et al.* (1987, p. 833) who argue that less information leads to greater uncertainty in problem solving and this theory can be applied to the number of problems in the following way.

As a manager is exposed to fewer specific problems, the manager will be less confident about what is causing the problems. For example, if a problem occurs each time product A is made, the manager will begin to think that there is something about product A which is causing the problem. But if product A is made and the problem is not recorded as occurring, the manager may be uncertain whether: (i) the problem occurred but the variance feedback system did not capture it, or (ii) the problem did not occur because it is unrelated to product A.

Consequently, as fewer incidences of a particular problem are identified (out of the total number that have occurred), the manager will be less likely to correctly diagnose the problem. Alternatively, the manager may wait until more incidents of the problem are recorded so that a correct diagnosis is more likely. Either way performance is likely to be impaired because the problem will be solved later than might otherwise be the case.

This discussion leads to the following proposition.

H4: The ability to solve problems will increase where increasing numbers of specific problems are identified.

These four propositions are outlined in the research model below (see Figure 1).

This concludes the theory section of the paper. The final section describes the cross-sectional study which empirically tests the four propositions.

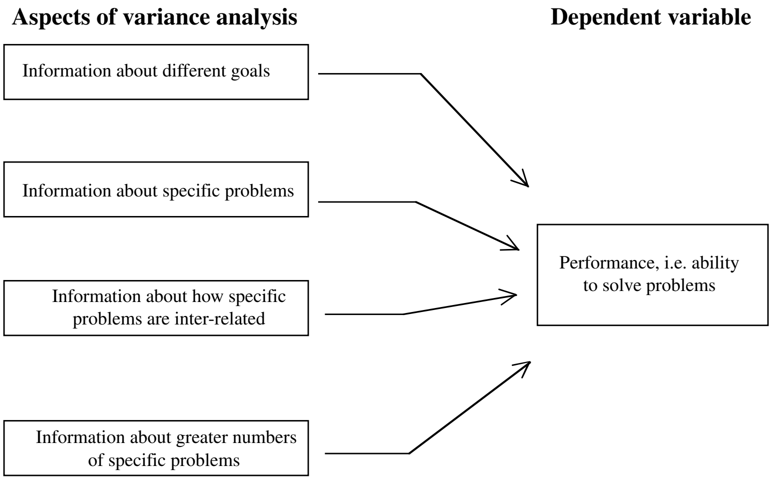

Figure 1. Research model.

Cross-sectional study

This section of the paper commences by outlining the interview and questionnaire method used to collect the data. The data analysis and results section that follows formally tests each proposition. The paper closes with a discussion of the results, together with the limitations of the study and possible future research.

Research design

A cross-sectional field study using interviews and questionnaires was used to quantify the effect of each aspect of variance analysis on problem solving and empirically test the propositions. This method also enabled potential confounding factors to be controlled as well as the results to be more generalizable than the case study.

A random sample of medium-to-large sized manufacturing companies was taken from a commercial directory. These companies were chosen because management accounting systems were likely to be well developed and extensively used in those settings (Merchant, 1984). Of the 28 organizations approached, twenty agreed to participate giving a response rate of 71% and all the departmental managers approached within those twenty organizations agreed to participate. This method resulted in a sample of 47 managers (nine of whom were used in the pilot study and 38 managers formed the basis of the final study). This sample size is similar to studies that have used a comparable method (e.g. Otley, 1978; Gordon and Narayanan, 1984).

Face-to-face interviews were considered the most appropriate medium to gather data about the four aspects of variance analysis because previous studies (e.g. Dew and Gee, 1973) have highlighted difficulties in focusing managers' attention on constructs associated with organizational feedback. This difficulty was also experienced in the pilot study and reaffirmed the decision to use face-to-face interviews.

The interviews were semi-structured and managers were asked both open and closed questions. The open questions enhanced construct validity by ensuring that a manager was focused on the construct associated with each aspect before the closed questions were asked. Face-to-face interviews enabled the questions to be repeated until such a focus was achieved. Once the researcher was satisfied that the manager had focused on the construct, closed questions were asked which quantified (on Likert-type scales) that construct. The manager's responses to these closed questions were subsequently validated by asking additional questions and, where the answers were inconsistent, this inconsistency could be resolved at the time of the interview. The rapport developed during the face-to-face interviews enabled these inconsistencies to be clarified and managers often provided additional evidence, such as printed company reports, to validate their responses.

Examining the construct from a number of perspectives in this manner is a strength of the method because it enhances convergent validity (Jick, 1979). The format of the interviews and the questions relating to the four constructs are summarized in Appendix A.

At the end of the interview, performance was operationalized by using a self-rating, weighted measure of the manager's ability to solve problems associated with important goals or outcomes (such as productivity, quality, customer service).[4] These goals varied from one manager to another and were identified during the preliminary part of the interview. These goals were weighted by the manager in order to take account of the importance of each goal (Steers, 1975; Abernethy and Stoelwinder, 1991) Then, for each goal, managers were asked: *'How would you rate your performance in terms of solving problems associated with ________'*(the researcher filled the blank space with the goal provided by the manager earlier in the interview, say, productivity, quality, customer service, etc.). The performance rating was scored on a seven-point scale (ranging from 'Well above average' to 'Well below average'), weighted by the importance of each of the manager's goals, and a single figure obtained. This single figure of overall performance was subsequently used in the data analysis.

Confidence that this self-rating, weighted performance measure was a valid measure of performance was provided in two ways. First, it was significantly correlated (at the 10% level) to ratings from managers' superiors. However, this validation was only possible with the data generated from the pilot study where it was possible to identify the superior.[5] Second, a self-rated, single item measure of overall performance was also collected from managers and this was also significantly correlated ($r^2 = 0.765$; $p = 0.000$) with the self-rated, weighted performance measure described above.

Data analysis and results

The data were scored such that the propositions would be supported if significant and positive relationships existed between the independent and dependent variables (details of how the questions were scored are provided in Appendix A). The data are presented in the following tables: descriptive statistics (Table 1), correlation matrix (Table 2) and multiple regression (Table 3).

Table 1 shows a spread of data across the sample that provides evidence that a

[4]Probably the most commonly used performance measure in management accounting research is the Mahoney *et al.* (1965) scale. But this scale was not suitable for this study because it focuses on processes (e.g. the ability to plan and coordinate); not goals or outcomes associated with problem solving.

[5]Corroboration of performance from superiors was possible in the pilot study because access to the managers was gained via the Finance Director and the manager's superior. However this approach was time consuming and for the main study the managers were approached directly where the manager's superior was not identifiable.

Table 1
Descriptive statistics

	Mean	Median	Std dev	Actual Min	Actual Max	Theoretical Min	Theoretical Max
Information about different goals	3.47	3.00	0.93	1.00	5.00	1.00	5.00
Question 2.1	3.18	3.67	1.26	1.00	5.00	1.00	5.00
Question 2.2	3.79	4.00	1.13	1.00	5.00	1.00	5.00
Information about specific problems	3.48	3.63	0.98	1.50	5.00	1.00	5.00
Question 3.1	2.93	3.00	1.07	1.00	5.00	1.00	5.00
Question 3.2	3.04	3.00	1.17	1.00	5.00	1.00	5.00
Question 3.3	2.81	3.00	1.04	1.00	5.00	1.00	5.00
Information about how problems are inter-related	2.93	3.00	0.96	1.00	5.00	1.00	5.00
Number of specific problems	3.11	3.00	1.43	1.00	5.00	1.00	5.00
Performance	4.95	5.15	1.21	1.70	7.00	1.00	7.00

Table 2
Correlation matrix

	$X2$: Specific	$X3$: Inter-related	$X4$: Number	Performance
$X1$: Information about different goals	0.54**	0.59**	−0.29	0.53**
$X2$: Information about specific problems		0.55**	0.00	0.56**
$X3$: Information about how specific problems are inter-related			−0.26	0.66**
$X4$: Number of specific problems				−0.26

** Significant at the 5% level.

Table 3
Summary of the three regressions (sequential sum of squares analysis)

	Sum of squares	t-ratio	p-value
Total sum of squares	54.49		
Less: the error sum of squares	26.48		
= the regression sum of squares	*28.01		
The regression sum of squares comprises:			
Shared explanatory power between all characteristics	19.09		
Incremental explanatory power for the aspect: $X1$: Information about different goals	0.20	0.51	0.308
Incremental explanatory power for the aspect: $X2$: Information about specific problems	2.60	1.81	0.040
Incremental explanatory power for the aspect: $X3$: Information about how specific problems are inter-related	5.42	2.61	0.007
Incremental explanatory power for the aspect: $X4$: Information about the number of problems	0.70	−0.94	0.178

* The regression sum of squares remains the same regardless of the order in which the characteristics are fitted in the regression equation and is equivalent to the r^2 of the model (i.e. 28.01/54.49) gives an $r^2 = 0.51$.

variety of responses were obtained across each of the four aspects.

Data were analysed in two ways. First, correlations between each of the four aspects of variance analysis and performance were run. These results are presented in Table 2 and show strong support for H1 ($r = 0.53$; $p = 0.001$), H2 ($r = 0.56$; $p = 0.000$), and H3 ($r = 0.66$; $p = 0.000$) but not H4 ($r = -0.26$; $p = 0.06$).

A further, more stringent, test was applied using multiple regression where each of the four aspects were included as separate explanatory variables in the regression equation outlined below.

$$Y = a + b1X1 + b2X2 + b3X3 + b4X4 + e.$$

Where Y = performance; $X1$ = information about different goals; $X2$ = information about specific problems; $X3$ = information about how problems are inter-related; $X4$ = number of problems.

Four regressions were run where each of the three aspects $X1$, $X2$, $X3$ and $X4$ were fitted last in the regression equation in turn. To test the propositions, the sequential sum of squares data for each aspect (when it was fitted last) was examined because this represents the incremental increase in explanatory power for the regression as a whole that has not already been explained by the other three aspects (fitted first, second and third in the regression equation). This process removes the effect of any intercorrelation between $X1$, $X2$, $X3$ and $X4$ when estimating each aspect's unique effect on the dependent variable. The regression output also details the t-statistic and p-value associated with the sequential sum of squares data.

The full regression output for each of the four regressions is not presented here; only the output that is necessary to test the propositions. The output needed to test the four propositions is summarized in Table 3 below.

For the three propositions (H1, H2 and H3) that were significant using correlations, H2 ($t = 1.81$; $p = 0.040$ in Table 3) and H3 ($t = 2.61$; $p = 0.007$ in Table 3) were also significant using this more stringent test. This analysis provides evidence to support H1, H2 and H3, although the strongest evidence was found for H2 and H3. No evidence was found to support $H4$.

Discussion

The results suggest that problem solving will be enhanced where variance analysis produces: (i) information about the different goals of the work unit (H1); (ii) information about specific problems (H2); and (iii) information about how the specific problems are inter-related (H3). However, there is stronger evidence for H2 and H3 whose results remain significant using the more stringent method in Table 3. The anecdotal evidence provided by managers during the interviews supported this result. For example, in terms of breaking the variances into specific problems (H2) one manager said:

> *Instead of all these variances all I want is a list of the top ten biggest problems to have occurred in the factory through the month.*

In terms of identifying the inter-relatedness of specific problems (H3), one manager identified how problems were inter-related by customer and said:

Our business depends on repeat business and it's really important that the problems which occurred last time (we made the customer's order) don't happen again. So we keep details of all the problems which happened last time and we review these to ensure that these problems were resolved before we make the customer's order again.

The results for H4, the number of problems produced from variance analysis, were opposite to that expected. A plausible explanation for this result may be that managers do not require certainty about the causes of problems before taking action. This explanation is likely to be most appropriate where the cost of misdiagnosing causes and implementing solutions is low. Moreover, waiting until conclusive evidence is accumulated may not be justifiable in terms of the delay or the potential for information overload, both of which might lead to lower performance.

There are a number of limitations to this study that provide the motivation for future research. The limitations associated with any one research method were reduced because of the multiple method approach which meant that the disadvantages of one method were, to a degree, off-set by the other method. For example, the lack of control over the variables in the case study is, partially, addressed in the cross-sectional study (although even greater control, possibly leading to the identification of causal relationships, could be exercised using a laboratory study). Using multiple methods, arguably, enables external validity and internal validity to be maximized but replication using a laboratory experiment would also enhance convergent validity further. However, there is a limit to what any one study can achieve and this paper has combined the use of a case study (which examined the breadth of issues involved with improved problem solving) with a cross-sectional study that focuses more deeply on one of those issues; namely, the contribution that the design of variance analysis can make to improved problem solving.

Another limitation was the context of the case study that motivated the subsequent cross-sectional study. For example, the case study examined the information used for problem solving at plant level and information for problem solving at higher organizational levels is likely to be different. Also, problem solving in the case study was largely a matter of how best to learn from previous mistakes where the technology was constant and this approach may be less appropriate where problem solving needs to analyse and interpret future trends or take account of new technologies.

Future research could overcome some of these issues but there are in addition other areas that also deserve attention. One such area involves developing a more holistic and comprehensive model of the problem solving process which identifies the various ways the system of variance analysis interacts or combines with other elements of the control system. While the case study illustrates the potential for interactive and diagnostic controls to interact, such a research agenda would need to set out with this aim in mind and consider how the different elements of the control system theoretically interact and combine, and then seek evidence to support or reject that theory. Finally, the different roles that formal and informal systems of variance analysis play in the overall control system also warrants further attention.

In conclusion, this paper has used a case study to highlight potentially important influences on problem solving at plant level. One of those influences, the changes to variance analysis, was examined further and three of the four changes were found to be associated with enhanced problem solving across a sample of organizations. These results should be of interest to management accounting practice where a recent survey (Chenhall, 1999) suggests 95% of organizations use variance analysis.

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Appendix A: Interview questions

Each manager interviewed was asked the following open and closed questions. The scoring for the closed questions that have a fixed number of alternatives is the number of the alternative selected by the manager. The exception is question 3.1(b) where the scoring is on a cumulative basis and is described at the end of that question.

Information about different goals

The hypothesis concerned feedback information about important and different goals which was measured by asking the manager about those goals (1.1(a)) and then weighting them (1.1(b)).

1.1 (a) What goals (in terms of outcomes) would you use to determine your performance? For example, a production manager may use productivity or quality or both.

(b) What weighting would you give each of the goal? That is, given 100 percentage points how would you allocate them between the goals.

(c) Thinking about the feedback you get about your operations—does this feedback reflect the weighting of the above goals or do you get too much feedback about one goal and not enough about another?

How would you rate the amount of feedback you receive for <u>each</u> goal on the following scale.

(1) Far too little; (2) Too little; (3) About right; (4) Too much; (5) Far too much.

The score for this aspect is the score for 1.1(c) multiplied by the weighting in 1.1(b) for each goal.

Information about specific problems
The hypothesis related to identifying specific problems which was measured by asking managers two questions. The first question asked managers about the actual information they received and whether this was in aggregate form or broken down into specific problems (2.1(c)). The second question asked managers about their perception of how difficult it is to explain variances in terms of specific problems (2.2(b)).

2.1 (a) What is the most significant operating problem? For example a production manager who identified productivity as an important outcome might say scrap.

(b) What feedback do you get about this problem (scrap)?

(c) Looking at the set of answers on the sheet, which answer best reflects the information you have about this problem?

(1) the problem (scrap) is not identified at all;

(2) the problem (scrap) is only identified in total;

(3) the major specific problems which cause scrap are identified;

(4) most specific problems causing scrap are identified.

2.2 (a) With your information systems, how easy or difficult is it to explain unfavourable variances in terms of specific problems which have caused them?

(b) How easy or difficult is it to explain unfavourable variances in terms of specific problems on the following scale?

(1) the variances are almost impossible to explain in terms of specific problems;

(2) the variances are relatively difficult to explain in terms of specific problems;

(3) the variances are not easy or difficult to explain in terms of specific problems;

(4) the variances are relatively easy to explain in terms of specific problems;

(5) the variances are easily explained in terms of specific problems.

The score for this aspect is the average of questions 2.1(c) and 2.2(b) and the Cronbach alpha is 0.68 which is acceptable.

Information about how specific problems are inter-related

The hypothesis concerned how inter-related the information about specific problems was, i.e. how many different ways the information could be sorted. The actual number of ways information could identify the inter-relatedness was measured (3.1(b)). Managers' perceptions about how easy or difficult it was to identify the inter-relatedness of problems was also asked (3.2(a) and 3.3(a)).

3.1 (a) Identifying and investigating variances can produce a lot of information about the specific problems. To what extent do you keep and process this information over time?

(b) Which of the following answers most closely reflects the extent to which information about specific problems is retained and analysed?

(1) no records about specific problems are kept;

(2) the prime entry about specific problems is kept (for example, on a supervisor's daily production sheets);

(3) information can be summarized about where in the plant specific problems occurred;

(4) information can be summarized about when specific problems occurred;

(5) information can be summarized about what specific problems occurred for each shift;

(6) information can be summarized about what specific problems occurred when making particular products.

This question was scored on a cumulative basis where one point was scored for each alternative chosen (except (1)). That is, the more alternatives that were chosen, the greater the score, to a maximum of five.

3.2 (a) With your information systems, to what extent can specific problems which recur be tracked over time? For example, is it easy or difficult to see if a (specific) problem is improving or getting worse?

(1) very difficult; (2) relatively difficult; (3) not easy but not difficult; (4) relatively easy; (5) very easy.

(b) Why is it easy (difficult) to track problems over time?

3.3 (a) With your information systems, how difficult or easy is it to tell whether a specific problem is systematic or random?

(1) very difficult; (2) relatively difficult; (3) not easy but not difficult; (4) relatively easy; (5) very easy.

(b) Why is it easy (or difficult) to identify systematic problems?

The score for this aspect is the average of questions 3.1(b), 3.2(a) and 3.3(a). The Cronbach alpha is 0.85 which is at an acceptable level.

Number of specific problems

4.1 (a) How frequently do you investigate variances?

4.2 (a) How many specific problems would you investigate each time?

This aspect was scored by using the information in 4.1 and 4.2 to calculate the average number of problems per day, classifying the data into quintiles and scoring 1 (least number of problems) to 5 (most problems) according to the ranking of each quintile.