Division of Research
School of Business Administration

April 1989

EXAMINATION OF THE CHANGE OF CONTROL ISSUES IN HIGH TECHNOLOGY PRODUCTION SYSTEM WITH THE HELP OF VARIANCE ANALYSIS

Working Paper #600

Tamas Koltai M. Eng
Visiting Scholar
The University of Michigan
from
Technical University of Budapest

Contents

Introduction

There is much argument today about the economic justification of new production technologies (Edwards and Heard [1984], Ingersby [1988], Kaplan [1984], Tatikonda [1987]). Very few people dispute that whereas production technology have developed very rapidly in the last few years, management methods have not been able to keep up with this process (Burstein [1986], Ettlie [1988], Kaplan [1983], Kaplan [1986]). We can not perform economic analysis based on traditional methods, because many new considerations have emerged which the traditional - highly production quantity oriented - methods are unable to consider, for example in the case of a flexible manufacturing system. Publications concerning the JIT systems, especially, emphasize the changes required in current methods for control and economic analysis of production processes (Jaouen and Neumann [1986], Jaouen and Neumann [1987], Maskell [1988], Hiromoto [1988]). In the fields of both planning and control of new production technology many open questions are waiting for answer.

In this paper we are going to focus our attention on the cost control of high technology production systems where due to the expensive resources used, the ratio of fixed cost is relatively high. Standard costing is a widely applied method, especially in the manufacturing industry. Some recent publications however are skeptical about its future (Dorward [1985], Dilts and Russell [1985], Inman [1985], Tait [1985]). We think that the reason for this pessimism is the fact that critics concentrate mainly on the application of the current methods in the new environment, instead of on the modifications required because of changing conditions.

In this study we suggest a generalized approach to standard costing which we believe will help in understanding many control issues stimulated by the changed cost-structure of modern production systems (Schwartzbach [1985]). After the modification of standard costing we justify its viability in the new technology environment.

However we have to emphasize that our primary objective is not the development of standard costing, but rather the exploration of some important control issues characteristic of high fixed cost systems. We have found that variance analysis - after a slight modification - might be a useful help to this effort.

The train of thought presented in this paper is supported by experimental calculations.

1. Generalization of standard-costing

When we are talking about the generalization of standard-costing our starting point is the traditional philosophy hidden behind the currently applied method, that is, to try to keep the costs that emerge in the course of production as close as possible to the planned costs that were set up as cost-standards(Benett [1958], Galway [1985], Steffy, Ahmed, Reyes [1980]). Based on this, traditionally determined variances supplied the information for either the management by exception or the evaluation of management performance (Dearden [1973]). Due to the high variable cost ratio of the production systems the variable cost-related areas were the primary interest of cost control. Consequently the current method of standard-costing is far too production quantity oriented.

There is no need to justify this assertion in the case of direct material variances, because these primarily depend on and have direct relation with the quantity produced. Even the examination of overhead variances tries to suggest that the best policy is to produce as much as possible while keeping to the predetermined time norms and costs. The change in the cost structure of modern production systems, however, raises some new issues. High level of production (and selling) do not necessarily mean efficient system performance. They can be inefficient in terms of profit, but even a high profit is not by itself proof of appropriate performance.

To demonstrate this claim let us consider a highly automated production cell which produces a very simple product having a high contribution margin. The quantity produced is enough to cover the overhead and yield some profit, but to engage the capacity with this product deprives us of the possibility to utilize the technological potentials of our system. It might mean that we give up considerable profit for the more secure capacity utilization. This question mainly belongs to the planning sphere but we will reveal some aspects concerning the field of control as well.

Another controversy about quantity orientation is the system consideration. Suppose that we put a great emphasis on the capacity utilization of a computer integrated manufacturing cell. The technological potentials are utilized, but this requires so much effort from the system that many joint subsystems (subcontractors, infrastructural units, etc.) can not work at their required efficiency. Apart from the planning and organizational issues raised by this problem some control aspects are also worth considering.

In order to be able to handle the new control issues in the highly integrated and automated production systems, we formulate standard costing in an abstract way. This abstract formulation will help us to work out a method valid for a much wider set of practical problems compared to the method applied so far.

1.1 General formulation

Let us consider the following very plausible objective as the basis of our further discussion:

> The objective of standard costing is to keep the price of the resources applied in the course of production as near as possible to the planned costs.

In this context, resource means the <u>direct</u> (invested in every production period and built in the product) and <u>indirect</u> (invested for the establishment of the system) resources, as well as the <u>technology</u> available for production. The direct materials as direct resources (in accounting terminology, current assets) or the machines, buildings, as indirect resources (in accounting terminology fixed assets) are classical elements of the prevailing costing systems (Deakin and Maher [1984]). Under the term technology we mean the applied method of production in terms of the physical process and the operation management technology. Resources belonging to this last group represent the information applied to realize a certain type of technology.

By examining the cost behavior patterns of these resource categories some well defined classification possibilities can be found:

- The cost of <u>direct resources</u> inherently relates to the quantity produced. This literally means that the more we produce the more the accumulated cost of these resources will be. Of course there are other factors influencing these costs, i.e. market situation, inflation, but these can be overlooked in this initial approach.

  In the further discussion the set of these resources will be examined in the <u>cost-quantity dimensions</u>.

- The cost of <u>indirect resources</u> inherently relates to time. This literally means that the more time passes, the more the accumulated cost of these resources will be. The fixed overhead costs belong to this field. (We have to note that, depending on the method of depreciation, some indirect resources may belong to the cost-quantity dimensions).

  In the further discussion the set of these resources will be examined in the <u>cost-time</u> dimensions.

- The cost of technology-type resources inherently relates to the information belonging to the current way of production. Theoretically the higher the technology requirement of the product the more the accumulated cost of technology will be.

  In the further discussion these set of resources will be examined in the cost-technology dimensions.

Furthermore one of the basic element of our approach is to divide the costs intended to be controlled among the previously defined dimensions. In every dimension pair the following four values should be determined in order to provide information for cost control:

(a) The resource utilization variance means the difference between the standard cost of resources applied and planned.

    The cause of this variance is that the quantity applied was not the quantity that had been planned for. Some possible reasons why this occurs include the use of more direct material for one piece of product, less working hour per unit, or higher capacity utilization.

(b) The resource price variance means the difference between the actual price and the standard price of the resources applied in the course of production.

    The cause of this variance is that a higher or lower price had to be paid for the resources effectively applied in the production.

(c) The passive cost means the cost of resources being engaged in the production but not representing products. We might call it the cost of nonproductive production.

    The cause of this cost is that while the system is existing and working no output can be perceived. These costs may be caused by the paid idle time of workers, non-utilized capacities, production of failed products, etc.

(d) The system cost means the cost of resources not utilized due to reasons that derive from inherent characteristics of the 'whole' process.

    The cause of this cost is that the system examined is not an individual entity separated from the environment. Connection to associated systems impose numerous restrictions that need to be considered in the course of cost control. The technological conditions and capacity bottle-necks are the most typical examples. To determine the system boundaries of the 'whole process' the flexible system boundary principle (Koltai and Farkas [1988]) can be applied.

It might be misleading that we used passive cost instead of a some kind of variance, but since this terminology is widespread in practice we adhered to the current usage. Sometimes the term capacity variance is used for the passive cost as well(Galway [1985]). The system cost is very similar to the passive cost by nature and the term system variance might be confusing; therefore we preferred to use system cost. In both case however we are talking about some kind of cost variance denoting the bias from the ideal cost of production.

In the next section a detailed examination of the various cost dimensions is presented.

2. Detailed analyses of cost dimensions

2.1. Cost-quantity dimensions

In these dimensions those costs related to the direct resources are examined. A possible behavior pattern of these costs is shown in fig.1. The classical elements of this group are the direct material and direct labour cost. In the case of quantity-related depreciation, however, the otherwise indirect-type resources have to be ranked here (Deakin and Maher [1984]). A general cost function of the resources belonging to this group can be represented on the following way:

$$C_{var}=f(p,q,u) \qquad (1)$$

where

- p - the price of the direct resources used in the course of production;
- q - the produced quantity;
- u - the resource utilization coefficient.

There are of course other variables determining the gross of variable cost but from the point of view of control of production these three factors can be considered particularly relevant. Using the terminologies of managerial accounting the variable costs and the variable overhead are controlled in these dimensions (Dearden [1973], Reece, Anthony, Welsch [1985]).

(a) The <u>resource utilization</u> variance defined in 1.1. can be expressed as follows;

$$V_{q,util}=f(p_{st},q,u_{st}+\Delta u)-f(p_{st},q,u_{st}) \qquad (2)$$

The resource utilization variance in the cost-quantity dimensions expresses the improper utilization of direct resources. The cost deviation caused by the change of direct material norms or direct labor norms and the non-expected energy consumption can be ranked here.

(b) The <u>resource price</u> variance defined in 1.1. can be expressed as follows;

$$V_{q,pr}=f(p_{st}+\Delta p,q,u_{st}+\Delta u)-f(p_{st},q,u_{st}+\Delta u) \qquad (3)$$

The resource price variance in the cost-quantity dimensions expresses the unexpected purchase cost changes. Since the time period embraced by the production control does not generally coincide with the procurement period, different prices may be incurred in one control interval. In this case some kind of average unit price can be used (Benett [1958]).

(c) The <u>passive cost</u> defined in 1.1. can be represented as follows:

$$V_{q,pas}=C_v-f(p_{st}+\Delta p,q,u_{st}+\Delta u) \quad (4)$$

where

C_v - the variable cost incurred in course of the production.

The passive cost in the cost-quantity dimensions expresses the costs incurred during the production but which did not contribute to the output of the system. These can be the production of failed products where the direct material and labor cost belonging to the rejected units are costs not represented by products at the output. Paid idle time is another very important element of variable passive costs. In concrete situations other specific elements belonging to this cost variance will certainly be detected.

It is in the sum of the variances of the cost-quantity dimensions that the essence of the whole examination becomes apparent.

$$V_q=V_{q,util}+V_{q,pr}+V_{q,pas}=C_v-f(p_{st},q,u_{st}) \quad (5)$$

(5) represents the difference between the actual and planned value of the variable cost. The three components help to analyze the causes of these differences. The final objective of cost control is to define the areas in which management is to intervene. The variances determined above might help to achieve the reduction of operation cost by detecting the causes of superfluous expenditures, or may help to reveal the reasons for the erroneous planning. Cost control based on these variances has been and is currently an efficient tool for the management of traditional production systems having <u>high variable cost ratios</u>.

2.2. Cost-time dimensions

In these dimensions those costs related to the indirect resources are examined. A possible behavior pattern of these costs is shown in fig.2. The general form of the cost function related to resources belonging to this group can be represented on the following way:

$$C_{time}=f(p,t,u) \quad (6)$$

where

p - the price of the direct resources used in the course of production;
t - the time spent on the performance of the system;
u - the resource utilization coefficient.

Generally the period of control embraces a time interval where these costs can be considered constant or stepwise functions. One of the reasons for this is the applied accounting practice which records these costs as if they incurred periodically. However, if we distribute this constant across the period to which it belongs a more realistic cost function is gained. If for example we predetermine that the value of a machine has to be depreciated within a certain period we do not commit a big mistake if we distribute it in hourly, daily or weekly details instead of yearly. This does not coincide with the requirements of the accounting system, but it better reflects reality from the management point of view. Something similar is suggested by Hakala (1985) in raising the question of hourly-based machine cost recording. The cost function introduced this way will be named 'time related' standard cost:

$$C_{time,st}=f(p,t,u) \qquad (7)$$

In order to simplify the interpretation of our thoughts we disregard some factors influencing the above cost but not strictly belonging to the production control sphere.

(a) The <u>resource utilization</u> variance defined in 1.1. can be expressed as follows:

$$V_{t,util}=f'(p_{st},t,u_{st}+\Delta u)-f'(p_{st},t,u_{st}) \qquad (8)$$

$f'(p_{st},t,u_{st})$ is a modification of (7) taking into consideration the constraints imposed by the bottleneck of the 'whole' system. If, for example, only 70% of our examined capacity can be utilized because of a subcontractor who can not deliver more parts, then the time related costs have to be distributed over this apparently shorter period.

The resource utilization variance in the cost-time dimensions reflects the non appropriate <u>intensity</u> of system performance. Since the resource utilization coefficient belonging to the time related resources expresses the time norm or time requirements of the given production task, the difference due to the change of this coefficient means informal capacity underutilization. In other words, more capacity (machines, hourly paid workers) was engaged for a certain task than was previously required. These capacities were engaged but did not produce. The elimination of this difference means more rigorous time norm control which may lead to more available capacity. Of course planning errors may also be a cause of this variance.

(b) The <u>resource price</u> variance defined in 1.1. can be expressed as follows:

$$V_{t,pr}=C_f-f'(p_{st},t_{st},u_{st}) \quad (9)$$

where

C_f - the time related cost incurred in course of the production. The f subscript reminds us that the fixed overhead belongs to the system examined.

The resource price variance in the cost-time dimensions expresses the unexpected costs incurred due to the change of resource purchase price. For example unexpected wage raise, higher energy price, etc. Using the terminologies of managerial accounting the fixed overhead costs are controlled in these dimensions.

(c) The <u>passive cost</u> defined in 1.1. can be expressed as follows:

$$V_{t,pas}=f'(p_{st},t_{st},u_{st})-f'(p_{st},t,u_{st}) \quad (10)$$

The passive cost in the cost-time dimensions expresses the value of resources not applied in the production. The elimination of this difference can be achieved by new job orders. This cost will always be incurred as long as we want to have the possibility to produce, and therefore we maintain a reserve of idle capacities. We can consider it as the cost of possibility or flexibility, a cost we have to pay for the fulfillment of would-be orders.

(d) The <u>system cost</u> defined in 1.1. can be expressed as follows:

$$V_{t,sys}=f(p_{st},t,u_{st})-f'(p_{st},t,u_{st}) \quad (11)$$

The system cost in the cost-time dimensions means the cost of capacity available in the system but underutilized due to the capacity constraints of the 'whole' system. When the subsystem examined is the bottleneck of the 'whole' system the value of (11) is zero. The elimination of this cost requires either strategic intervention (reduction or widening of capacities) or the help of the control concerning the 'whole' system.

If we examine the sum of variances in the cost-time dimensions some interesting results similar to the ones gained in 2.1. can be obtained. That is,

$$V_t=V_{t,util}+V_{t,pr}+V_{t,pas}+V_{t,sys}=$$
$$=C_f-f(p_{st},t,u_{st}) \qquad (12)$$

(12) represents the difference between the actual value of fixed cost and that fixed cost belonging to the engaged indirect resources in the actual production. We compare our current fixed cost to an ideal system which has the same cost characteristics as our system but in which the current production is at total capacity utilization. In (12) only $V_{t,pr}$ means extra expenditures compared to the planned cost. The other part of (12) is always incurred, and when a decrease of these variances is suggested we strive to drive the system toward a performance which assures coverage of these costs. The components of (12) help to identify the areas that are to be examined in order to achieve this goal. This effort is one of the primary issues in the high fixed cost production systems.

2.3. Cost-technology dimensions

In these dimensions those costs related to the technology type resources are examined. A possible behavior pattern of these costs is shown in fig.3. The general form of the cost function related to the resources belonging to this group can be represented in the following way:

$$C_{tech}=f(p,i,u) \qquad (13)$$

where

- p - the price of the technology-type resources available in the production system;
- i - the technology-type resources represented by the output (in terms of information);
- u - the resource utilization coefficient.

Generally (13) is some kind of discrete function because a wide range of output representing different information content can be covered by a given system. We may suppose that every step of the discrete (stepwise) function represents an increase in the costs belonging to the higher information level output. Practically it might mean a change of machines for more sophisticated ones, application of more highly-paid skilled workers, introduction of new quality control systems or production control systems, etc. in order to gain higher level output in terms of the technology represented by the product. The difference in the cost of various technologies comes from the alternate value and ratio of fixed and variable costs. It has to be remarked again that there are other factors influencing (13) which can be disregarded from our point of view.

(a) The resource utilization variance defined in 1.1. can be expressed as follows:

$$V_{i,util}=f(p_{st},i,u_{st}+\Delta u)-f(p_{st},i,u_{st}) \qquad (14)$$

The resource utilization variance in the cost-technology dimensions reflects the non appropriate utilization of available used technology-type resources. It means that the objective of the production was an output representing a certain level of information, but the information resource content of the actual output differs from this. The lower than expected quality, or less than planed functions are some examples of this situation. One of the most important ways to decrease this variance is by improving of quality assurance.

(b) The resource price variance defined in 1.1. can be expressed as follows:

$$V_{i,pr}=f(p_{st},q,u_{st})+f(p_{st},t,u_{st})-f(p_{st},i_{st},u_{st}) \qquad (15)$$

The resource price variance in the cost-technology dimensions means that higher costs than the standard of the expected information level of output were planned. The planned overpayment of work-force as compared to wages that can be considered standard for the required tasks is a characteristic example of the possible reasons. The decrease of this variance requires analysis of the reasons that led to the planning of higher costs than standard. More explanation of this variance can be found in 3.2.

(c) The passive cost defined in 1.1. can be expressed as follows:

$$V_{i,pas}=f'(p_{st},i_{st},u_{st})-f(p_{st},i,u_{st}+\Delta u) \qquad (16)$$

where

f'(pst,i,ust) - the technology related system standard cost.

f'(pst,i,ust) is a modification of (13) by taking into consideration the constraints imposed by the 'information' bottleneck of the 'whole' system. We can consider as an example the case when the parts delivered by a subcontractor are not suitable for the production of a product having the highest information content it would be possible to achieve in our system under optimal conditions.

The passive cost in the cost-technology dimensions expresses the value of technology-type resources not applied in the production but available in the system. The elimination of this variance can be achieved by raising the information level of output by taking orders for higher quality products, for production of more complex parts, etc.

(d) The system cost defined in 1.1. can be expressed as follows:

$$V_{i,sys}=f(p_{st},i_{st},u_{st})-f'(p_{st},i_{st},u_{st}) \qquad (17)$$

The system cost in the cost-technology dimensions means the difference in information content of the output at standard level, on the one hand in the case when the system is considered as a self-contained unit and on the other hand when it is considered as an integrated part of the 'whole'. The decrease of this difference means that the connecting subsystems impose fewer and fewer constraints in terms of the information level of the output.

Examining the sum of differences in the cost-technology dimensions the result similar to (5) and (12) can be obtained, that is,

$$V_i=V_{i,util}+V_{i,pr}+V_{i,pas}+V_{i,sys}=$$

$$=f(p_{st},q,u_{st})+f(p_{st},t,u_{st})-f(p_{st},i,u_{st}) \qquad (18)$$

(18) expresses the difference between the planned variable and fixed cost of an output of certain quantity and quality and the general standard cost of the same output. By general standard cost the accepted competitive expenditures based on the current state of engineering science is meant. We have to emphasize that the 'i' variable contains the technology resources represented by the produced quantity and quality. Thus if our production represents a small lotsize than we can not use as a standard the information level of automated continuous production. Obviously the accepted standard refers to the currently competitive job shop technology.

3. Detailed analyses of variances

In the previous section the variances in all cost dimensions were defined. The variances denoted by the same name in the certain dimensions have many common features but significant differences as well. Both the general elements of our approach and the reason of the shift of emphasis in cost control can be understood by a comparison of the same types of variances.

3.1. Resource utilization variance

As was stated in 1.1., resource utilization variance means that the different kinds of norms referring to the utilization of resources were not kept. The effect of this phenomenon is that a more than expected resource quantity was used up or built into the product. Depending on the type of resource the cost consequence as well as the control policy for elimination of this kind of variance will be different.

The higher than expected (or less than expected) resource usage causes higher (or lower) expenses only in the cost-quantity dimensions, where the result might be (for examples) higher or lower labour and/or material cost.

In the other two cases the effect is more indirect. In the cost-time dimensions the outcome is less available capacity which means decreased potential profit. This potential profit would be achieved by an increase of production. It means that the more efficient resource utilization does not necessarily yield higher profit or less cost. In the case of this variance attention is directed toward the possible loss of return. Thus the incentive is not only to gain profit but also to consider the 'price' in terms of profit-yielding resources.

In the cost-technology dimensions the case is similar to the previous one but the emphasis is put on the 'knowledge' of the system. We assume that we utilize the technological capacity of the system to a certain extent but the reality is different. Consequently the non utilized 'knowledge' of the system is greater than planned. If we would produce our output in a system having less 'knowledge' at a lower price, then it would increase the competitiveness of our product. The other possibility is to produce an output of higher information level in the same system which would improve the efficiency of the 'smarter' system. The philosophy is the same as before; profit is not the only performance measure, the price of profit in terms of profit yielding resources has to be considered too.

In all the three cases the control policies are either measures to ensure accurate observance of the resource utilization norms, or the modification of them in order to eliminate possible planning errors. However this intervention has direct consequences only in case of norms belonging to the set of direct resources. In the two other cases further steps should be taken in order for the effects of interventions to be reflected in terms of profit.

3.2. Price variance

The resource price variance indicates that we spent more than planned for the procurement or maintenance of resources. The higher expenditures are approached here from the direction of resource procurement policy.

In the <u>cost-quantity</u> dimensions this means that the more we produce the more overpaid direct resource will be required, and the result is the higher production cost.

In the <u>cost-time</u> dimensions the variance does not directly correlates with quantity. The more we pay for the indirect resources the higher the overhead burden for a time unit and the more difficult it is to ensure the competitive product background to recover this burden.

In the <u>cost-technology</u> dimensions some more detailed explanation is required. The resource price variance in this field reflects the higher cost acknowledged as the standard of our system than the competitive standard of the industry in question. There may be different reasons for this (manpower policy, erroneous technology or process planning) but if the system output does not reflects this higher information level then the recovery of these costs can not be assured. This variance may help to understand why a product produced with the same technology but under different operations management strategy can have different competitiveness. This variance is also relevant to the product-process relationship (Hayes and Wheelwright [1979], Hayes and Wheelwright [1979a]). Sometimes it is hard to judge the trade-off between producing small lots in a job shop environment or large lots in a continuous production environment. The technology standard - which apparently is not easy to determine - can help in the evaluation. The possible conclusion is obvious; if the production technology is uncompetitive, no matter how strictly we keep the norms in the long run, the calculable variance will indicate inefficient performance of the system.

It has to be emphasized that the difference between the ideal cost and the current production cost of our system contains all the three variances, but the effort to decrease these gaps requires different type of interventions. The variance in the cost-technology dimensions reflects the accepted higher cost while the other two components create additional expenditures which can be eliminated by more strict cost control.

3.3. Passive cost

The passive cost indicates the value of resources applied in the production but which did not contribute to the output. It means that the system was in operation but did not yield products.

In the <u>cost-quantity</u> dimensions a typical example is the production of rejected products. In this case we incurred all the variable costs but could not sell anything. By eliminating this variance we have less variable cost, that is, we save direct expenditures. The cause of this cost in the other two cases is the same but the effect of their reduction is different.

In the <u>cost-time</u> dimensions the passive cost does not mean direct cost saving. It only means that resources of certain value are idle. If we use these resources and produce something, then the passive cost does not vanish, but we may be able to recover this cost by the contribution margin of the product. The conditional mode was used to indicate that producing a product does not necessarily mean that we will really be able to ensure the revenue side of the costs.

The passive cost in the <u>cost-technology</u> dimensions indicates that our production system is able to produce output of higher information content, that is, it is possible to perform the current production in a system of lower technology cost. The reduction of this cost drives the system into a more efficient utilization of the technological capabilities.

It is important to understand the difference between the passive cost and resource utilization variance. In both cases increased resource usage may be experienced but while in the first case those resources are necessary to the actual output, in the second case the resources are idle and can directly be transformed into useful products.

3.4. System cost

The system cost indicates the expenditures paid for the nonutilized resources due to the structure of the 'whole' production system.

In the <u>cost-quantity</u> dimensions it is not easy to separate the resource utilization variance from the system cost. It is difficult to express explicitly - especially in general discussion - which part of the changed resource utilization belongs to improper performance of the activity in question and which belongs to causes derived from the system's surroundings. Whereas theoretically the system cost exists in these dimensions, from the point of view of practical control we suggest that the 'system effect' should be considered when the reasons for resource utilization variance are investigated. In the other two cases system cost is well defined, easily expressed and has great importance.

In the cost-time and cost-technology dimensions the meaning of the system cost is the same as that of the passive cost, that is, we paid for resources non-represented in the output. However the reason for this is different and so consequently is the method of its elimination. In the first case there are direct ways of eliminating passive cost by increasing production. In the second case, without the influence of the system structure there is no way to eliminate system cost. In a situation where capacity underutilization derives more from system cost than passive cost it would be a mistake to blame it upon lack of customer orders (Koltai [1986]).

The system cost in the cost-time dimensions refers to the effects of capacity bottleneck while in the cost-technology dimensions it indicates problems due to technology bottlenecks. These are new issues especially characteristic of flexible manufacturing systems where the constantly changing material flow makes the system more sensitive to the logistics of the process.

4. Comprehensive consideration of the generalization of standard costing

The main issue in the foregoing points was very simple: we considered on one hand the cost of actual production and on the other hand the competitive cost of the performance of the same production task. The difference between these two was divided into parts. The principle of this division was that we tried to detect the possible causes of the difference and to determine the different causes to which those parts belong. Some hazy definition - but not overlapping - can be experienced (e.g. in case of the system cost) however we assume that this organization of differences can be an appropriate guideline to the cost control. Some of these variances are not new (Benett [1958], Dearden [1973], Reece, Anthony, Welsch, [1985]) but the introduction of system cost and the variances in the cost-technology dimensions means new viewpoints dictated by very lively and uptodate requirements (Brimson [1988], Maskell [1986], Meredith [1988]). Examining the sum of all differences this basic idea becomes clear:

$$V=V_q+V_t+V_i=C_v+C_f-f(p_{st},i,u_{st}) \tag{19}$$

The first two elements of (19) are the current costs of the production rendering an output of definite quantity and quality . The last element means the 'absolute' standard cost of the same production task. The definition of this cost is not easy but has primary importance. It is a task not without difficulty to determine the best possible technology resources, operation management strategy, etc. in order to obtain this cost as reference point. However this effort is crucial primarily for the following two reasons:

(a) Beside the design and technology a third major element of the competitiveness of a production system is the production organization. A good example is the success of just-in-time systems which sometimes produce the same product with much greater success than a traditionally organized process. The significance of the product technology relation can not be neglected. The absolute standard cost of production forces management to drive the system in the best possible design, technology and production organization.

(b) With the appearance of high-value flexible manufacturing systems the technology utilization obtained greater emphasis. Many failures of the introduction of new technology can be derived from the selection of improper product profile. Sometimes high technology is used only for the substitution of the traditional one and the surplus expenditures are not reflected in the output.

The cost-technology dimensions are to support the correction of a policy of this kind.

If we examine all the variances it turns out that only some of them can be considered direct variance. Under 'direct variance, is meant those costs that actually cause more expenditures. The indirect variances have to be paid in every case. Their elimination does not necessarily mean less cost but the possible recovery of the current cost by increased revenue. Considering the definition of variances given in point 2. the value of direct and indirect variances are the followings:

$$V_{dir}=V_q+V_{t,pr}+V_{i,pr} \qquad (20)$$

$$V_{indir}=V_t+V_i-V_{t,pr}-V_{i,pr} \qquad (21)$$

The ratio of (20) and (21) reflects one of the reasons leading to the change of control issues in high technology production systems.

5. Simulation model for the examination of variances

In the previous sections we have described the theory and method by which we suggest the information for cost control should be calculated. In the following a computational example will be provided. The absolute value of data used may be debatable but the ratios (ratio of direct labour costs, overhead costs, etc.) are based on surveys published in the literature. Since most of our conclusions are based on changes in percentage and ratios of values, we strived to use simple absolute data. It will be borne out by the analysis, however, that this fact does not affect the validity of the results.

The principle of the examination is to set up a model for the calculation of variances. The structure of the model makes it possible to change the cost characteristics of the system examined and the data intended to describe a certain performance condition. The possibility of flexibly changing the data allows us to examine and compare the variances of standard costing in different production systems working under similar conditions, or in the same system exposed to the change of operation characteristics.

5.1. The structure of the model

Our hypothetical production system is over-simplified in order to emphasize the main issues we want to examine. The basic supposition is that only one type of product is produced and the control period is one month. Also, for the sake of simplicity immensely aggregated date have been used. Instead of a detailed list, resources are grouped according to the following cost categories:

- direct material,
- direct labor,
- variable overhead,
- fixed overhead.

The basic data of the model can be grouped as follows:

(a) General data concerning the main characteristics of the system structure and working conditions (Table 1.):

- total planned cost is the expenditure the system considers acceptable for this production,
- variable cost ratio is the ratio of direct and variable overhead costs in the total planned cost,
- available time is the time period available to perform the planned production,

- relative maximum is the maximum quantity it is possible to produce considering the capabilities of the subcontractor, attached processes, etc.,
- planned quantity is the output the system is to provide.

(b) General data concerning the output (Table 1.):

- actual quantity produced,
- actual time used for the production.

(c) Detailed data of cost and resource utilization standards (Table 1a.):

- resource utilization standards expressed in terms of the quantity of resource in one unit of output,
- variable cost standards expressed in terms of the cost paid for one unit of resource,
- fixed cost standards expressed in terms of the cost of indirect resources used during the control period.

(d) Detailed data of technology standards:

- standard fixed cost of the technology of production unit examined (Table 2a.),
- detailed data of cost and resource utilization standards of the technology of the production unit examined (Table 2a.),
- standard fixed cost of the technology of the 'whole system' examined (Table 3a.),
- detailed data of cost and resource utilization standards of the technology of the 'whole system' examined (Table 3a.),
- standard fixed cost of the technology of the planned production (Table 4a.),
- detailed data of cost and resource utilization standards of the technology of the planned production (Table 4a.),
- standard fixed cost of the technology of the actual production (Table 5a.),
- detailed data of cost and resource utilization standards of the technology of the actual production (Table 5a.).

(e) Detailed data of actual production (Table 6a.):

- actual resource utilization expressed in terms of the quantity of resource in one unit of output,
- actual variable costs expressed in terms of the cost paid for one unit of resource,
- actual fixed costs expressed in terms of the cost of direct resources used during the control period.

5.2. Generating data for the analysis and simulation

To facilitate analysis of the different kinds of production systems, auxiliary formulae are used to generate the required information. The type of relations applied refers to the data groups defined in 5.1. respectively:

(a) Generating general data concerning the main characteristics of the system structure:

- the variable cost ratio serves to set the basic cost structure of the supposed production system used for examination.

(b) Generating the general data concerning the output:

- the rejection ratio, expressing the rate of actual and planned output, serves to set the general working conditions.

(c) Generating the detailed data of cost and resource utilization standards (Table 1b.):

- the resource utilization standards are determined directly,
- the cost standards are generated by the determination of the ratios of the variable cost components and the total variable cost.

(d) Generating the detailed data of technology standards (production unit (Table 2b.), whole system (Table 3b.), planned production (Table 4b.) and actual production (Table 5b.)):

- the fixed cost is generated by the determination of the ratio of change compared to the previously planned fixed cost,
- the resource usage standards are generated by the determination of the ratio of changes compared to the previously planned resource usage standards of the planned production,
- the cost standards are generated by the determination of the ratio of changes compared to the previously planned cost standards of the planned production.

(e) Generating the detailed data of actual production (Table 6b):

- the actual resource usages are generated by the determination of the ratio of changes compared to the resource usage standards of planned production,

- the actual cost standards are generated by the determination of the ratio of changes compared to the cost standards of planned production,
- the total actual cost of the denoted resource categories are generated by the determination of ratio of changes compared to the total costs calculated by the actual resource usage and cost standards.

5.3. The presentation of results

With the help of the generated data described in 5.1. and 5.2. we performed the analysis suggested in point 2. The following results are calculated and presented either in tables or in the form of graphs:

- the variances concerning the different resource categories in all the three dimensions (Table 7., 8. and 9.),
- the sum of the various differences in the several dimensions (Table 10.),
- the ratio of the same variance in different dimensions in form of a bar chart (Fig. 4a),
- the ratio of variances in the total variance in form of a pie chart (Fig. 5a),
- the distribution of variances in the different dimensions in form of a bar chart (Fig. 6a),
- the ratio of dimensions in the total variance in form of a pie chart (Fig 7a),
- the sum of direct and indirect variances in form of pie chart (Fig 8a),
- the change of the variances in function of the variable cost ratio in absolute and relative values (Fig. 9 and 10).

6. Experimental calculations, evaluation of the results

6.1. The data and initial conditions applied

The model formulated in the previous points was tested with a wide range of data. In order to be able to draw conclusions of general concern a data structure based on information from the relevant literature was set up. The results gained are undoubtedly highly dependent on the initial conditions, therefore it is important to examine the underlying assumption applied in the generation of the data structure. In the course of the experimental calculation we supposed the following:

- From the introduction of computer aided manufacturing in a traditional job-shop environment a considerable change in the cost structure of the production system can be expected. In a conventional job-shop the overhead is expected to be 10-40%. Due to the introduction of high value machines and equipment as well as the changed requirements of maintenance and work force characteristics this ratio in a CIM environment is expected to increase up to 70-90% (Dhavale [1988], Patterson [1984a]).

- Compared to the 5-25% direct labor cost rate in a traditional job-shop environment a significant drop can be expected in the case of CIM systems. The expected ratio of these costs is 1-6% (Dilts and Russell [1985], Patterson [1984a]).

- In the total cost of the manufacturing of a product a considerable shift can be experienced from the material costs to the transformation costs. The significance of transformation costs as opposed to the direct material costs presumably will increase (Dhavale [1988]).

- Sensitivity to the changes of both capacity and technological bottlenecks is a general feature of every job-shop system. The significance of technology bottlenecks are increasing in a CIM environment (Production Engineering [1984], Stecke and Solberg [1985], Koltai [1986]).

Some further assumptions were applied in order to generate data describing the current production. Some of these preconditions were used in order to make some trends traceable. Others were used to simplify the complexity of the real situation. The latter do not restrict significantly the validity of the results. The actual production has the following characteristics:

- The deviation of the resource utilization and cost norms expressed in percentage are summarized in table 6b.

- It was supposed that the actual production could have been produced in a system of lower fixed cost, with 10% lower resource utilization norms and 2.5% lower variable cost norms. The data used for generating the technological standards are summarized in table 3b., 4b. and 5b. These data express the percentage change of fixed cost, variable cost and resource utilization standards compared to these data of the planned production.

- While examining the effects of the changing cost structure we kept the ratios of table 3b., 4b., 5b., and 6b. constant. This assumption means that for example the change of the resource utilization norms in terms of percentage is the same in the traditional technology and in the CIM environment. We have to emphasize that it does not mean the equality of the absolute values. It only means that for example the variable labor cost norm is exceeded by 10% in both cases but in absolute values it is a higher change in the traditional technology environment where the variable labor cost ratio in the total production cost is higher. This assumption is probably not always true but can be considered as a compromise in order to avoid the overly complex situation.

In the experimental calculation two systems having 0.8 and 0.2 variable cost ratio were examined first. The former represents the traditional technology system while the latter describes a CIM environment. The detailed data of the system cost characteristics, resource utilization, cost and technology standards as well as the result of the actual production are presented in table 1a.-6a. After the detailed variance analysis of the two system we examined the change of the direct and indirect variances with the change of the variable cost ratio of the production system.

6.2. Evaluation of results

The results of the detailed variance analysis and the summary of variances can be found in table 7-10. The visual representation of the results concerning the system of 0.8 and of 0.2 variable cost ratio can be found in fig. 4a-8a and 4b-8b respectively.

In fig. 4a and 4b the ratio of the same type of variances in the different dimensions can be studied. It is borne out by the figures that the resource utilization variance has much less significance in the cost quantity dimensions in the higher fixed cost system than in the lower one. The resource price variance in the cost-technology dimensions is negative in both systems, which indicates low planned costs. The distribution of passive costs has changed too. In the lower variable cost system the passive cost of the cost-quantity dimensions is less significant.

In fig 5a and 5b an aggregated form of the variances can be seen. As is seen in the figures the significant difference are in the system cost and the resource price variance. Of course the equal ratio of a variance in both system does not necessarily mean similarities in the system performance since the same aggregate data can be composed of different components. The case of the passive costs well characterizes this situation.

Figure 6a and 6b show the distribution of the variances in the different dimensions. It is borne out by the figures that the distribution of variances both in the cost-quantity and cost-time dimensions is similar in both systems but there are changes in the emphasis. The significance of the cost-quantity dimensions is less in the lower variable cost system while the cost-time dimensions is more important in the other one. The distribution of the variances in the cost-technology dimensions is different.

In fig 7a and 7b the aggregated ratio of the variances belonging to the specific dimensions are presented. The dramatic decrease of the variances of the cost-quantity dimensions and the increase of the variances in the cost-time dimensions can be experienced in the system of high fixed cost.

Fig 8a and 8b show the ratio of direct and indirect variances. The big shift toward the indirect variances in the system representing the CIM environment is obvious.

Figure 9 presents the change of the absolute values of direct and indirect variances furthermore the sum of all variances. We supposed that the total planned cost is the same but the variable cost ratio is changing between the two hypothetical extremes, 0 and 1. Every other condition is similar. Figure 10 shows the same thing but for relative values. From the figures it is clear that the increase of the ratio of fixed costs leads to relatively and absolutely higher indirect variances.

7. General conclusions

The presented model and the attached calculations have mainly demonstration purpose. A model based on estimated data is always manipulable and the conclusions drawn by the results may be questionable. We think however that the results of this model taken together with experience of current management practice relevant to the field, and with trends we presume will prevail in the future, allows us to make some general remarks. These remarks try to highlight the changing emphasis of the control issues in high technology production systems.

One of the most important results of the train of thought presented in this paper is to show the increasing significance of indirect variances. It means that the effort made to improve resource utilization in a production system can not necessarily be measured by more favorable cost performance. In cases of high value, high technology oriented production systems a major element of the performance measures is the value of the non producing or passive resources. Thus the effort of improving the utilization of direct resources and of keeping to the cost norms does not necessarily mean the recovery of the high overheads, and even if it does the system can not necessarily be considered efficient. This assertion has some very theoretical and some strongly practical consequences.

One of the more interesting philosophies of today the entropy world view which observes many phenomena prevailing in the world in new perspective. Riffkin (1980) applies the second law of thermodynamics in many spheres of life and proves its significance in industrial, agricultural, educational, social, political, and other fields. The very basic idea is that every energy (or material) transformation is accompanied by energy dissipation. This energy loss sometimes shows up very 'far' from the real transformation process. The more developed the system the further the dissipated energy can be found and/or the more difficult to detect. Therefore sometimes it is not easy to measure or even estimate the energy efficiency of a process. This perspective suggest that every effort which tries to incorporate into performance measures the indirect consequences of a production process brings about a practical contribution to Riffkin's philosophy. The indirect variances try to focus on that part of the energy dissipation which can be controlled in the operation management sphere.

We would like to point out the importance of three particular changes in relation to the practical consequences.

(a) <u>In a high technology environment the overhead control has particular significance.</u> A considerable part of the indirect variances comes from the inefficient utilization of those resources belonging to the system overhead. In the new environment however overhead control takes on a new dimension. Efforts can be made to directly decrease the cost caused the high overhead. This policy though may have its limitations. The direct reduction of overhead cost may endanger appropriate system performance (inefficient maintenance, unstable energy supply, inappropriate logistics, etc.). Furthermore overhead control of the system has to focus on the contribution margin of the products the overhead were used for.

The efficient performance of the minimum necessary overhead is again a very complex problem. So far not much attention has been paid to this question when the system (company) was apparently successful enough. This has had severe consequences for the international competitiveness of American industry (Thurow [1987]). The inefficient utilization of available technology may be successful in the short run in a monopoly situation or an isolated market, but does not lead to long term stability. This assertion may be justified by the example of the Japanese success in many industrial fields versus the failure of many American companies which have tried to change technology while continuing to produce the same product structure. The introduction of the cost-technology dimensions is to enforce the system toward an efficient performance in terms of the available technology utilization. In addition referring back to the entropy philosophy, efficient technology utilization serves the efficient utilization of nonrenewable resources also, by considering more efficient a less complicated system that results in less energy dissipation, although sufficient profit can be ensured even in the more complicated system.

Talking about this issue one might have the feeling that the topics of this paper belongs more to the strategic field instead of to the control sphere. This leads to the second change we are trying to point out.

(b) <u>The interrelation between the control and strategic issues are becoming stronger.</u> Many problems which up to now have belonged to the control sphere gain strategic importance and strategic issues now have stronger impact on the control area. If we consider the fields that were touched upon in this study, of which main topic was the control based on operating costs, we can see that the strategic field was ineluctable. When we examined the capacity utilization of the system we found that we had to consider both control and strategic factors (passive cost and system cost). The appearance of the technology dimension and the increasing emphasis on technology control shows how strategic issues have become elements of the control sphere.

Conversely, the increasing role of scheduling also proves this process. The influence of scheduling on set-up times and work-in-process inventories indirectly effects the production management philosophy suitable for application in a system. In the traditional systems it was also true, but with the amplified importance of capacity utilization and inventory issues the set-up time has acquired strategic importance (Hall [1983]). The application of just-in-time systems in Japan is a clear example of the strategic effect of set-up times (Monden [1983]).

(c) The third change we think worthy of mention is the increased role of system effects. The system cost in both the time-cost and technology-cost dimensions tried to grasp these effects from the cost point of view. The relatively high system costs direct the attention to the fact that high technology systems are sensitive to system interrelationships. Any change in the operating characteristics of a certain subsystem may change the site of both the technology and capacity bottlenecks. Approaching this phenomenon from the other direction, when changing the technology in a subsystem we may find the operation of another subsystem becomes inefficient from cost point of view. The chain of analysis of the kind presented in this paper might help to answer the questions raised in this field.

The issues discussed in this section are only parts of a very complex problem with far-reaching ramifications for different disciplinary fields. To ignore the interrelated consequences in managerial accounting, operations management, process control or even in some human disciplines may lead only to particular solutions. We took the risk of making mistakes when using the terminology of accounting. However our objective was not to do research in accounting but to understand and highlight issues that might be interesting for the further research in the control of modern production systems from operations management point of view.

Computations presented were to serve the above mentioned objective. The model, even in this very simple form raised some interesting questions which are worth to consider at the control of high technology systems. Further refinement of the examination shown (introduction of probability variables, resolution of the constraints applied, examination of a multy-product situation, etc.) may give us on one hand a deeper insight into the nature of cost control of high technology production systems and on the other hand may provide efficient means for the operations management in practice.

References

Bennett, C. W. 1958. Standard cost ... How they serve modern management. Prentice-Hall, Inc, Englewood Cliffs, N.J.

Brimson, J. A. 1988. Bringing cost management up to date. Manufacturing Engineering. June, 49-51.

Brown, G. M. 1986. Variance analysis: trend and materiality. Management Accounting (UK). Vol. 64. June, 38-39.

Burstein, M. C. 1986. Guidelines for the estimation of costs in the economic justification of flexible manufacturing technology. Presented for the meeting Flexible Manufacturing Systems'86 of the Society of Manufacturing Engineers in Rosemont, Illinois, March 4.

Deakin, E. B. and Maher, M. W. 1984. Cost accounting. R.D. Irwin, Homewood,Illinoi. 1984.

Dearden, J. 1973. Cost Accounting and Financial Control Systems. Addison-Wesley Publishing Company. Reading, Massachusetts.

Dhavale, D. G. 1988. Indirect costs take on greater importance, require new accounting methods with CIM. Industrial Engineering. Vol. 20. July, 41-43.

Dilts, D. M. and Russell, G. W. 1985. Accounting for the factory of the future. Management Accounting. Vol. 66. April, 34-40.

Dorward, N. 1985. Variance analysis: pitfalls of present costing techniques. Accountancy. November, 204-206.

Edwards, J. B. and Heard, J. A. 1984. Is cost accounting the no. 1 enemy of productivity. Management Accounting. Vol. 65. June, 44-49.

Ettlie, J. E. 1988. Taking charge of manufacturing. Jossey-Bass Publisher, San Francisco, London.

Galway, A. 1985. Standard costing and control by variance analysis. Management Accounting (UK). Vol. 63. June, 58-61.

Hakala, G. 1985. Measuring costs with machine hours. Management Accounting. Vol. 67. October, 57-61.

Hall, W. H. 1983. Zero Inventories. Dow Jones-Irwin. Homewood, Illinois.

Hayes, H. R. and Wheelwright, S. G. 1979. Link manufacturing process and product life cycle. Harvard Business Review. January-February, 134-140.

Hayes, H. R. and Wheelwright, S. G. 1979a. The dynamics of process-product life cycle. Harvard Business Review. March-April, 127-136.

Hiromoto, T. 1988. Another hidden edge - Japanese management accounting. Harward Business Review. July-August, 22-26.

Ingersby, T. 1988. 'We have met the enemy and it are management'. Manufacturing Systems. 16 June, 16-19.

Inman, M. L. 1985. Overhead absorption variance analysis. Compounding the problem? Management Accounting (UK). Vol. 63. September, 30-31.

Jaouen, P. R. and Neumann, B. R. 1986. Kanban, ZIPS and cost accounting: A case study. Journal of Accountancy. Vol. 162. August, 132-141.

Jaouen, P. R. and Neumann, B. R. 1987. Variance analysis, kanban and JIT: A further study. Journal of Accountancy. Vol. 163. June, 164-173.

Kaplan, R. S. 1983. Measuring manufacturing performance: A new challenge for managerial accounting research. The Accounting Review. Vol. 58. October, 686-705.

Kaplan, R. S. 1984. Yesterday's accounting undermines production. Harvard Business Review. July-August, 95-101.

Kaplan, R. S. 1986. Must CIM be justified by faith alone? Harvard Business Review. March-April, 87-95.

Koltai, T. and Farkas A. 1988. A multy-dimensional approach of large scale material flow systems: An Integrated Logistic Concept. In: Cybernetics and Systems'88 (ed.: Trappl, R.). Kluwer Academic Publishers. pp. 1119-1121.

Koltai, T. 1986. The analysis of industrial processes together with the production system based on logistics concept. In: Advances in Production Management Systems 85 (ed.: Brown, J.). North-Holland Publishing Company. New York, Oxford, Tokyo. pp., 267-277.

Maskell, B. 1986. Management accounting and just-in-time. Management Accounting (UK). Vol. 64. September, 32-34.

Meredith, J. 1988. Installation of flexible manufacturing systems teaches management lessons in integration, labor, cost, benefits. Industrial Engineering. Vol. 20. April, 18-27.

Monden, Y. 1983. Toyota production system. Practical approach to production management. Industrial Engineering and Management Press. Institute of Industrial Engineers. 1983.

Patterson, W. 1984. Is the choice full-scale CIM or death? Industry Week. July 9, 15-16.

Patterson, W. 1984a. The software solution forging manufacturing's missing link. Industry Week. Vol. 222. September 17, 93-99.

Production Engineering. 1984. Network of flexible flow. Vol. 31. No. 3. 44-55.

Riffkin, J. 1980. Entropy: A new world view. The Viking Press. New York.

Schwarzbach, R. H. 1985. The impact of automation on accounting for indirect costs. Management Accounting. Vol. 67. December, 45-50.

Reece, J. S., Anthony, R. N., Welsch, G. A. 1985. Fundamentals of management accounting. R.D. Irwin, Homewood, Illionoi.

Stecke, E. K. and Solberg J. J. 1985. The optimality of unbalancing both workloads and machine group sizes in closed queuing networks of multiserver queues. Operations Research. Vol. 33. July-August, 882-910.

Steffy, W., Ahmad, N., Reyes, T. 1980. Productivity and cost control for the small and medium-sized firm. Industrial Development Division, Institute of Science and Technology. the University of Michigan. Ann Arbor, Michigan.

Tait, G. 1985. The truth about standard costing. Management Accounting (UK). Vol. 63. October, 36-38.

Tatikonda, U. L. 1987. Production managers need a course in cost accounting. Management Accounting. Vol. 68. June, 26-29.

Thurow, L. C. 1987. A weakness in process technology. Science. Vol. 238. December 18, 1659-1663.

Table 1.: INITIAL DATA CONCERNING THE PRODUCTION SYSTEM

Total planned cost:	100000.00	$
Variable cost ratio	0.80	
Available time:	2860.00	hour/period
Relative maximum:	2000.00	pieces/period
Planned production:	1500.00	pieces/period
Reject ratio:	0.20	
Actual production:	1200.00	pieces/period
Actual time:	2250.00	hour/period
Maximum quantity:	2200.00	pieces/period
Rel. avail. time:	2600.00	hour/period
Actual standard t.:	1560.00	hour/period

Table 1a.: COST AND RESOURCE USAGE STANDARDS OF PLANNED PROD.

PLANNED STANDARDS	resource usage (quant./piece)	cost var.($/q.)	fix($/period)
Direct material	3.00	7.11	
Direct labor	1.30	12.31	
Variable overhead	10.00	1.60	
Fix overhead			20000.00

Table 1b.

STANDARD	resource usage (quant./piece)	cost (ratio) variable	fix
Direct material	3.00	0.40	
Direct labor	1.30	0.30	
Variable overhead	10.00	0.30	
Fix overhead			1.00

TECHNOLOGY STANDARDS

Table 2a.: PRODUCTION UNIT

Fixed cost: 24000.00 $/period
Variable cost: 64896.00 $/quantity
Var. cost ratio: 0.73

PRODUCTION UNIT STANDARDS	resource usage (quant./piece)	cost var.($/q.)	fix($/period)
Direct material	2.93	7.40	
Direct labor	1.27	12.80	
Variable overhead	9.75	1.66	
Fix overhead			24000.00

Table 2b.

PRODUCTION UNIT STANDARDS	resource usage (ratio)	cost (ratio) variable	fix
Direct material	-0.025	0.04	
Direct labor	-0.025	0.04	
Variable overhead	-0.025	0.04	
Fix overhead			0.20

Table 3a.: WHOLE SYSTEM

Fixed cost: 22000.00 $/period
Variable cost: 63840.00 $/quantity
Var. cost ratio: 0.74

WHOLE SYSTEM STANDARDS	resource usage (quant./piece)	cost var.($/q.)	fix($/period)
Direct material	2.85	7.47	
Direct labor	1.24	12.92	
Variable overhead	9.50	1.68	
Fix overhead			22000.00

Table 3b.

WHOLE SYSTEM STANDARDS	resource usage (ratio)	cost (ratio) variable	fix
Direct material	-0.05	0.05	
Direct labor	-0.05	0.05	
Variable overhead	-0.05	0.05	
Fix overhead			0.10

Table 4a.: ACTUAL PRODUCTION

Fixed cost: 20400.00 $/period
Variable cost: 60800.00 $/quantity
Var. cost ratio: 0.75

ACTUAL PRODUCTION STANDARDS	resource usage (quant./piece)	cost var.($/q.)	fix($/period)
Direct material	3.00	6.76	
Direct labor	1.30	11.69	
Variable overhead	10.00	1.52	
Fix overhead			20400.00

Table 4b.

ACTUAL PRODUCTION STANDARDS	resource usage (ratio)	cost (ratio) variable	fix
Direct material	0.00	-0.05	
Direct labor	0.00	-0.05	
Variable overhead	0.00	-0.05	
Fix overhead			0.02

Table 5a.: ACTUAL OUTPUT

Fixed cost: 15000.00 $/period
Variable cost: 56160.00 $/quantity
Var. cost ratio: 0.79

ACTUAL OUTPUT STANDARDS	resource usage (quant./piece)	cost var.($/q.)	fix($/period)
Direct material	2.70	6.93	
Direct labor	1.17	12.00	
Variable overhead	9.00	1.56	
Fix overhead			15000.00

Table 5b.

ACTUAL OUTPUT STANDARDS	resource usage (ratio)	cost (ratio) variable	fix
Direct material	-0.10	-0.025	
Direct labor	-0.10	-0.025	
Variable overhead	-0.10	-0.025	
Fix overhead			-0.25

Table 6a.: DETAILED DATA OF ACTUAL PRODUCTION

ACTUAL PROD.	resource usage (quant./piece)	cost var.($/q.)	cost fix($/period)	Total ($)
Direct material	3.15	8.18		42504.00
Direct labor	1.33	13.54		28274.40
Variable overhead	15.00	1.60		36000.00
Fix overhead			22400.00	22400.00
Total				129178.40

Table 6b.

ACTUAL PROD.	resource usage (ratio)	cost (ratio) variable	cost (ratio) fix	Total (ratio)
Direct material	0.05	0.15		0.1
Direct labor	0.02	0.10		0.05
Variable overhead	0.50	0.00		0
Fix overhead			0.12	0

EXTENDED VARIANCE ANALISYS

Table 7.: VARIANCES IN THE COST-QUANTITY DIMENSION

VARIANCES ($/q.)	Res. utilisat.	Res. price	Passive cost	System cost	Total
Direct material	1280.00	4032.00	3864.00	xxx	9176.00
Direct labor	384.00	1958.40	1346.40	xxx	3688.80
Variable overhead	9600.00	0.00	0.00	xxx	9600.00
Fix overhead	xxx	xxx	xxx	xxx	xxx
Total	11264.00	5990.40	5210.40	xxx	22464.80

Table 8.: VARIANCES IN THE COST-TIME DIMENSION

Standard. unit cost.: 6.99 $/hour
System standard. unit cost. 7.69 $/hour

VARIANCES ($/p.)	Res. utilisat.	Res. price	Passive cost	System cost	Total
Direct material	xxx	xxx	xxx	xxx	xxx
Direct labor	xxx	xxx	xxx	xxx	xxx
Variable overhead	xxx	xxx	xxx	xxx	xxx
Fix overhead	5307.69	2400.00	2692.31	1090.91	11490.91
Total	5307.69	2400.00	2692.31	1090.91	11490.91

Table 9.: VARIANCES IN THE COST-TECHNOLOGY DIMENSION

Total techn. st. cost of production unit:	88896 $
Total techn. st. cost of whole system:	85840 $
Total techn. st. cost of actual production	81200 $
Total techn. st. cost of actual output:	71160 $

VARIANCES ($)	Res. utilisat.	Res. price	Passive cost	System cost	Total
Direct material	1856.00	-358.40	1216.00	422.40	3136.00
Direct labor	1392.00	-268.80	912.00	316.80	2352.00
Variable overhead	1392.00	-268.80	912.00	316.80	2352.00
Fix overhead	5400.00	-4000.00	1600.00	2000.00	5000.00
Total	10040.00	-4896.00	4640.00	3056.00	12840.00

Table 10.: SUMMARY OF VARIANCES

($)	Res. utilizat.	Res. price	Passive cost	System cost	Total
Cost-quant. dim.	11264.00	5990.40	5210.40	xxx	22464.80
Cost-time dim.	5307.69	2400.00	2692.31	1090.91	11490.91
Cost-techn. dim.	10040.00	-4896.00	4640.00	3056.00	12840.00
Total	26611.69	3494.40	12542.71	4146.91	46795.71

Sum of direct variances:	19968.80 $
Sum of indirect variances:	26826.91 $
Total	46795.71 $

Fig 1: Cost-quantity dimensions

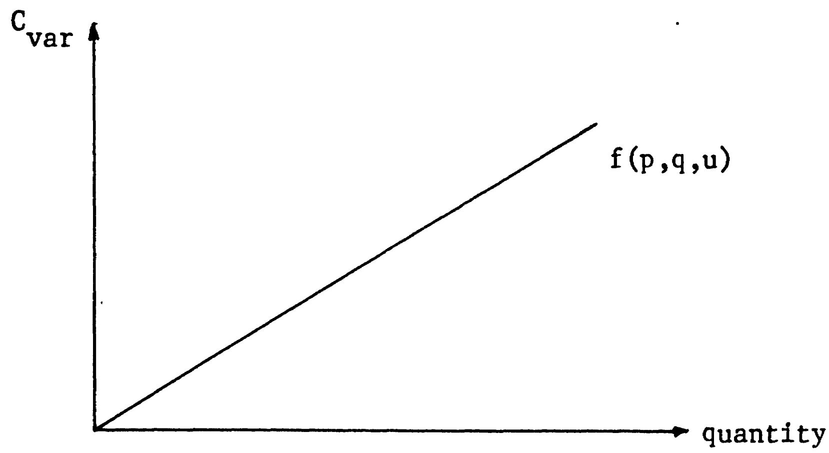


Fig 2: Cost-time dimensions

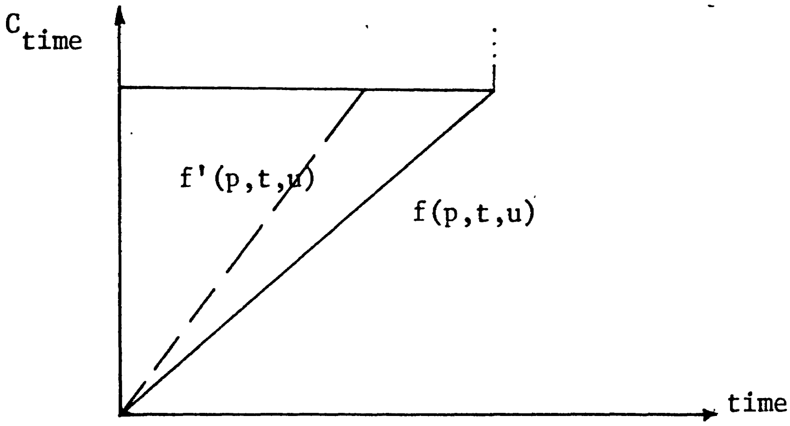
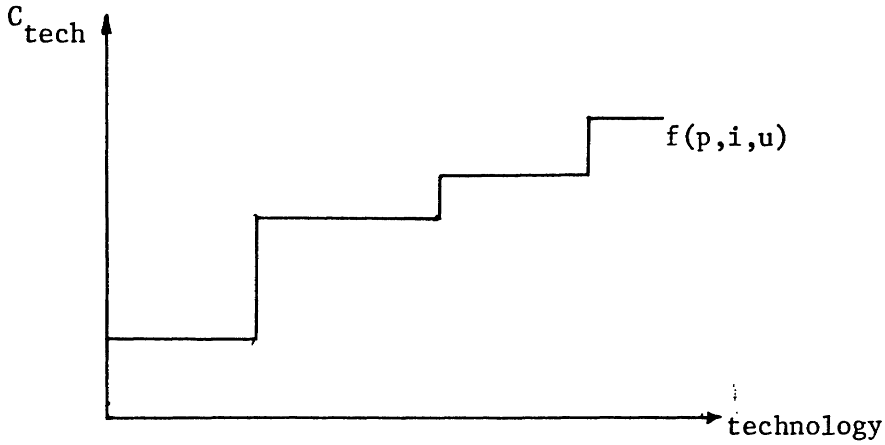


Fig 3: Cost-technology dimensions



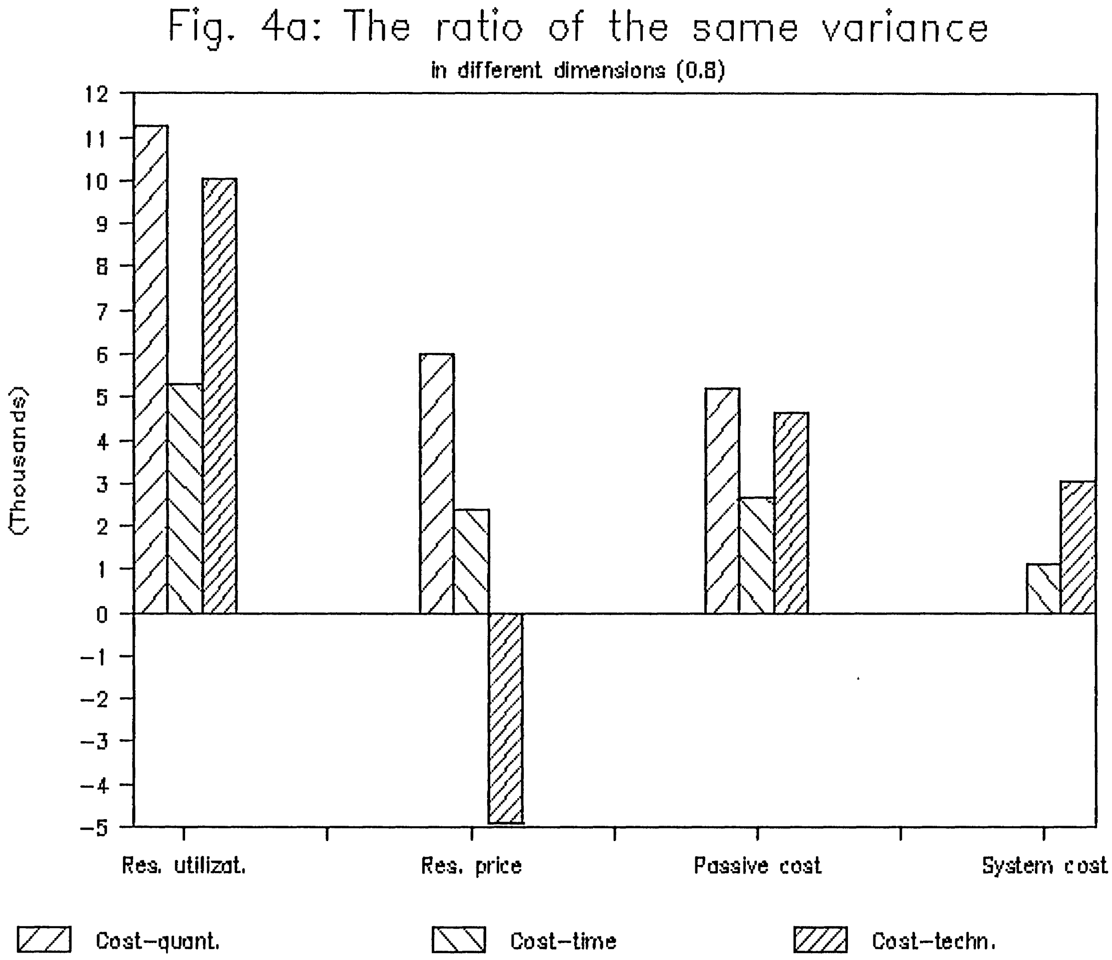


Fig. 4a: The ratio of the same variance
in different dimensions (0.8)
(Thousands)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
Res. utilizat.
Res. price
Passive cost
System cost
Cost-quant.
Cost-time
Cost-techn.

Fig. 4b: The ratio of the same variance

in different dimensions (0.2)

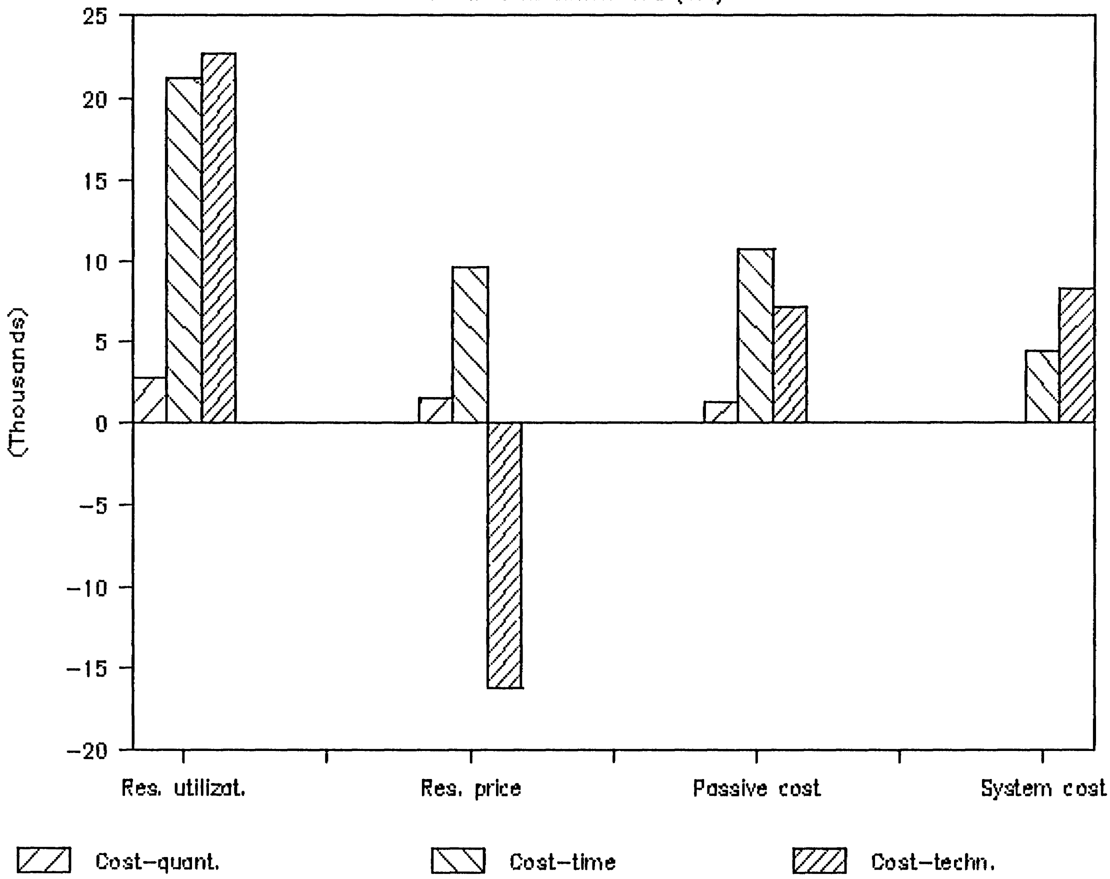


Fig. 5a: The ratio of variances in the total variance (0.8)

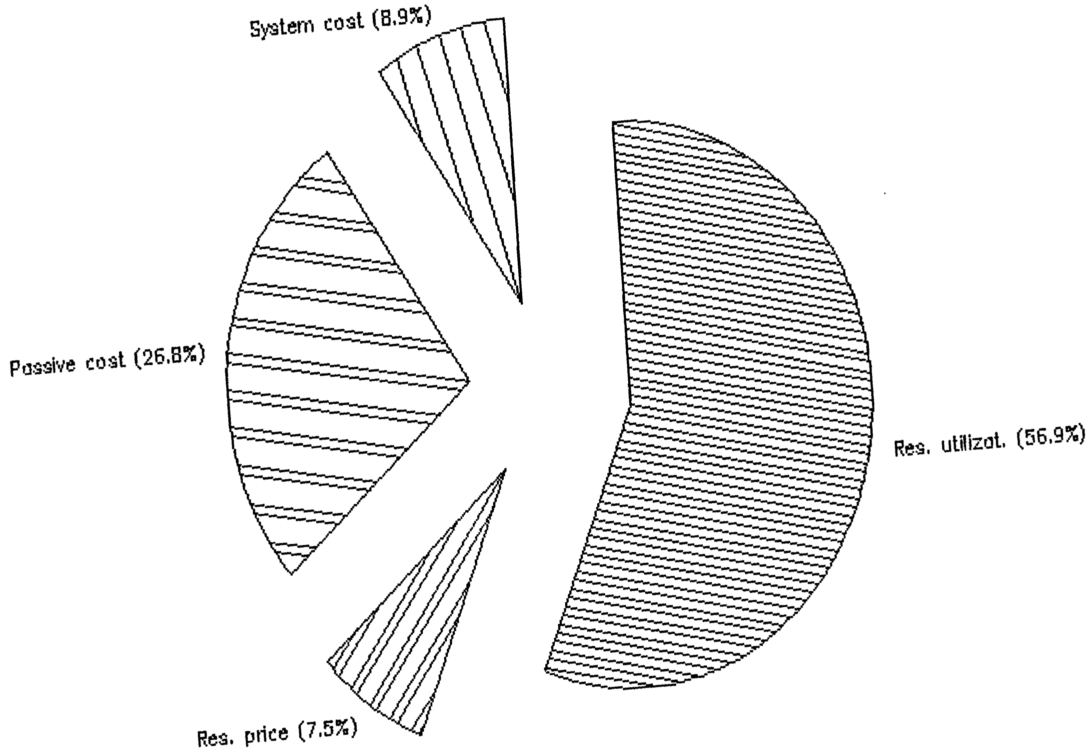
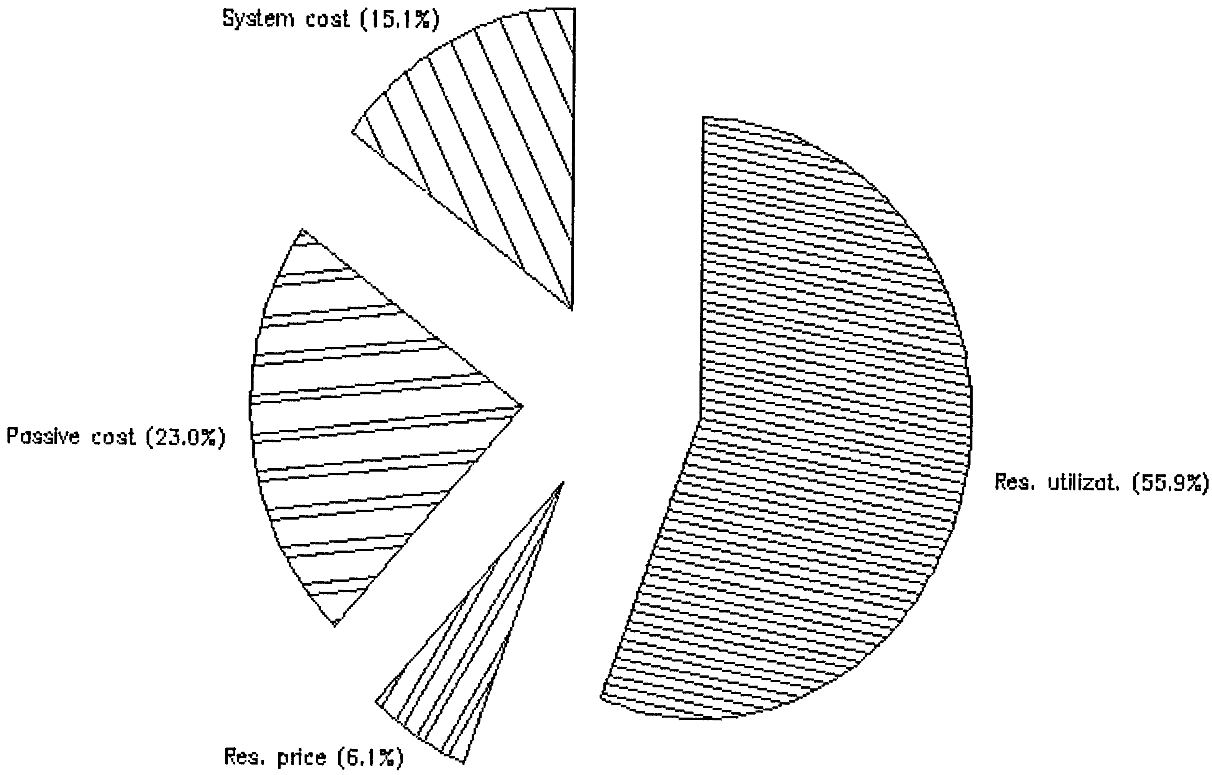


Fig. 5b: The ratio of variances in the
total variance (0.2)



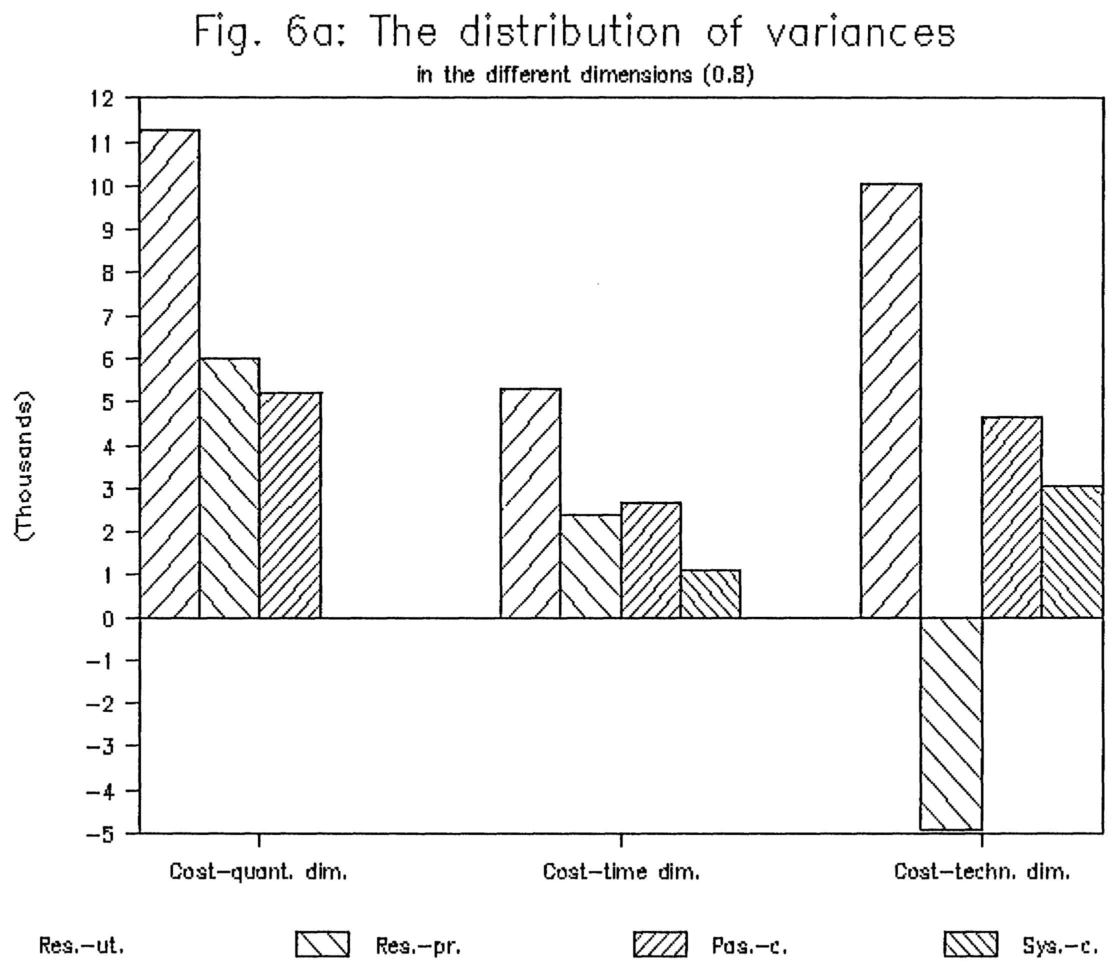


Fig. 6a: The distribution of variances
in the different dimensions (0.8)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
(Thousands)
Cost-quant. dim.
Cost-time dim.
Cost-techn. dim.
Res.-ut.
Res.-pr.
Pas.-c.
Sys.-c.

Fig. 6b: The distribution of variances

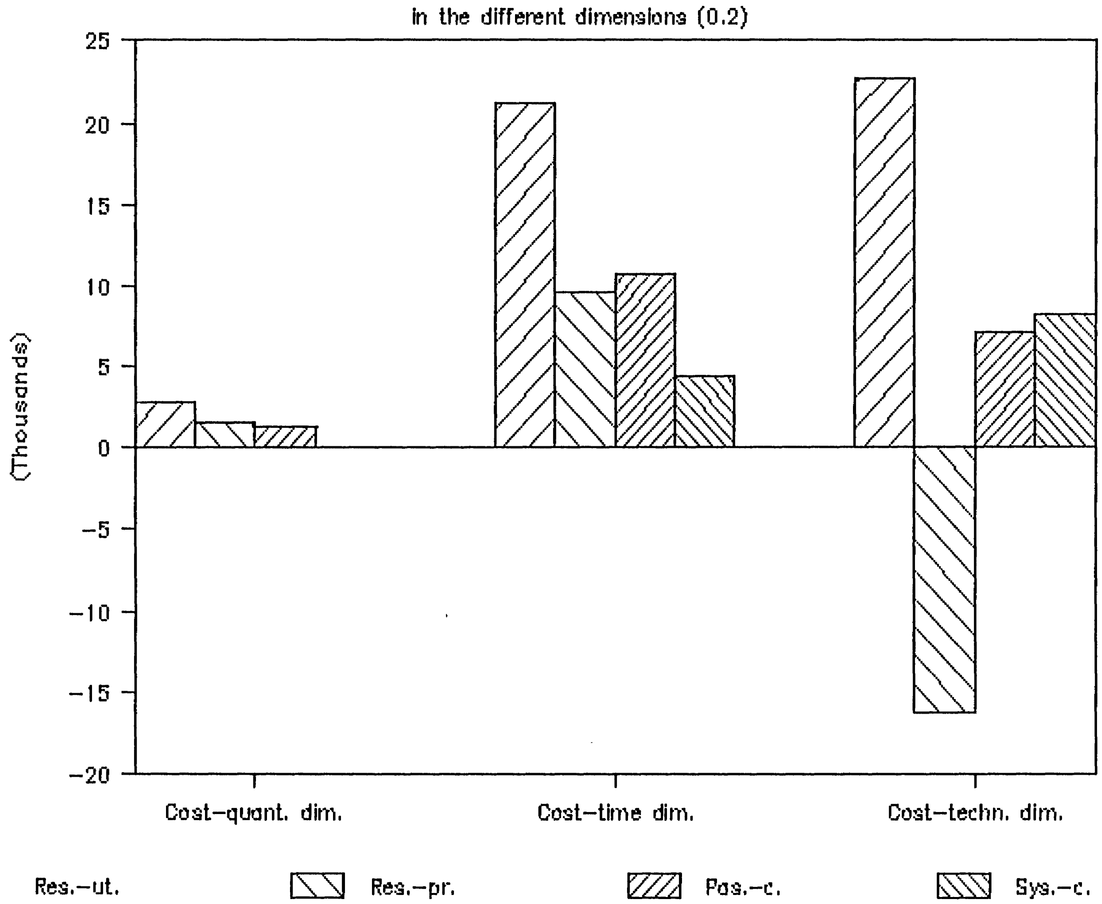


Fig. 7a: The ratio of dimensions in the
total variance (0.8)

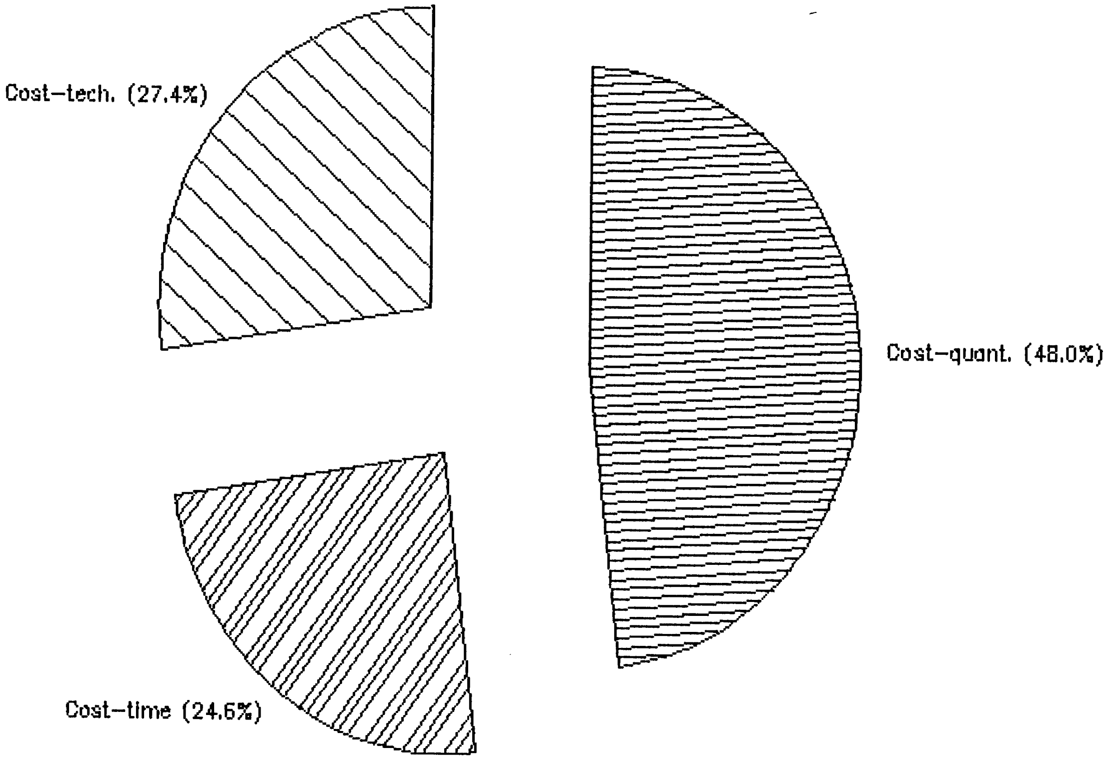


Fig. 7b: The ratio of dimensions in the

total variance (0.2)

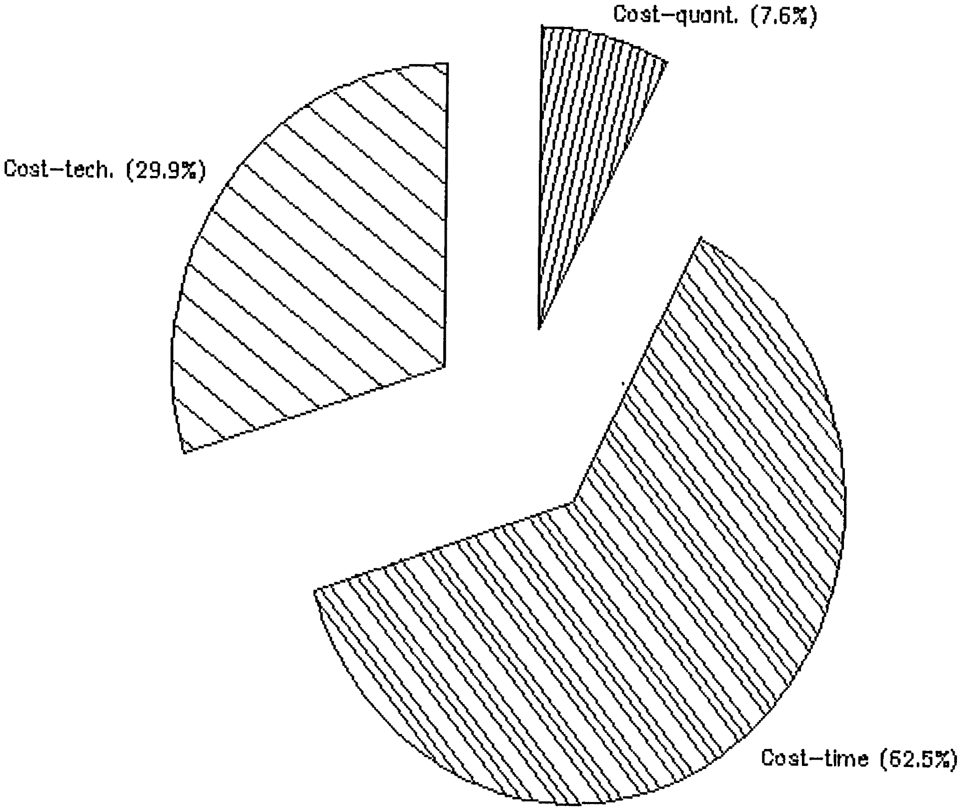


Fig. 8a: The ratio of direct and
indirect variances (0.8)

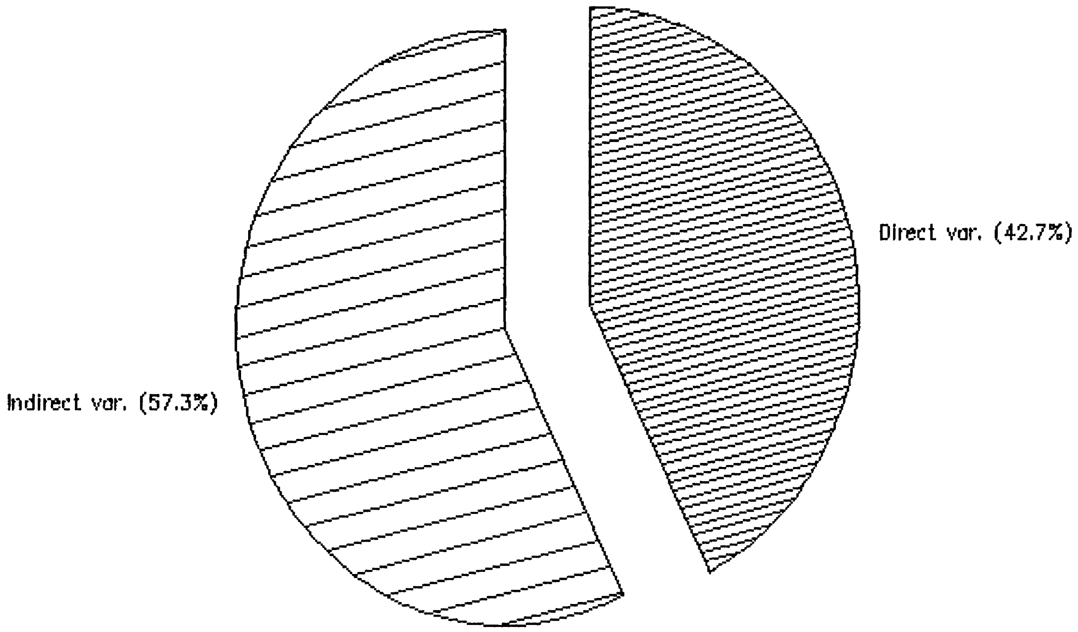


Fig. 8b: The ratio of direct and

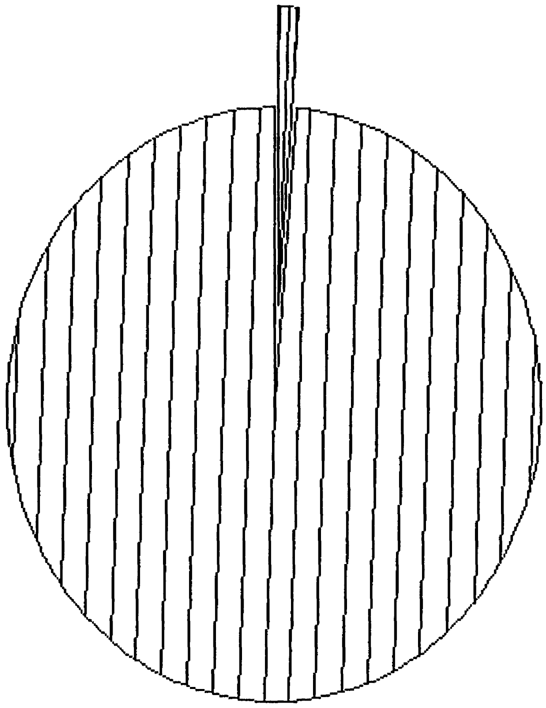
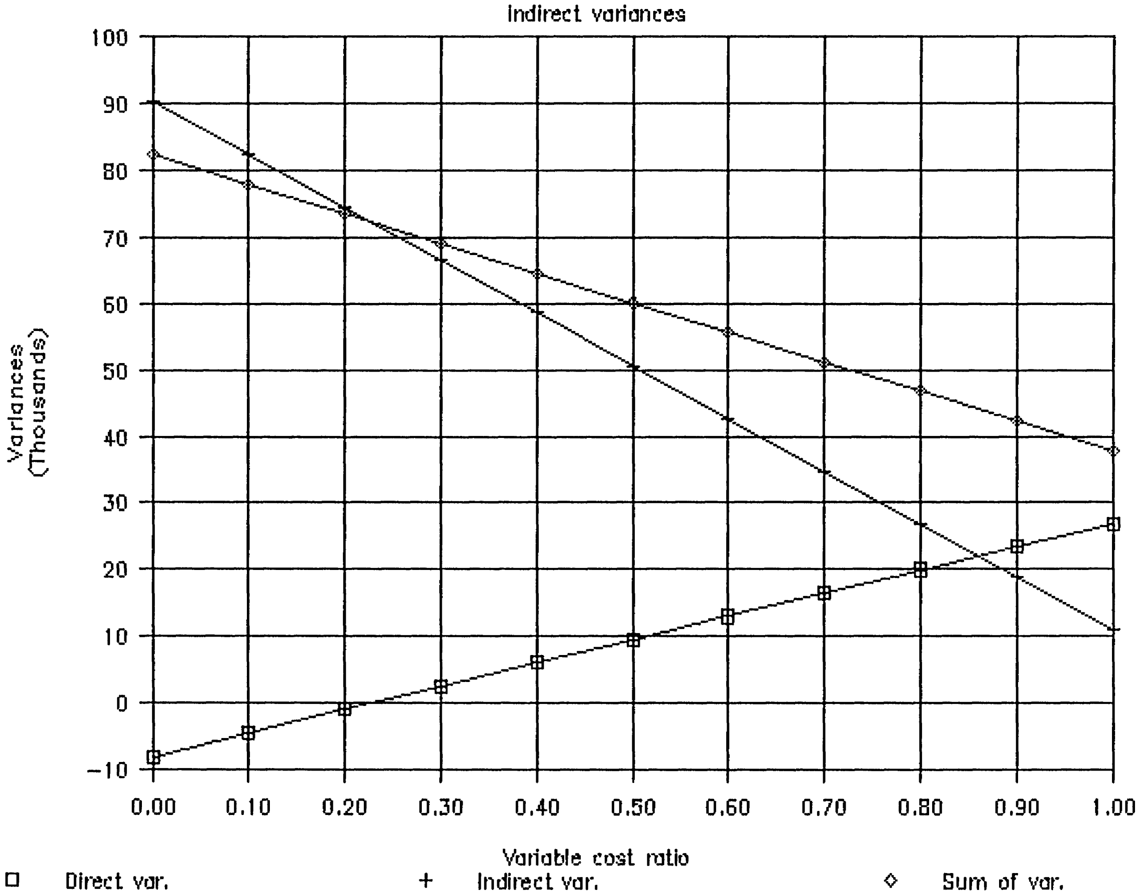


Fig 9 : The change of direct and



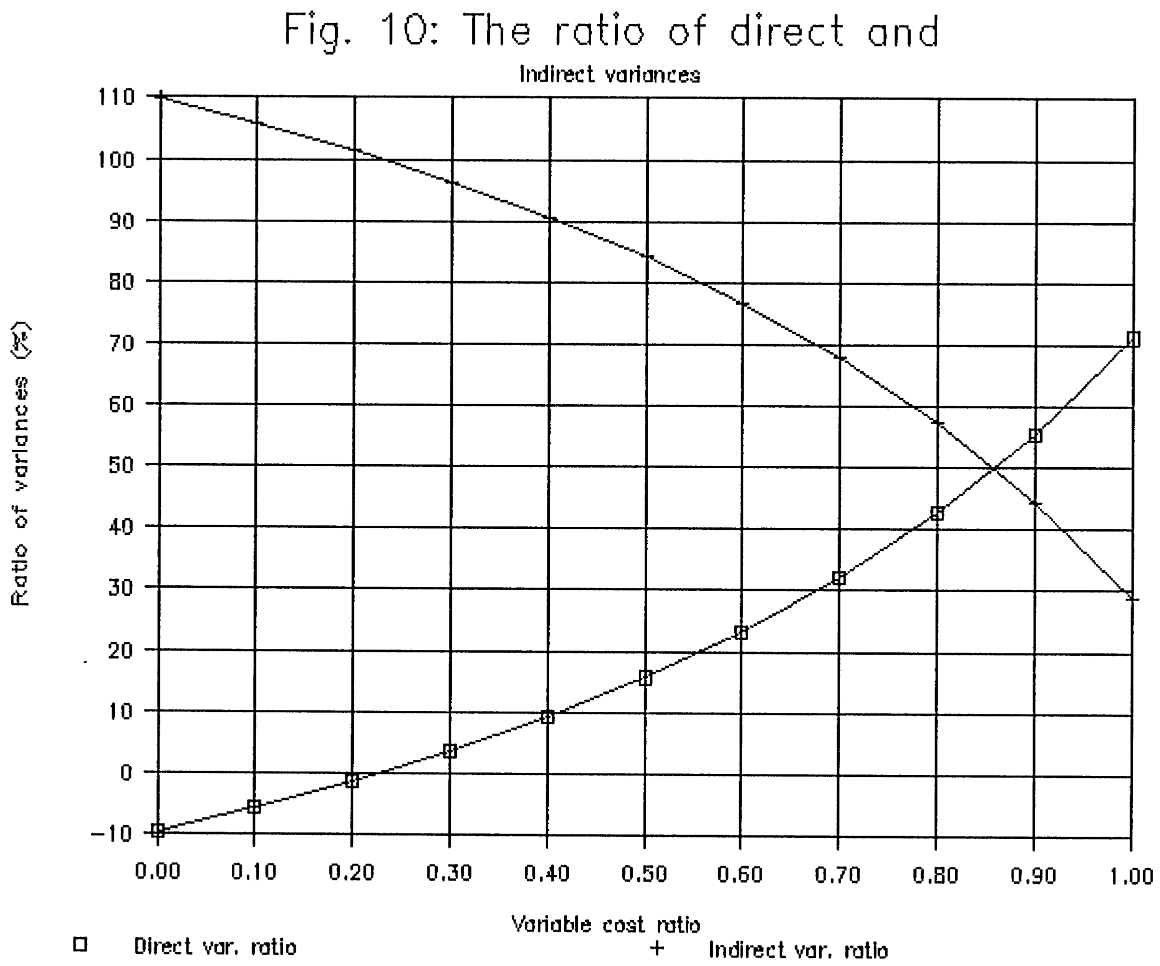


Fig. 10: The ratio of direct and
Indirect variances
Ratio of variances (%)
110
100
90
80
70
60
50
40
30
20
10
0
-10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Variable cost ratio
Direct var. ratio
Indirect var. ratio