特別寄稿

Value-Based Business Process Reengineering :

An Objective Approach to Value Added

by

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Abstract

The promise of business process reengineering (BPR) must be validated by its effect on the "bottom line." It will be taken seriously as a new process improvement framework only when executives can be assured, a priori, that it will produce the desired ROI in the reengineered processes, and after the BPR, whether there have been actual improvements. An objective way to measure the value added by component processes must be developed to make this kind of assessment possible. Using an extension of Kolomogorov's Complexity theory, this paper offers a solution to this problem.

Introduction

The purpose of business process reengineering (BPR) is to radically improve company core processes in order to :

1. Increase process capacity
2. Increase, or satisfy, demand for products and services.[1]

Most reported reengineering efforts focus on the first purpose without reference to the second purpose. This may be a result of the current business environment and the demand for cost competitiveness.[2] Increased process capacity can be translated into a more favorable cost structure by using the extra capacity to produce the same number of "widgets" with fewer employees or more "widgets" with the same number of employees.

For example, Mutual Benefit Life reengineered its processing of insurance applications process and went from 25 days for application processing to as little as four hours. The result of this cycle time improvement was elimination of 100 field office positions. Using BPR, Ford was able to reduce its accounts payable department from 500 to 125 employees.[3] In this way BPR fits nicely into American corporations current obsession with squeezing as much cost as possible out of operations. While an admirable goal, it is not clear how BPR efforts will ensure cutting the "fat" and not the "meat" out of operations.

Reducing unnecessary operational costs is critical to competitiveness. However, increasing, or satisfying demand for products/services also is critical to competitiveness. And this second purpose of BPR cannot be achieved if BPR efforts inadvertently destroy value in the end product/service. A clear understanding of both cost and value is required to ensure a successful BPR effort.

Traditional financial approaches use dollars (generated as a result of sales of end products/services) as the only representation of value. Thus, they do not allow disaggregation of value along the value-adding component processes because a market price can be set for most of these interim process outputs. So, these approaches limit objective analysis of the value-producing capabilities of the component processes. Since it is the component processes that will be modified or eliminated in a reengineering effort, it is critical to objectively measure the value they produce, otherwise it will be impossible to know whether the BPR effort has added value.[4]

Today, there is no ***objective, countable*** way to measure the value added by component processes before and after a reengineering effort and, therefore, no way to provide executives with return-based assurances. Objective value allocation among the component processes of a compound process cannot be gotten through existing approaches (e.g., generally accepted accounting practices, activity-based costing, cost of quality, quality function deployment).[5] These approaches focus on cost or various subjective assessments of value. No matter how cost is allocated or manipulated, it cannot be a surrogate for value. Likewise, subjective assessments of value cannot be used in return based financial ratios because they do not use comparably objective units of measurement (i.e. dollars).

The promise of business process reengineering (BPR) must be validated by its effect on the "bottom line." It will be taken seriously as a new process improvement framework only when executives can be assured, *a priori,* that it will produce the desired ROI in the reengineered processes, and after the BPR, whether there have been actual improvements. An objective way to measure the value added by component processes must be developed to make this kind of assessment possible. Using an extension of Kolomogorov's Complexity theory, this paper offers a solution to this problem.

Financial measures are the *lingua franca* of business primarily because they are objective, countable, general, and fundamental. Therefore, assessing the success of BPR efforts requires an equally defensible measure of the reengineering's ROI impact. Failing to provide such a measure will relegate BPR to the trash heap of other management fads.[6]

But, the focus of many BPR efforts is to improve the component, or subprocesses within an overall compound process. Many of these component processes do not produce a sellable output : calculating ROI requires a sellable output (for the revenue side of the equation). The problem, then, is to allocate value (e.g., market price) objectively throughout all component processes in a way that return on investment in process (**ROP**) can be calculated for each component affected by the BPR.

The resulting calculation would also provide an objective approach for understanding how value is added throughout the compound process. Even those component processes not directly targeted by a reengineering effort will be affected by it. Therefore, the reengineering analyst needs to understand how the value generating capabilities of all component processes may be affected by the BPR effort.

Value Defined

Value is a nebulous term that is often approached from subjective perspectives. Common definitions of product/service value rely on a direct connection with the customer's perception of value or willingness to pay. This perception can be manifested in the way that products/services meet customer needs through features or functionality, i.e., the customer's perception of ***value***. Commonly we cull "precise" information about customer perception of value through, for example, market research, quality function deployment techniques. These approaches often lead to products/services that do not have the anticipated value to the customer, as reflected in their unwillingness to pay for the new or redesigned product/service.

Businesses that rely exclusively on the capriciousness of short term customer perceptions of value are often caught in the losing game of trying to "outguess" the customer. While it is critical to understand what customers perceive as valuable, this understanding may be necessary, but is not sufficient, to predict a product/service's success in the marketplace.

For these reasons, it is necessary to use a more objective measure of value not wholly dependent on customer perceptions. Purchase price is a representation of the value of a product/service a customer is willing to pay for an end product/service at a given point in time. The advantage of using purchase price is that value can be expressed in the commonly accepted universal unit of value, i.e., money/dollars. The purchase price then becomes an objective way to represent customer perception of value.

The problem is that dollars cannot be used to allocate value to the component processes, for which a price cannot be established. For example, a component process of the order-provisioning cycle for telephone service results in the generation of a service order that defines service features and provides some instructions to an installer. The output of this process, i.e., a service order, has absolutely no value to the end customer. Neither are down stream internal process customers willing to pay a margin over the upstream component process' output cost (otherwise there is no benefit in performing the process tasks in-house).

Therefore, a price for this component process output cannot be objectively established by normal willingness-to-pay pricing criteria. Yet, it is obvious that this component process adds value to the end service because it can be found in the definition of the end product/service. In other words, the end product/service would not be possible without the output of this interim component process.

Given that the customer pays for telephone service, the analyst needs a way to allocate a portion of the total price backward to the component process, based on the value this component contributes to the end service. Because no price can be set for this component process' output, dollars cannot be used to measure the value-added. A way must be found to establish a new universal unit of value that can be used to objectively allocate value (measured in purchase-price dollars) across component processes.

- ***A Customer Perspective.*** The approach described in this paper ensures that the "naive" customer definition of the product/service's features, functionality, characteristics, which represent the value they are willing to pay for in the end product/service, is preserved in spite of the BPR. On the other hand, this new approach will also provide an objective way of verifying that new value has been added to the product/service when the BPR results in a redefined product/service.

- ***An investor / Analyst Perspective.*** Armed with a better understanding of how value is created in a company, the investor, analyst can objectively compare companies within an industry in terms of the value-producing performance of their operations in an objective way. The new approach presented in this paper also will allow them to avoid exclusively cost based methods for assessing operational performance. Instead, it will offer a new performance indicator which will encourage companies to quantify the amount of value-added by each process.

Given the inadequacies of the traditional methods of assessing a company's performance, this approach represents an important new window for investors and analysts to examine the inner workings of an organization in an expanded language of finance. This is particularly important when a merger or acquisition takes place. Because the resulting new company probably will not require redundant functions (e.g., two finance, accounting, purchasing departments) and decisions will be have to be made about which companys' processes produce the best **ROP**.

- ***A Company Perspective.*** For the company reengineering analyst, this new approach helps determine where to start a BPR effort and how to tell whether the effort has been successful. The decision about where to start the BPR effort will be based, in part, on how the final product is defined in terms of the outputs of each component process. Those component process that do not contribute value to the product/service's final definition are candidates for BPR.

The analyst must also be able to estimate the **ROP** of the BPR effort before beginning as well as calculate any change in **ROP** resulting from the effort. Calculating **ROP** is critical to understanding the effect of a BPR effort on the "bottom line".

An objective understanding of value-added and **ROP** will directly or indirectly benefit customers, analysts, and company reengineers. The problem is that no current approach to process value estimation provides such an objective method.

This paper describes a new objective, countable, general, and fundamental solution to the problem of measuring value-added using an extension of Kolomogorov's Complexity Theory. Complexity theory is a well established, proven framework used extensively in the natural sciences to analyze structure creation in self-organized systems.[7]

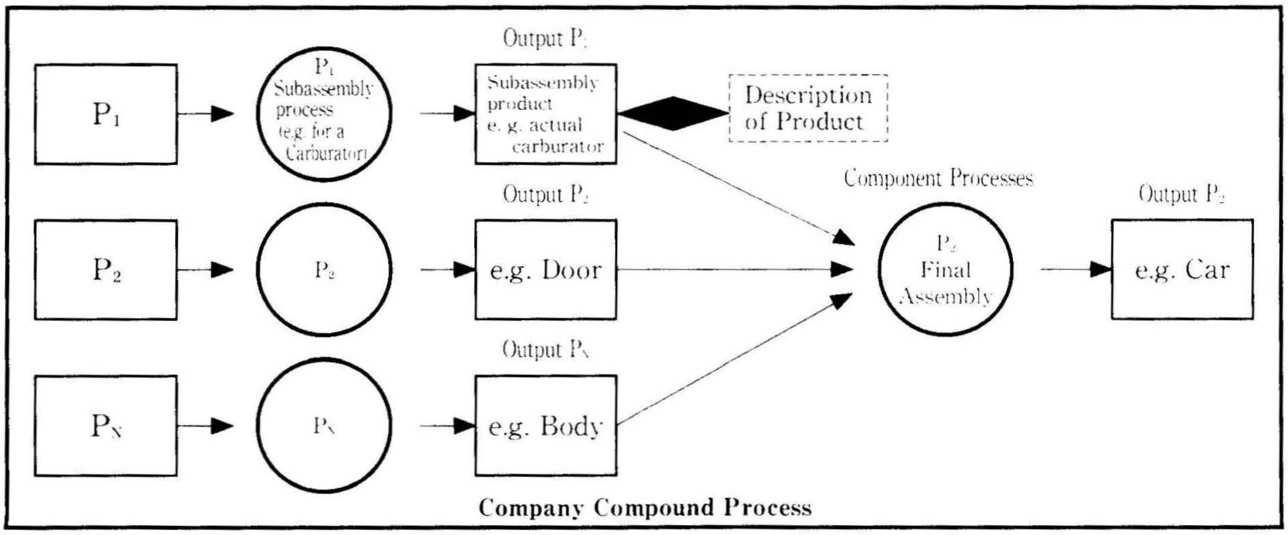
Kolomogorov Complexity and a Definition of "Value-added"

Businesses are open systems-systems that exchange information, substance, and energy with their environments.[8] As such, businesses have the capability, through their processes, to change the structure of raw material inputs (i.e., substance, energy, information) into final products/services. The structures resulting from these changes (e.g., from nuts and bolts to car doors) can be formally described. Descriptions of the changed structures (process outputs) can be measured using Kolomogorov complexity (K-complexity). The resulting K-complexity of a component process output reflects the amount of change to its inputs.

K-complexity and Value-added

In business, these changes in raw materials are called "value-adding." The value-adding process incrementally changes raw materials into increasingly more "K-complex" structures in the form of interim outputs (e.g., components, subassemblies). In automobile manufacturing, a car begins as a collection of raw materials, which serve as the inputs to subassemblies (e.g., doors, engines, etc.). These are brought together in the final assembly process to produce the "car" (see Figure1-Value-Adding Stream). In the telephone business, a customer supplies information about desired service features, name, address. This, with company supplied information about billing, installation, and maintenance (i.e., "raw material" inputs to this service production process), is "sub-assembled" into a service order. The service order provides the billing and installation processes with information to activate service.

Figure1 VALUE-ADDING STREAM



These interim outputs of the value-adding component processes can be formally described in terms of their inputs. For the car, the interim outputs (door, engine) can be described in terms of their inputs (nuts, bolts, carburetors, pistons, handles). The output descriptions can be measured using K-complexity to figure out how much complexity was added, i.e., how much the process's input structure has been changed, by a given process step in the value-adding process. If a direct correspondence between changes in complexity and changes in "value" can be established, K-complexity can be applied to measure value-added changes in product/service production.

Component and Compound Processes

To understand how K-complexity can be used to measure value-added, the value-adding process must break the compound process down into its component processes. Component processes are those interim processes (e.g., subassemblies,) whose outputs provide the inputs to other subsequent value-added steps in the production chain. The compound process is the representation of the overall process, including all the component processes (and their outputs) necessary to produce the final product/service.

As the output of each component process makes its relative contribution ,to the final output product/service, these changes in structure can be measured via K-complexity. The compound process output, then, is the accumulation of all the K-complexities introduced at each step of the value-adding process.

- ***Creating formal descriptions.*** Having identified the component processes of a compound process, it is possible to formally describe the outputs of these processes in terms of their corresponding inputs. The K-complexity contained in these formal descriptions reflects the changes in structure brought about by the value-adding process. The compound product/service is the total accumulation of the K-complexity manifested in the component process output descriptions. It will be reflected in the formal description of the compound process' final output (i.e., product). Measuring the K-complexity of different output descriptions provides a formal way to quantify the intuitive understanding that an automobile is a more complex structure than any of its components.

- ***K-complexity and information.*** The problem, then, is to specify a unit of K-complexity so that processes and their outputs can be compared in terms of the amount of K-complexity they contain. K-complexity is both a universal measure of changes in the form of matter and a universal property of matter. (Just as weight is a universal measure of gravity's influence on matter, it is also a universal property of matter itself.) Once these changes are formally described, their information content can be derived quantitatively. Creation of K-complexity (and the equivalent information) can be viewed as the universal activity of people. K-complexity (amount of information contained in the product of their activity) itself can be seen as the universal product of their activity.

With K-complexity/information as the universal product, all processes, and the products they produce, are comparable. This kind of comparison permits executives to determine the comparative value of each process across a company as well as between companies. This approach allows a new way of setting process performance goals based on objective benchmarking of ***all processes, including component processes,*** regardless of industry.

If the relationship between K-complexity/information and value can be rigorously established, there will be an objective method for measuring value added. To do this, K-complexity must be defined and unambiguously connected to the value-adding phenomena.

A Formal Definition of K-complexity

There are three basic concepts from Complexity theory that are necessary to define K-complexity :

1. Finite alphabet
2. Language, i.e., the set of all finite words that can be created with this alphabet

3. "Universal computer" that can accept any word as a program and with output as a word of the same language.

These three concepts provide the requirements for developing formal descriptions of process outputs in terms that allow the amount of information contained in each to be objectively calculated. They are also necessary to ensure that equivalent units of information are used in the formal descriptions of process outputs. This permits comparisons of process outputs to be calculated in equivalent information units.

The length of the descriptions of the same process output can vary. This would create a problem in comparing descriptions in terms of the amount of information they contain. This problem of comparability can be resolved by requiring that the process output descriptions be the shortest length possible that would allow a precise reproduction of the output. This parsimony rule presumes the three defining concepts of Complexity theory.

This theory provides a critical contribution to the **PVE** approach: the requirement of using the shortest description of a process output in terms of its input, which is a reflection of the concept that complexity is conditional upon the available "building blocks" to create this formal description.

Historically, the definition of complexity was formulated for a finite string of letters, i.e., the corresponding word, written in a finite alphabet. For example, in a binary alphabet (i.e., 0, 1), a "word" would be a string of 0's and 1's such as: 0000011 . Complexity was defined as the length of the shortest computer program that reproduced the original string. For example, a finite binary string such as 0101010101010101010101010101010101010101 could be programmed as:

- print 0101010101010101010101010101010101010101, or
- print 01, twenty times.

It is obvious that the second is a shorter program than the first. To make this definition consistent it was assumed that the program was created for the "universal computer" (e.g., "Turing machine").[9]

Extending this approach to business result in:

Definition 1. **The conditional K-complexity of the output (product) of a process, given its inputs, is the length of the shortest description necessary to reproduce the process's output in terms of its inputs.**

- ***Conditional K-complexity.*** The length of the shortest description is dependent upon the formal "vocabulary" used. The more powerful or comprehensive the vocabulary used, the shorter would be the shortest description. An example of this phenomenon in human languages is the use of acronyms to shorten texts. The acronyms are more comprehensive because they represent a summary of larger segments of texts.

The description of a product can be shorter or longer depending on the formal vocabulary "building blocks" (i.e., inputs) used to describe it. This implies that the complexity of a product is conditional upon the level of aggregation of the process' inputs. For example, the description of a car in terms of inputs such as doors, engines, transmissions, bodies, etc. would be much shorter than the car described in terms of position of nuts, bolts, pistons, sheet metal, welds, etc.

This simplified explanation of conditional K-complexity shows that the definition of K-complexity depends on the language used to describe the inputs and outputs of the process in focus, as well as the method of description. The BPR analyst's job is to help establish the shortest description of process outputs using the appropriate vocabulary.

An example of how the language used depends on conditional K-complexity is drawn from automobile manufacturing (which most readers have an implicit understanding of at an aggregate level) to illustrate the point. At each point in the car assembly process, value is added as the output of one component process serves as the input of the next higher level component process output. Oversimplifying a bit, nuts, bolts, sheet metal etc. are transformed to become engines, doors, transmissions, etc. and finally, the engines, doors, etc. are assembled to become a car. To calculate the K-complexity of the car in terms of the "raw materials," it is necessary to accumulate the conditional K-complexities at each step in the value-adding process between the raw materials and final assembly.

The "value-adding" process is nothing more than accumulating conditional K-complexities across the component processes given the definition of the final product. Since conditional complexity can be objectively calculated this approach provides a way to quantify the intuitive notion of value-adding.

A Calculus for K-complexity in Business Processes

PVE is designed to measure value creation for processes with predetermined outputs (**PPO**). For example, in the telephone service provisioning process, the output of a sales contact is a service order that represents the result of negotiating potential features with the customer. Flexible manufacturing systems are another example of software applications that predetermine what, how, and when component processes will be executed in the manufacturing process to produce a given set of outputs.

Outputs of these processes can be described in a common formal language. There also are processes whose outputs are not predetermined, e.g., creative processes such as strategic planning, product／service design, as well as art or science. In the future, **PVE** will be extended to creative processes that have no predetermined output.

There is a natural correspondence between the set of the **PPOs** and the set of their formal descriptions {**D**} :

$$\{\mathbf{PPO}\} < - - - - - - - > \{\mathbf{D}\}$$

This correspondence can be extended further to the set of computer programs that are realizations of **D** written in a universal computer language. For example, an assembly line process can be first described in terms of the evolution of raw materials to finished product through the value-adding process. Second, this description can be translated into a computer program that serves as a model of the original process.

Thus, all **PPO**s can be ultimately translated into a universal formal common language (e.g., computer language). This approach is analogous to the common formal language used in accounting and finance. Accounting and finance have formal languages that allow comparisons across business domains in terms of common categories such as time and money.

Still, in practice, for **PVE**, it is possible to use domain specific descriptions. For example, in the documentation of a car assembly line it is possible to extract descriptions of component products (e.g., engine, transmission, etc.) produced by the corresponding component processes. With these formal descriptions, it is possible to calculate the conditional complexities of each large subassembly (i.e., component products) in terms of its immediate preceding components.

V and Vm Defined

The outputs of information processes can be viewed as texts written in a formal language. It has been proven that the K-complexity of a text is nearly equivalent to the Shannon amount of information in the text : A unit of K-complexity is identical with a Shannon unit of information. (For a detailed description of the logic and mathematical reasoning of this relationship see Cover.[10]) Therefore, amount of information will be used as a substitute for complexity in what follows.

We will define the internal performance of a process, i.e., **V(P)**, given its input, as the amount of information, i.e., **I(P)**, it produces per dollar of process cost, i.e., **C(P)**, over a given period of time. This can be expressed as

$$V=I/C \qquad (1)$$

Since, all companies' products/services can be measured in terms of their complexity, companies can be compared in terms of their efficiency in producing complexity during a given time period.

PVE can be extended to market driven (i.e., external) definitions of performance. **Vm(P)** represents the market price of a unit complexity/information and changes simultaneously with the market price of a product/service. Price was selected as the most objective determination of market value given that it can be fixed at one point in time.

$$Vm(P)=M(P)/I(P) \qquad (2)$$

Where ***M(P)*** *is the market price of the output of a* **compound process P and** ***I(P)*** *is the amount of information in the output, given the process input, over a designated period.*

The same formula (2) can be applied to component processes when **M** is allocated along the outputs of the component processes. The problem is to establish an objective way to allocate the market price or value using a method that is consistent with an ROI approach. This can be done in the following way. Let **Pi** represent an arbitrary component process (i = 1,...,n ; where n is the number of component processes) of the compound process **P**. Then **M(Pi)** is calculated as (i.e., allocation formula) :

$$M(Pi)=(Ii/I)M \qquad (3)$$

Where ***M(Pi)*** *is proportional to the information contributed by* ***Pi****(i.e.,****Ii****) to the compound process output (i.e.,* ***I****).*

This formula solves the value allocation problem because M(Pi) represents allocation of value in proportion to the information (i.e., universal product of all processes) produced. (See Appendix A for the averaging method across product lines and processes).

Calculating ROP. **ROP** shows the decision maker how much return can be expected per dollar of investment in ***any*** process (i.e., component and compound processes). The relationship between **V**, **Vm**, and **ROP** for any process is as follows :

$$ROP=V \times Vm=(I/C) \times (M/I)=M/C \qquad (4)$$

Where ***M*** *is proportional to the market price or value of the end product, with the coefficient equal to the ratio between the information produced by the given component process and the total information produced. For compound processes that produce the end product/service,* ***ROP*** *is equivalent to* ***ROI****.*

Calculating **ROP** and **Vm** for components is possible only after the corresponding amounts of information **(I)** for each component within a compound (that produces a sellable product/service) have been determined. Using formula (3),**Vm(Pi)** is calculated :

$$Vm(Pi)=M(Pi)/Ii=((Ii/I)M)/Ii=M/I \qquad (5)$$

As the formula shows, the price per unit of information does not depend on a given component process. The customer pays for the output of the compound process in the form of a final product. This product is represented by a fixed amount of information distributed throughout the components included in the product's definition. The customer is paying the same price for each unit of information, regardless of which component process produces it.
It follows that :

$$ROP(Pi)=Constant \times V(Pi)$$

Where the **Constant=M/I.**

Therefore, the application of **PVE** for a given compound process can be reduced to the calculation of **V** for all the components of that compound. So, **V** is the crucial measure in making comparisons of the value producing capabilities of the various components of a compound process. This conclusion is also consistent with operational managers intuitive belief that the key to adding value lies in an understanding of processes.

ROP allows decision makers to predict value creation, or "value-adding" throughout the production process, not just on the results of the compound process. As such, this approach allows them to make more precise investment allocations in the operations of a company based on a market-dependent estimator, or **Vm**, and a market-independent estimator, or **V**.

In this context, creation of K-complexity is a metaphor of the same sort as "making money." Measures of productivity become the amount of K-complexity produced per dollar of cost. Measures of profitability can be represented as the price per unit of K-complexity. Indexes of productivity based on **ROP** can be used as new indicators of company, industry, and an economy's performance.

Calculating V, Vm, and ROP: An Example

The following example will help explain how **PVE** might be applied in a telephone company provisioning context. Some calculations of amount of information produced by component processes have been supplied to simplify the example.

Assume that the basic telephone provisioning compound process (i.e., $\boldsymbol{P}$) is defined as billing (i.e., $\boldsymbol{P_1}$), installation (i.e., $\boldsymbol{P_2}$)and sales (i.e., $\boldsymbol{P_3}$)component processes. Assume that a **PVE** has provided the K-complexity calculations for the billing and installation. The K-complexity for billing is 10 bits per hour (i.e., $\boldsymbol{I_1}$)and4bits per hour (i.e., $\boldsymbol{I_2}$) for installation. Thus, the numerator of **V** is provided for two of the component processes.

For the purposes of this example, the sales process was selected for explicit calculation of $\mathbf{I_3}$.The sales component process reduces the initial uncertainty through the creation of information by the customer answering several questions. Assume that, in the simplest case, the sales process (whose output is a new service order) consists of two sub-component processes: selecting number of lines and selecting features for each line. Assume that there is a customer order with only two kinds of features and line assignment:

1. call forwarding	YES NO
2. call waiting	YES NO
3. number of lines.	1-2

If all possible service configurations are equally likely, the initial uncertainty in an order is equal to the log of the number of all possible service configurations. If the customer only wants one line it would be four possible configurations: YES,YES; YES,NO; NO,YES; and NO, NO. If the customer selected two lines, the number of configurations wOuld be4×4or 16 possible configurations. The total number of possible configurations would be$4+4^2=20$. The amount of information necessary to reduce the initial uncertainty is equal to log (base 2) of 20 which is approximately4bits. If a service representative is can process 10 new orders per hour then $I_3 = 10$ x4bits=40 bits/hour.

Assume that the cost is approximately $30 per hour for each of the three components (i.e., ***C1 = C2 = C3 = $30 per hour***), and that the average price of a new service order is $25. With the amount of K-complexity or information and cost for each component, it is an easy task to calculate the compound process output **V** and **Vm** and **ROP** as follows:

$$V(P) = I_1 + I_2 + I_3 / C_1 + C_2 + C_3 = 54/90 = .6\text{bits/dollar}$$

$$\{V(P) = [10\text{bits}] + [4\text{bits}] + [40\text{bits}]/[\$30] + [\$30] + [\$30] = 54/90 = .6\text{bits/dollar}\}$$

$$Vm(P) = M / I = \$25/54 = \$.462 \text{ Per bit}$$

$$ROP(P) = V \times Vm = .6 \times .462 = .277$$

With the Is and end service price established, it is possible to calculate **Vm** for P_1, P_2, and P_3 by calculating the **Ms** for each component. These are calculated as in the explanation of **M** allocation for formula (***3***). It follows that, for P_1, **M** is $4.63 per order, for P_2, **M** is $1.85 per order, and for P_3, **M** is $18.52 per order which totals the market price of $25.

The calculation of the component **ROP**s becomes a simple task once price, cost, and amount of information are known. For example the **ROP** for (P_1) is **(10/30) x ($4.63/10)=.152.**

For a better understanding of what component processes need the most performance tuning and which ones provide the most value, compare the relative value of the component processes within the compound provisioning process by comparing **V** for all the components. For example, $V(P_3) = 1.33$ **bits /dollar** and $V(P_2) = .133$ **bits/dollar.** In targeting a BPR, two options for raising the **V(P)** would be to eliminate installation or drastically reduce the cost of installation. (While the current example is hypothetical, we have used **PVE** to calculate the **ROP**s for a number of **BPR** projects within the company. **PVE** is required for all new **BPR** projects within our Division.)

The Importance of Product Definition in PVE

The BPR analyst must define the final product in terms of a minimal extension of the "naive" customers understanding of the product's features and characteristics. For example, the naive customer's definition of telephone service may include only features such as call forwarding, call waiting. He/she would not include telephone switch programming explicitly. However, this programming is necessary to deliver the expected service features. So the analyst must set the product definition boundary in such a way that it extends the minimal customer definition to include those component process outputs which cannot be eliminated given the current or near term technology.

This minimal extension of the naive product definition serves several purposes:

A. It serves as the criteria for establishing which components will be included in **PVE** analysis and therefore considered value-adding for purposes of calculating **ROP**

B. All other component processes should be evaluated in terms of how they may contribute to future value through new product development or customer services or should be considered overhead cost and candidates for elimination or significant change

C. It ensures preservation of the minimal defining product features which the customer expects to receive.

There are significant implications of using a narrow (naive customer definition of product) versus a broader definition of final product in focusing BPR effort. A narrow definition will result in viewing any component process, whose output is not explicitly reflected in the final product definition, as overhead which is not contributing to the value-adding process. This approach to product definition motivates the BPR team to eliminate or significantly curtail the activities of the "non-value-adding" components. This in turn leads to the possible reduction or elimination of components which ensure product quality or customer service. For example, in providing basic telephone service, the customers naive definition of service might include only the features which he/she ordered (e.g., call forwarding, call waiting). The fact that the installer normally shows the customer how to use the features properly and that a technician ensures that the switch is correctly programmed would not be included in the customers definition of the final product. However, without these activities the customer would receive less service instruction and potentially lower quality telephone service.

With a broad definition of the final product, the threat is that every component will be included. If all current components were included, BPR efforts would be severely restricted since the final product requires them in its definition. This would inhibit a company's enthusiasm and creativity in seeking process improvements of the magnitude promised by BPR.

A potential resolution to this dilemma is to examine each component beyond those required to meet the narrow product definition to determine which could be excluded from the final product definition while maintaining a necessary level of quality or customer service. This approach would help focus the BPR effort to ensure that the optimum product definition was maintained. In this way, the product definition becomes the critical tie-breaker in BPR decision making. With the final product definition fixed by this method, the value produced by each necessary component will sum to the total represented in the final product definition. This approach also points out the need to ensure that this final product definition will not be changed by BPR efforts otherwise the product's "value" might be reduced.

PVE and Activity-Based Costing (ABC)

Applying ABC to a process will not help the decision maker understand the relationship of cost to value produced in component processes. For example, assume that an ABC of a telephone service provisioning process revealed that 20% of the cost was due to poor quality. After the process was reengineered, the cost of poor quality was essentially eliminated. This was because the service representatives were provided with a new information system that helped ensure mistakes were not made on orders. Yet, the number of orders processed (i.e., information processed) per time period increased only slightly because the new process was more time consuming than the original. Without **ROP**, the result that the cost of poor quality improvement was significant might lead the decision maker to conclude incorrectly that reengineering was successful.

This example points to the need to capture change in process value creation (i.e., information/complexity creation), not just change in cost, to determine if BPR efforts are successful. **PVE** is designed to "take the temperature" of the process. The precision of ABC is useful in establishing the true costs of the component and compound process outputs. Traditional company measures of process performance, such as cycle time and error rate, are required for "tuning" the component processes. **ROP** will help the decision maker decide whether the tuning had the desired effect.

Need for Business Process Auditing

PVE must be conducted periodically to audit the performance of major company processes as well as the company itself. "We need new measurements--call them a 'business audit'--to give us effective business control." [13] **PVE** forms the basis of a new approach to auditing: business process auditing (BPA) that will offer a new method for, and set of supporting tools to, evaluate company performance.

The need for new "tools" to measure a company's capacity for value creation has been widely acknowledged. "For the first time big institutional investors, including some very large pension funds, are working on such ideas and tools to measure the business performance of the companies in which they invest." [14]

With BPA process tracking tools, the process auditor develops a model of major component and compound processes. This model reveals interdependencies and input/output rates. The processes and outputs are described in terms that allow PVE. [15]

BPA will supplement existing internal and/or external auditing practices when the goal of the audit is to examine the performance of major company ***processes***. Given the difficulties that current auditing practices have in providing a true picture of company performance, BPA may provide an "insurance policy" for auditors as well as very useful information about the efficiency of a client's internal operations which could be used in Annual Reports to help analysts and investors better understand the viability of the firm.

V As A Benchmarking Index For Overall Company Performance

V can be used as an index of overall a company's performance. A company level **V** would give executives, as well as analysts, a way to compare the performance of a company's operations to other companies within an industry. This would provide an invariant (with respect to the nature of the company product) index for objective benchmarking based on the common product of all companies: **complexity**. Comparisons among companies can be made as well as comparisons of a single company to itself over time by routinely auditing business processes and, once the data gathering procedures are automated, **V** would be available on a real-time basis.

PVE can be applied at the company level by treating the major compound processes as components of the overall company "process" or ***P***. Averaging the **V** values across all the company's processes, following a generalization of formula (**1**) extended to the necessary number of components, provides the total **V** value for the company's process performance. (For an example of how to partition a company's processes prior to calculation of the overall company **V**, see Appendix C--Partitioning Hueristic.)

Conclusion

PVE is an objective way to measure value based on the understanding that business processes are just another variety of natural processes, all of which can be characterized in terms of K-complexity creation. **PVE** offers a new organizing principle based on value creation that will supplement or replace existing approaches to measuring company performance. As such, **PVE** may hasten a paradigm shift to the use of the K-complexity as the basis for evaluation of value creation in business.

The call for value creation resonates well in the 90's. Executives realize that manipulating assets will not be enough to ensure survival. Investors and customers expect companies to create value.

> "The 1990s are shaping up as the 'value' decade. Value comes not just from identifying business needs (the demand side), but also from managing the supply side of the equation. Efficient technical resources become a key component of value. Universally, companies are reexamining and reengineerng themselves to provide demonstrable value in the 1990s." [16]

We need the results of **PVE** : **ROP**, **V**, and **Vm**, to decide which company processes really are adding value. Until we measure value creation throughout ***all*** company processes, we will not make the process adjustments necessary to ensure successful value-based business process reengineering.

Appendix A

PVE assumes that the market price is set for a given configuration of the product at a given time. The same business processes can produce a variety of configurations of products with their accompanying prices. So, **M** must be defined by averaging the prices of the possible configurations based on the frequencies with which these configurations occur.

To calculate **V** and **Vm**, let **L** be the number of possible configurations of the product/service produced by the same process, and, let $X_1, \ldots, X_L$ be the frequencies of the corresponding product/service configurations. Let $M_1, \ldots, M_L$ be the market prices of these products/services and $C_1, \ldots, C_L$ be the costs for the products/services. And, $I_1, \ldots, I_L$ be the amount of information necessary to describe products/services from **1**, ..., **L** correspondingly. Given this, the precise definition of **V** and **Vm** are the ratio of averages :

$$V=(X_1I_1+\ldots+X_LI_L)/(X_1C_1+\ldots+X_LC_L)$$

$$Vm=(X_1M_1+\ldots+X_LM_L)/(X_1I_1+\ldots+X_LI_L)$$

Appendix B

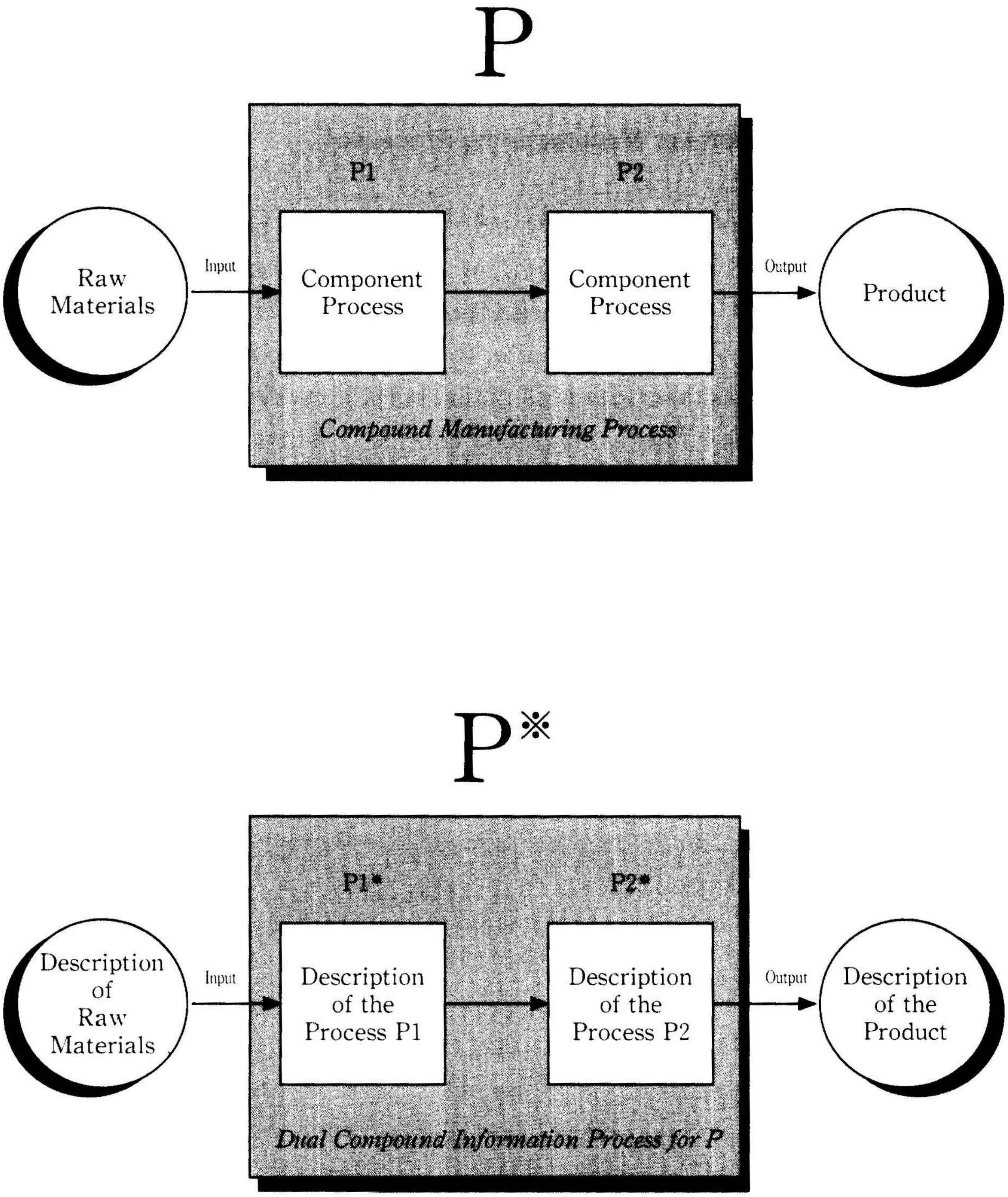
Process Value Definition For Manufacturing Processes

As shown, **PPO**s (such as those found in manufacturing) can be described and the resulting information content of the descriptions can be counted. Likewise, the product of manufacturing processes can be represented as descriptions of the same.[11] For example, in an automated assembly line the "program" (i.e., process description) is an isomorphic representation of the actual physical process. (The same logic can be applied to non-automated **PPO**s.)

Therefore, the amount of information necessary to describe a product ultimately is invariant with respect to the manner in which it is described. It follows, that the definition of K-complexity for manufacturing products is essentially the same as for information products (see Definition 1).

The duality between manufacturing processes and their information descriptions is depicted in Figure 2. In this example, only two components were included for purposes of illustration.

Figure 2 Process Description Duality



- ***Application of PVE to manufacturing.*** In this section, we will apply K-complexity to calculate **V** and **Vm** for manufacturing component and compound processes. Assume a manufacturing compound process, P, includes *n* component processes, P1,...,Pn: $P=P_1$U(i.e., union),...,Pn. In Figure 1, the actual process P and its dual information process P* are represented. To calculate V, define time for P*as the corresponding time for P. For example, the time to execute a P1component might be one hour, therefore the corresponding time to execute the P_1^*component is one hour also.

With the relationship between P and P* and time defined, calculate the value of P* as the substitute value for P and the values of P_1^*,...,Pn as the substitutes for P_1,..., Pn:

$$\mathbf{V}(P_1)=\mathbf{V}(P_1^*)=\mathbf{I}_1/\mathbf{C}_1,\ldots,\ \mathbf{V}(Pn)=(Pn^*)=\mathbf{In}/\mathbf{Cn},$$

$$\text{and } \mathbf{V}(P)=\mathbf{V}(P^*)=\mathbf{V}(P_1^*\ U\ldots UPn^*)=(\mathbf{I}_1+\ldots+\mathbf{In})/(\mathbf{C}_1+\ldots+\mathbf{Cn})$$

$$=C_1\mathbf{V}(P_1)/(\mathbf{C}_1+\ldots+\mathbf{Cn})+\ldots+\mathbf{CnV}(Pn)/(\mathbf{C}_1+\ldots+\mathbf{Cn}) \tag{8}$$

That is, the **V** performance of the compound process is equal to the weighted (by relative costs) average of the component process performance. Since **I** and **C** for the dual processes are defined, **Vm** and **ROP** can be calculated using formulas (2) and (3) above.

A consequence of formula (4) is that the compound process performance cannot exceed the highest value of the individual component processes:

$$V(P) \leqq \mathbf{Max}\ (V(P1),\ldots,V(Pn))$$

However, the compound process performance cannot be lower than the lowest performance of the individual component processes:

$$V(P) \geqq \mathbf{Min}\ (V(P1),\ldots,V(Pn))$$

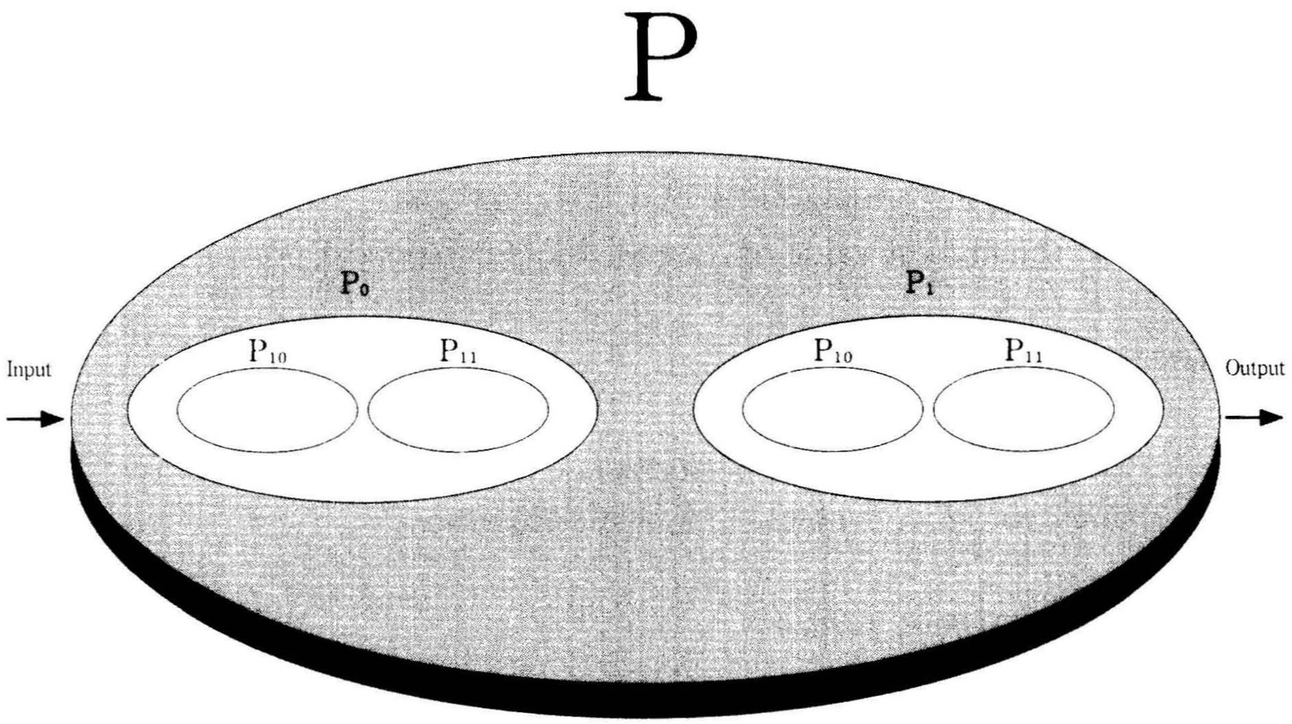
Finally, if all the component process are equal in performance, then the **V** performance for the compound is equal to this common value.

Appendix C

Partitioning Heuristic

Describing a company's products (e.g., jet aircraft) in terms of inputs (e.g., the one million parts need to build it) might be as impractical as trying to describe an ocean in terms of the location and velocity of each molecule of water in it. One approach for selecting the appropriate level of detail for averaging in **PVE** is the use of partitioning heuristics. Partitioning can follow binary or any other heuristic partitioning method which leads to the highest level of aggregation for which concrete process descriptions are available. Using the binary approach, the highest level of aggregation would split the company level compound process $\boldsymbol{P}$ into two major components that each produce approximately half the K-complexity of the whole company product (s), i.e., $\boldsymbol{P_0}$ $\boldsymbol{P_1}$ Such that $\boldsymbol{P = P_0\ U\ P_1}$.

Figure 3 Binary Partitioning Heuristic



Using the same binary principle, further partition the components such that, $P_0 = P_{00} \cup P_{01}$ and $P_1 = P_{10} \cup P_{11}$ and so on until the acceptable level of aggregation is reached to allow calculation of **V** for ***P***. Subject matter experts on the company processes should be used to help determine the appropriate partitions.

References

1. T. House and A. Bell, *Value-Based Reengineering: A Life Cycle Approach* (New York: Prentice Hall, in press).
2. F. Bleakley, "Many Companies Try Management Fads, Only to See Them Flop," *The Wall Street Journal* (July6,1993): p. Al . T. Housel, A. Bell, and C. Morris, "Value-based Reengineering: A Historical Perspective," (in press).
3. M. Hammer, "Reengineering Work: Don"t Automate, Obliterate, "*Harvard Business Review* (July-August, 1990): 104-112.
4. T. Housel, C. Morris, and C. Westland, "Business Process Reengineering at Pacific Bell" *Planning Review* (April-May 1993): 20.
5. See P. Drucker, "We Need to Measure, Not Count," *The Wall Street Journal* (April 13, 1993) p. A14; R. Eccles, "The Performance Measurement Manifesto," *Harvard Business Review*, (January-February 1991): 131-137; H. Johnson, *Relevance Regained: From Top-Down Control to Bottom-Up Empowerment* (New York: The Free Press Inc. 1992); and T. Davenport, *Process innovation: Reengineering Work* (Cambridge, Ma: Harvard Business School Press, Inc.); and T. Housel, C. Morris, and C. Westland (1993).
6. T. Steward, "Reengineering: The Hot New Managing Tool, "*Fortune*, (August 23, 1993): 41-48.
7. G. Nicolis and I. Prigogine, *Self-Organizations in Nonequilibirium Systems* (New York: Wiley Interscience 1978); I. Prigogine *From Being to Becoming* (New York: Freeman Inc. 1980); I. Prigogine and I. Stengers, *Order Out of Chaos* (Chicago: Bantam Books Inc. 1984).
8. W. Zurek, *Complexity, Entropy and the Physics of Information*, (Redwood City, California: Addison-Wesley Publishing Company 1990)
9. See G. J. Chaitin, "On the Length of Programs for Computing Binary Se-

quences" *Journal of Association of Computing Machines* (Vol. 13 1966): 547-569; A. N. Kolomogorov, "Three Approaches to the Quantitative Definition of Information" *Problems of Information Transmission* (Vol. 11965): 4-7; and R. J. Solomonoff, "A Formal Theory of Inductive Inference" *Information Construction* (Vol.7 1964): 224-254.

10. See proof in Thomas M. Cover and Joy A. Thomas, *Elements of Information Theory* (New York: John Wiley & Sons, Inc. 1991): 153-155.

11. For a similar employed line of reasoning in a manufacturing economics context see Paul M. Romer, "Are Nonconvexities Important for Understanding Growth?" *AEA Papers and Proceedings* (May 1990): 97.

12. P. Drucker (1993);
R. Eccles (1991): 131-137;
H. Johnson (1992);
and R. Kaplan and D. Norton, "The Balanced Scorecard-Measures That Drive Performance,"*Harvard Business Review* (January-February 1992): 71-79.

13. P. Drucker (1993)

14. P. Drucker (1993)

15. T. Housel and A. Bell (in press)

16. B. Rogow, "Putting the 'T' Back Into IT: Developing the IT Management Agenda for the Mid-1990s, "*SIM Executive* (Spring 1993): 2.