MODELING AND MEASURING THE BUSINESS VALUE OF INFORMATION TECHNOLOGY[1]

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Abstract

Determining the 'business value' of information technology (**IT**) requires managers to choose performance measures which are well-suited to capturing the economic impacts of the application they are evaluating. In this paper, the authors discuss a promising approach for bridging the gap between a theory for rational decisions and management practice in evaluating investments in IT: Data Envelopment Analysis (**DEA**). The referent discipline for the discussion is production economics, and the authors review basic concepts concerning performance measurement, efficiency, productivity and economic contribution or value-added from an economist's perspective. DEA's promise lies in its ability to handle multiple input and output production environments and its management action orientation. As an illustration of this potential, DEA is applied to assessing the performance of an automated teller machine (**ATM**) network, an IT which creates economic impacts at various organizational levels of a commercial bank.

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The founder and chairman of Wang Laboratories once observed that the most important technological development of the Twentieth Century has been hidden in "the back room." It is hard to imagine that "the computer" could become more conspicuous than it is today. Information technology (**IT**) permeates our society. It influences how business is conducted and it determines which businesses will survive in our economy. The performance gains of pure IT are legendary; but have the returns it contributes to the enterprise exceeded the investment costs? The benefits attributed to IT range from vastly improved operating efficiencies to strategic opportunities for competitive advantage in the marketplace. Many of these benefits are readily documented after the fact, however, too often the original commitment by management has relied on an act of faith. The economic climate and competitive warfare of the international economy continue to pressure management to reduce costs and improve efficiency. Yet in this belt- tightening period of declining budgets (for most areas), expenditures on IT in information systems (IS) and telecommunications continue to grow at near alarming rates. Are IS budgets out of control? Is your firm spending too much or, maybe, not enough? How can you know, or doesn't it make any difference? The critical problem in this arena confronting top management today is how to determine the "business value" of information technologies in order to guide investment decisions.

Of course, many investments in IT are predetermined; that is, you can't be in business without the capability. (The telephone is a trivial illustration.) However, for most investment decisions there is room for discretion and hence the need for a procedure to discriminate among the alternatives. The theory for guiding this process in a rational way is the concept of cost-benefit analysis. To that end, a common mechanism employed in practice is the calculation of net present value (**NPV**) or the discounting of future cash flows (**DCF**) associated with the investment at an appropriate interest rate. There is nothing faulty in the logic underlying NPV or DCF, and the procedure has been employed in industry for over seventy-five years. The Achilles' heel in applying this approach realistically to IT investments is the benefits component of the cash flow equation. More often than not, management is unable to estimate and quantify the full magnitude of benefits realizable from an investment in IT at the time the "go-no go" decision is required. For example, the greatest actual benefits may obtain from new business opportunities available after an IT-based infrastructure (e.g., a telecommunications network or an integrated electronic office) is in place, but in the short run the IT investment adds to rather than reduces operating costs. These higher order and often indirect contributions tend to be ignored in DCF analyses because they are difficult to address and understand. Given the wide range of management experience, the actual performance of IT in industry, and competitive pressures, the fallback temptation is to make (at least some of) the investments on faith in the future -- hardly, a satisfying resolution, although wishful thinking can be a strong deterrent for hard analysis.

In this paper we discuss an approach for bridging the gap between a theory for rational decisions and management practice by describing a "new" method of analysis and presenting an illustrative application of the approach. The following section briefly reviews some basic concepts concerning performance measurement, efficiency, productivity and economic contributions or value added. Here we also raise considerations which stem from existing management accounting practices and the complications they create for developing "business value" measures of IT from conventional data sources. Next, we provide an overview of a new, management action-oriented method of productivity assessment called "Data Envelopment Analysis" (DEA). We follow this with a discussion of a real world application of the technique to IT: assessing the business value of automated teller machines (ATMs) for retail payment networks in financial services. The paper concludes with several prescriptive observations on the approach, the application and the problem in general.

1. Some Basic Definitions, Concepts and Principles

The effective analysis of performance presupposes an understanding of some basic ideas. Plain and simple, the underlying discipline for the concept of "business value" is economics. Business value subsumes goal attainment, relative scarcity (or effort) and economic worth. Informed management action is the key to achieving business value in a firm.

1.1. Measurement, Efficiency, Productivity and Economic Contribution

Measurement provides a unit of analysis. The process of measurement involves the definition and calibration of a metric, determination of a reference/standard/goal, monitored observations, comparison of observation against the standard, and a record of the result. The critical step in this sequence is defining an appropriate measure (or several), since to a large degree this step determines the relative ease or difficulty in executing the entire process, and its effectiveness. Factors which weigh in establishing a measure (or several) include the criteria listed in Table 1-1. While all of these factors should be recognized, the importance of any of the criteria depends on the objectives of management for assessing performance and, consequently, their applicability varies with purpose.

For example, the purpose or function to be served by the measure(s) will substantially influence which measures are relevant. The NPV or payback period may be entirely adequate for analyzing isolated equipment investments, but they are seriously lacking for comparing strategic oppor-

Table 1-1: Criteria Influencing Definition and Choice of Performance Measures

Criterion	Questions Influencing Choice of Measure
PURPOSE or FUNCTION	Measurement goal? What is the organizational level, scale, and scope of analysis?
ACCURACY REQUIRED	What is the significance of measurement errors and/or randomness ("noise") in the environment?
VALIDITY or RELEVANCE	As a performance indicator, does it encompass "important" inputs and outputs (is it monitoring the "right things") and create the "right" incentives?
CONSISTENCY and RELIABILITY	Does it yield comparable results under similar conditions (inputs) and over time?
RESPONSIVENESS or SENSITIVITY	Does it reflect changes in the environment in a timely manner?
QUANTIFIABILITY	Is it numerical, multi-dimensional, and/or "formula-based"?
PRACTICALITY	What is the cost to do; time required to understand, design and build; people effort involved; data required?
INFORMATIVENESS	Will it aid in decision-making or problem identification?
GENERALITY or TRANSFERABILITY	Can the measure and approach be utilized by different units of the organization?

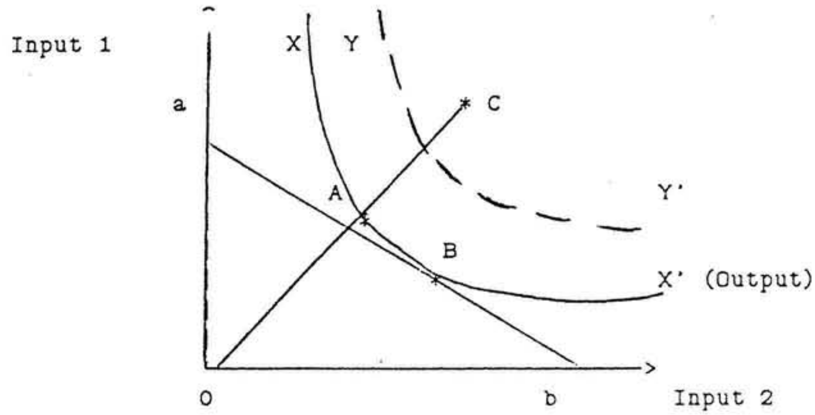
tunities from new products or services. The accuracy required and/or consequence of data measurement errors will influence the available methods and feasible measures; e.g., often for purposes of planning interest is focused on general trends or direction and not on absolute numbers. Existing data and data sources will also circumscribe the opportunities for analysis. The simple fact of the matter is that performance measurement is complex in all aspects: calculation, monitoring, evaluation and implementation. However, from a pragmatic viewpoint, the important consideration is for relative comparisons with a "standard" or benchmark and not the absolute figures of merit.

One baseline reference for performance is the concept of "efficiency." The engineer defines efficiency (for the proverbial "black box") as the ratio of (its) output to input. For comparisons through time, the engineer may define a base period efficiency as the initial condition of a process and then compute index numbers for future periods as the ratio of each period's efficiency relative to the base in the form of a time series. The economist's equivalent concept of efficiency is captured in the theory of production (or "the theory of the firm").

Figure 1-1 is an abstract and oversimplified characterization of a production process; it depicts physical output (production) in terms of two required inputs to the process (e.g., "Input 1" might be labor hours and "Input 2" units of a raw material). The diagram assumes the process represents the "best practice" or "state-of-the-art" technology for the production of this output. That is, for a given level of output units the curve labeled X-X represents possible tradeoffs between the two inputs to produce the same level of output with the known production technology. For example, the point A on the curve X-X employs more of Input 1 to produce the given output relative to Input 2, and the opposite is true for point B on the same curve. However, both points A and B are equivalent in terms of their technical efficiency -- they each employ the same technology. This property is assumed true for all points (i.e., the locus of all the combinations of the inputs, in addition to A and B) which lie on the curve X-X , and the curve is referred to as an isoquant or a "production frontier." (The dashed-line curve labeled Y-Y is an analogous production frontier, however, it corresponds to a higher level of physical output because it lies above X-X in the diagram.)

The point C in Figure 1-1 lies above and to the right of the production frontier X-X (in the interior of the curve), and corresponds to inefficient production of the given output level, since it requires more of both inputs. A measure of the inefficiency of point C can be computed as the ratio of the line segments OA to OC relative to 100%. That is, the fraction OC/OA minus 1.0 multiplied by 100% represents the excess amount of inputs employed by production at point C above the production frontier to yield the same level of output. Movement along a production frontier, such as X-X , corresponds to substitution of one input factor for the other (which is assumed to be continuous here) and the slope of a tangent line to the curve at any given point is called the "rate of technical substitution" between the inputs. A change in one input with respect to a unit change in output, ceteris paribus, is referred to as the marginal product of that input. The concept of marginal product is closely related to that of "productivity" as we discuss it below.

Figure 1-1: A Graph of Production Economics



From the diagram in Figure 1-1 the points A and B on the frontier are both technically efficient and hence equivalent in these terms. Is there any basis to prefer one combination of the inputs over another? Economics gives the answer to this question in terms of the prices of the inputs (or their cost). That is, suppose in Figure 1-1 the line a-b corresponds to the cost of the fixed inputs for the specified output, assuming the firm buys the inputs in perfectly competitive markets at constant unit prices.[1]

This diagram and analysis assumes that the total cost of production is a line a-b is the negative of the input price ratio. Then optimizing behavior (profit maximizing or cost minimizing) for the firm dictates that production should occur at point B, that is, at the mix of inputs on curve X-X that is a tangent point to the cost (input price) line a-b. This theoretical solution is optimal with respect to economic (or allocative) efficiency. As such, it equates the value of the marginal product (output price multiplied by marginal product) of each input to the input price (or unit cost) -- given the assumption.

The economist's perspective on technical and economic efficiency is essentially a statement

[1] The slope of the linear function of the inputs, e.g., for input prices p and p , respectively, Cost = p I + p I + A with A a constant.

about productivity and production factors (inputs and process); this differs somewhat from the conventional view in management accounting where the emphasis is on financial factors. That is, profitability analysis traditionally associates a change in profits with a change in revenues minus the change in costs (see vertical center blocks in Figure 1-2). In a recent paper Banker, Datar and Kaplan (1986) argue that the traditional approach arises naturally in accounting where the focus of investigation is on the income statement which segments revenues and expenses. The analysis can be extended incrementally by factoring revenues into the components of output quantity sold multiplied by unit sales price, and factoring costs into the components of quantities of inputs employed multiplied by unit input prices (see the top and bottom row sequence of blocks in Figure 1-2).

Figure 1-2: Components of Change in Profits

```
 ---------------         -------------        ----------------
| Change in    |        |  Change     |      |  Change in     |
|  Output      | >>>>>  |    in       | <<<<<|   Output       |
|  Quantity    |        |  Revenues   |      |    Price       |
 ---------------         -------------        ----------------

      ||                     |||                   ||
      ||                     |||                   ||
      ||                     |||                   ||
      vv                     vvv                   vv

 ---------------         -------------        ----------------
|  Change      |        |  Change     |      |  Change in     |
|    in        | =====> |    in       | <=====|   Margins      |
| Productivity |        |Profitability|      |(Price Recovery)|
 ---------------         -------------        ----------------

      ^^                     ^^^                   ^^
      ||                     |||                   ||
      ||                     |||                   ||
      ||                     |||                   ||

 ---------------         -------------        ----------------
| Change in    |        |  Change     |      |  Change in     |
|  Input       | >>>>>  |    in       | <<<<<|   Input        |
|  Quantity    |        |  Costs      |      |   Price        |
 ---------------         -------------        ----------------
```

As a result, changes in profits can be explained by a variance analysis of changes in each of the components added together in the profit equation. The American Productivity Center[2] has provided an alternative explanation of profit variance (profitability ratio) in terms of a change (ratio) in productivity multiplied by a change (ratio) in margins or price recovery. This analysis can also be extended as before by factoring productivity into the ratio of output quantities to input quantities and factoring margins into the ratio of product output prices to input resource prices (see the far left and right vertical column sequences of blocks in Figure 1-2).

The cited paper by Banker, Datar and Kaplan (1986) addresses several of the problems involved with either of the aforementioned approaches to profitability analysis. One of these concerns the issue of multiple inputs and multiple outputs, and the need to relate and convert partial measures of productivity and price recovery into total factor equivalents (e.g., see Craig and Harris, 1973). Another concern, alluded to earlier, is the fact that performance measures (such as productivity) in isolation are not very meaningful. They acquire significance only when they are juxtaposed with comparable measures for other business units/facilities or prior time periods to accommodate relative comparisons of performance. The production frontier approach can be used to analyze multiple inputs and multiple outputs with little difficulty. Even though for convenience we limit our illustration in Figure 1-1 to two inputs and one output, the mathematics of the approach has no such computational restriction. Our example also suggests how measures, such as efficiency/productivity, can be calculated employing the frontier. Exploring the frontier along different input resource dimensions can focus on key cost drivers and potential opportunities for management action.

Profit improvement through cost management is only one aspect of the performance opportunity set. The marginal value (revenue) product defined above constitutes the gross economic contribution or gross value added of an input resource (process) to the firm's output. (N.B., this is not the value added at the margin in terms of profits.) For some input resources, such as in the conversion of a natural raw material into a finished product, the economic contribution is direct and can be readily calculated from engineering and accounting data. However, for many other resources, such as IT, the contribution is more indirect, it involves "one input" and many outputs or many inputs and many outputs, and its primary impact (value) obtains through higher-order rather than first-order effects. IT is notorious in this regard due to its pervasion in the organization, its contribution often depends on other primary input resources, notably people,

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[2]See APC (1981) and von Loggerenberg and Cucchiano (1981-82).

and there is a time displace- ment between the acquisition of IT capability and the organizational learning required to realize economic returns.

1.2. Management Accounting and the Data Problem

The American Productivity Center's (**APC**) approach to profit variability through productivity and price recovery analysis employs actual quantities and prices/costs for calculating comparative ratios and change. This differs from the accountant's variance analysis employing a standard cost system which specifies input and output relationships in terms of product standards for labor, material and overhead. Accounting standard cost systems also assume a separable and linear (constant marginal product) production technology. Banker, Datar and Kaplan (1986) discuss procedures for reconciling these differences (i.e., APC measures in terms of "standard costs") and describe "profit variance" as the sum of "sales activity variance," "productivity variance" and "price recovery variance." While standard cost systems and other accounting data structures can provide a wealth of information for management decisions, they do not serve the direct needs of "business value" measurement analysis, particularly in the context of IT. Nonetheless, it is foolhardy to ignore or discount the inertia of the existing accounting infrastructure.

As an illustration, the Federal Accounting Standards Board (**FASB**) released a recommendation (Statement 86) in August 1985 concerning professional practice for the treatment of the costs of IT as either a capital investment or an expense. (See Young, 1986). The accepted practice for the costs of purchased hardware and most purchased software is to capitalize them as an investment over some useful life of service. The accounting for the cost of internally developed software is less straight-forward. Common practice has been (and in all likelihood will continue to be) to expense software development costs within the accounting period, i.e., to write them off in the fiscal year incurred. This asymmetric treatment of IT costs presents major difficulties for analyzing IT opportunities, especially, since software accounts for in excess of 60% of the total. It also runs counter to much of the "conventional wisdom" that has evolved regarding R&D planning and investment decisions. The software development required for most (major) IS products typically has a useful economic half-life on the order of three to five years. But the accounting conventions for information systems technology (**IST**) assets, such as ROA/ROI or DCF, tend to overemphasize the IT (physical) capital considerations in the analysis. From the creation of the IST asset and its maintenance over a productive life (e.g., through required enhancements), software costs become "current" expenses which may not coincide in time with their economic returns.

1.3. Business Value Measures of IT

The net economic contribution of an input resource to an output product is measured by the unit profit (sales price minus cost) of the output multiplied by the marginal product of the input. Where the input contribution to output is direct and the relative impact is focused, this statement becomes operational as an exercise in arithmetic. However, as we have already observed in the case of IT the contribution to output(s) is usually indirect and different technologies have different kinds of impacts, for example, ATMs or point-of-sale (**POS**) terminal devices versus telecommunications networks or a MIS infrastructure. The more diffuse the impact on the firm the less, direct business value can be attributed to IT. Moreover, IT business value measures should not be confused with criteria intended to track the performance of the MIS/IS organization as an entity. While the latter issue is important on its own, it is a different management consideration which is not synonymous with IT business value. From experience, one approach to the diversity of potential impacts from IT is through a classification of IT applications which can facilitate the identification and selection of appropriate measures by type (for example, administrative cost reduction productivity improvements, customer service in marketing, new product strategies, etc.). The problem historically has been the mindset to rely on one or two direct measures, such as ACR, and attempt to employ it for all application opportunities, regardless of type. This bias in IT portfolios is well known.

Business value measures should be derived from senior management goals which in turn acquire coherence as the building blocks of the firm's corporate strategy. From the pluralism of this principle, it follows that a system of measures (not a "single measure") must be employed. Despite the seductive appeal of a unitary conceptual measure, such as "shareholder wealth," operationally it appears that no candidate readily decomposes into a convenient hierarchy of consistent sub-goals. For example, the concept of "quality" must be a component of the measurement system, but its translation entails multiple dimensions, some involving subjective or personal judgments.

The resolution of this issue begins with top management establishing an institutional framework within the organization for measurement and monitoring. This institutional framework should target management decision and actions (e.g., make or buy, capital/labor tradeoffs, and the like). The framework should facilitate incorporation of a process for the organization to determine policy, procedures and methods for developing (possibly "new") business value measures.[3] We now describe in further detail one approach based on these first principles.

[3]One such framework with emphasis on organization and process (not necessarily "business value measures," per se) is Ackoff, (1970), especially, Chapters 5 and 7. Our following discussion deals more with approach and method.

2. A Management Action-Oriented Approach: Data Envelopment Analysis

Production environments outside manufacturing place special demands on the tools managers use for productivity and performance assessment. Historical reliance on accounting, engineering and operations as sources of data may have served manufacturing environments reasonably well, but they appear inadequate in meeting the needs of service environments where qualitative indicators may dominate results. This is especially true when managers attempt to gauge the business value of IT as an input to, or mediator of, production.

2.1. Productivity Assessment with DEA

One approach which can enhance our ability to measure the business value of IT is Data Envelopment Analysis. DEA is a non-parametric frontier analysis approach to the estimation of production correspondences. It enables a manager to distinguish among efficient units which lie on the frontier, and those which are less efficient and lie inside the frontier. DEA is based on mathematical programming and production economics.

Use of DEA initially requires managerial judgment in the identification of input resources which are transformed by the productive technology into a set of output commodities. Recently, DEA has been extended so that its productivity measures are robust to a variety of production environments and managerial evaluation requirements. Banker, Charnes and Cooper (1984), for example, extended DEA to enable a manager to decompose overall inefficiency measures into resource waste and scale effects. Banker (1984) provides a method to identify the most productive scale size. Other extensions involve efficiency measurement in production environments which have fixed or categorical inputs or outputs, and the identification of resource allocation inefficiencies.

2.2. Management Action Orientation and Applications to Non-Traditional Production Environments

DEA is attractive for the assessment of IT performance because of its management action orientation. Unlike other productivity assessment techniques, DEA provides measures which can lead to managerial decisions congruent with profit maximization in non-traditional production environments. DEA does not require a prespecified functional form for the production correspondence being investigated. For example, consider how hard-pressed a manager would be to define the input-output relationship between a micro- computer on his desk and his division's sales revenue. Yet, the characterization of a frontier representing best observed performance can suggest performance targets for less efficient units and overall resource allocation involving IT.

Since IT is often an input to a multiple input and output production environment, DEA is appropriate because it provides strong measures which are sensitive to the input and output mix. Productivity ratings also can be explained in terms of aspects of the managerial environment within and beyond a manager's control. This helps a decision maker to identify and adapt to the key influences on production.

DEA has recently been applied to a number of IT and services settings, including the analysis of the economic impact of IT on organizations (Chismar and Kriebel, 1986), bank branch operating efficiency (Sherman and Gold, 1985), corporate voice communication network performance (Crow, 1987) and data center efficiency (Elam, Henderson and Thomas, 1985). DEA has also been combined with multivariate regression and a logit model to explain how programmer experience and the introduction of a structured analysis method affect the productivity ratings of software development teams (Kemerer, 1987).

3. An Application: Retail Payment Networks in Financial Services and ATM Technology

Retail payment networks, including ATMs, point-of-sale debit cards and credit cards, are among the new electronic financial services that have fundamentally changed the ways in which people effect cash transactions. Today, more than 70,000 machines have been installed nationwide, and the number is still growing. According to one industry estimate, the industry spent more then $2 billion on retail electronic funds transfer between 1982 and 1985 (Wagner, 1985). And that figure is expected to balloon to at least $20 billion by the year 2000, while participants in the financial services industry extend retail electronic funds transfer into a communications network linking nearly 50,000 firms (Coats, 1984). As retail payment networks continue to grow, their operators require improved tools to evaluate their resource consumption, cost efficiency and effectiveness as delivery mechanisms for a variety of financial services. This application of DEA is aimed at developing methods which help financial service managers to measure the business value and contribution to corporate goals that ATMs can provide.

3.1. From Usage to Business Value: A New Approach to Performance Measurement

Current evaluation methods for ATMs rely heavily on rules-of-thumb to assess performance. For example, network managers often try to overcome the "33% wall," i.e., convincing more than 33% of their ATM card holders to perform more than three or four transactions at an ATM each month. For individual ATMs, a usage criterion is often used to distinguish between acceptable and unacceptable performance. For supermarket and other locations where a bank may be required to pay the host for ATM installation, the generation of an acceptable level of "interchange fees" may be most important. Interchange fees are fees charged by a bank when other banks' customers use its ATMs.

Each of the performance measures suggested above provides an incomplete picture of the business value that an ATM network can provide to a bank. Surpassing the "33% wall" for active ATM card use may only be important if the convenience that card use provides can be shown to be linked to customer willingness to leave deposits with the bank. Other times, it may be important to promote cost control in bank branches. In addition, there are situations in which usage is not the best surrogate for business value.

For example, usage will not provide a good surrogate for business value when transaction levels are similar. Instead, we should value an ATM more highly if it services a clientele leaving a higher level of deposits. However, first we must test whether ATMs, and the convenience they provide, influence customers to leave deposits with the bank. A second example in which usage is misleading involves the impact ATMs have on branch costs. For similar usage levels, ATMs at branches with expensive teller labor save a bank more money.

Current rules-of-thumb are also unreliable because they do not address the context dependency of production at an ATM. For example, competitive pressures for deposits among banks, the density of network ATMs in a region, and the presence of a competing ATM network are all likely to affect an ATM's business value. In the following sections, we demonstrate that it is possible to build more consistent and robust measures for the business value of ATMs.

3.2. The Production Process for ATM Services

We view the creation of ATM services as a microeconomic production process. Gauging the productivity of such a process involves quantifying input resources and capturing the process by which they are transformed into service and other outputs, representing benefits derived by the bank. Production occurs at an individual ATM under the influence of market and other conditions which we term "exogenous factors". Exogenous factors are those over which management has little short run control. Some examples are local demographics, participation in a shared ATM network of regional or national scope and coverage by competitors' ATMs. Each of these conditions a manager's expectations for an ATM's business value.

Location strategy factors also influence production at an ATM. They describe the bank's business goals which drive the location of an ATM. One example of a location strategy is siting at ATM where other banks' customers are likely to use it to earn interchange fees. Network management can exercise discretion in the location, configuration and service quality associated with each ATM. But the actual performance of an ATM is likely to be significantly influenced by the strategic choice underlying its location. Thus, location strategy factors are endogenous influences in our model. A representation of the ATM production process is shown in Figure 3-1.

3.3. Direct and Indirect ATM Outputs: The 'Business Value' Linkage

A basic characteristic of the production process for an individual ATM is that it yields direct and indirect outputs. Direct ATM outputs are those which can be measured directly at the ATM. An obvious example is the number of transactions involving cash withdrawals, deposits or transfers. Direct ATM outputs are local outputs of the production process. Knowing their quantity, however, provides little information about the economic contribution of an ATM to the bank, in the absence of information about its operating context.

Indirect ATM outputs are those which cannot be measured directly at the ATM level; they are tangible at higher levels of the firm. An example is the contribution an ATM transaction makes to reducing direct teller labor hours for retail transaction processing at a nearby bank branch. Indirect outputs are non-local outputs for an individual ATM because their impacts are felt at the branch or bank levels. Nevertheless, in order to carry out an evaluation of ATMs' economic performance, we require a means to determine their values at the local ATM level. Specifically, in the context of Table 1-1, we need to answer questions such as:

1. At what organizational levels do the indirect outputs of individual ATMs become measurable?

2. What are the underlying production processes associated with the relevant organizational levels?

3. How can we use the knowledge of these production processes to attribute business value from the indirect outputs to individual ATMs?

Figure 3-1: The Production Process for ATM Services

```
                         ------------------------------
                         |     Demographic factors    |
                         |     Competitive forces     |
                         |   Regulatory constraints   |
                         |============================|
                         |    EXOGENOUS INFLUENCES    |
                         ------------------------------

                                       ||
                                       ||
                                       ||
                                       vv

                              --------------------
INPUTS ========>              | PRODUCTION PROCESS |          =======>  OUTPUTS
                              |                    |
                              |    ATM SERVICES    |
                              --------------------

                                       ^^
                                       ||
                                       ||
                                       ||

                         ------------------------------
                         |    LOCATION STRATEGIES     |
                         |============================|
                         |  Improve Branch Workflow   |
                         |   Protect Deposit Share    |
                         | Earn Interchange Revenues  |
                         ------------------------------
```

We identify the business value linkage between direct and indirect ATM outputs by considering more aggregated levels of production within the organization. For example, the contribution of an ATM to the reduction of bank labor primarily impacts the production processes associated with nearby branches. ATMs displace human labor to the extent that they handle transactions that would have been handled at a teller's window of a branch. Thus, we need to identify those ATMs which can contribute to the production process of a particular branch.

To do this, we define the branch operating territory as the local region around the branch which the bank perceives to be its primary service area. In our work with a large commercial bank, we have operationally defined this region in terms of United States population census tracts. We build up the branch operating territory by identifying nearby census tracts where people live, who have accounts at the branch. The residences of the majority of account holders tend to cluster near the branch. A branch operating territory can otherwise be defined consistent with the bank's internal operating policies. Not all branches need to have the same size territories, and the territories need not be entirely disjoint. All ATMs and competitive branches located in this region are identified as members of the branch operating territory.

Figure 3-2 shows a sample aggregation for two branch operating territories of Bank A. It competes with three other banks: B, C and X. A, B and C operate a number of ATMs on the same shared ATM network. Bank X operates two ATMs on a competing network. Now, let's focus for a moment on Branch Operating Territory A20 to illustrate the relationships among the competitors. In this territory, Bank A's branch competes for deposits with another branch operated by Bank C. A and C also operate ATMs in the territory, A3 and C1 respectively. Bank X operates an ATM, X2, which cannot be shared by A, B and C's customers. In this territory, only A1 and C3 can contribute to Branch A20's production process; X2 cannot contribute.

Development of a retail deposit base in a region involves competition among banks, which configure branch and ATM networks through which a variety of financial services are delivered. We term this configuration the retail service cluster. In the example above, Bank A has a retail service cluster which consists of the branch operating territories A10 and A20. The bank's service delivery configuration, relative to those of its competitors, determines its ability to gather a retail deposit base. Our cluster concept is quite flexible. Clusters can be built up in terms of a bank's own view of its regional retail markets. The county level, for example, is one basis to define a cluster of branches and ATMs, though a higher or lower level of aggregation might be used.

We attribute business value to an ATM using multivariate regression to identify the significance of the presence of ATMs, among other factors, in the production of retail deposits. This approach is in the mainstream of literature on bank branch performance which we have surveyed to date (for example, Hansen and Weinberg (1979) and Lord and Olsen (1979)). Yet we have not been able to identify any studies which include variables to describe the impact that retail payment technologies might have on branch performance. A representative regression involves estimating the amount of deposits captured by a branch as a function of various branch operating territory variables. These variables are summarized and described in Table 3-1.

Figure 3-2: Branch Operating Territory and Retail Service Cluster Aggregations

```
Local Level          Branch Operating Territory


ATM  A1  = = > |
ATM  A2  = = > |
ATM  B1  = = > | = = = >  Branch  A10   |
ATM  B2  = = > |                        |
ATM  X1        |                        |
                                        |  = = > Retail Service Cluster
                                        |
                                        |
ATM  A3  = = > |                        |
ATM  C1  = = > | = = = >  Branch  A20   |
ATM  X2        |              (**)

Key: A signifies an ATM or branch belonging to Bank A.
     B signifies an ATM belonging to Bank B, A's competitor
        on same network.
     C signifies an ATM belonging to Bank C, A's competitor
        on same network.
     X signifies an ATM belonging to Bank X, A's competitor
        on another network.
     ** signifies that Branch  A20 competes with a branch
        owned  by Bank C nearby.
```

Assuming this simple explanatory model has been validated and the ATM variables are significant, then the regression yields a coefficient for the presence of bank-operated ATMs in the set of branch design variables. It also gives coefficients of contribution for other shared ATMs, and the negative impact of non-shared ATMs on other retail payment networks. Alternate models involve estimations of demand and savings deposits separately, or even the number of these accounts that a branch is able to gain, provided information on the competition is publicly available. Multiplying the regression coefficient for an ATM by the amount of deposits at a branch gives a simple measure of ATM contribution. If the ATM variables are not significant in our regression, then we have established grounds for arguing that ATMs are not providing business value by protecting a deposit base. Subsequent analysis of ATM performance should exclude this output variable.

Table 3-1: Variables for ATM Business Value Assessment

Branch Operating Territory Variables	Description and Breakdown of Variables in Each Category
TERRITORY DEMOGRAPHICS	Census tract descriptors, including population, average income, etc.
BRANCH CHARACTERISTICS	Variables which describe the branch service facilities, such as: - no. of teller and platform stations - presence of bank-run ATMs - walk-up and drive-up facilities - time-in-place - dummy variables for varying service levels the branch provides - interest rate on deposit products - recognition of bank's name in the consumer marketplace
COMPETITOR BRANCHES	Number of competitors' branches in territory
SHARED ATMs	Number of shared ATMs in territory
COMPETITORS' ATMS	Number of non-shared ATMs in territory

We use a similar multivariate regression approach to identify average teller processing times, specific to different branch environments, for transactions that could be handled by an ATM. Then, using data for the direct transaction and uptime outputs from bank-operated ATMs in the branch operating territory, we can calculate an implied value for the hours of teller labor contributed by the ATM.

3.4. DEA Assessment

Although we have proposed a method to attribute business value to ATMs, we still need to consider whether that value has been efficiently produced. To perform this assessment, we use Data Envelopment Analysis for a sample 30-ATM network. The inputs and outputs of the ATMs in this network are shown in Table 3-2. We assume that the bank will have initially performed the ATM business value estimations described earlier. Our analysis also requires operating data on the number of interchange revenue-generating transactions, the support trips made to maintain an ATM in a period, and the average working capital on hand at a machine. The latter two represent the primary variable costs for ATM locations. Utilizing an appropriate DEA formulation (Banker, 1985), we arrived at the sample results shown in the far right column of the table.

The DEA results measure the technical efficiency of ATM production. The focus is on input resource waste. All ATMs which rated 1.000 occupy positions on the production frontier. They consume the least input resources, given their output levels. Those which rate less than 1.000 are technically inefficient. Seven ATMs have efficiency ratings of less than 0.800: A3, A4 A17, A18, A23, A24 and A25. These represent roughly the bottom quartile in efficiency. Management should more carefully study the circumstances of their production and performance, to determine whether working capital and maintenance trips can be reduced while output levels are maintained.

In Table 3-3, we present additional results from DEA for the lowest quartile to further guide managerial action. The rating for ATM A3 of 0.785, for example, is based on a comparison to a weighted average of the efficient ATMs in its reference set: A1, A11, A14 and A26. This composite ATM lies on the multi-faceted production frontier. It can be thought of as a target for the inefficient ATM's improvement. Notice also that A17 and A18 have identical referent sets. This implies that these ATMs possess relatively similar, though not identical, input and output mixes. Management should probe how to improve the performance of A17 and A18 by investigating why A9, A14, A19 and A26, which have similar input-output mixes, are on the nearby frontier. This kind of analysis allows managers to design policies to improve operating efficiency which are customized to the circumstances of production.

A word of caution in the use of these results is also in order. It is important for managers to understand how the exogenous environment impacts the creation of ATM-related outputs. It is unlikely that changes to the input variables that we have included, in the absence of changes in the exogenous environment, can lead to substantial changes in the business value of outputs. Thus, the analysis we propose is best suited to input reduction, where possible, and not output augmentation.

Approaching ATM performance assessment in the two-step process we describe above, managers may learn that the number of transactions processed at an ATM is insufficient to determine its business value. Managers should also recognize that a technically inefficient ATM can still be a

Table 3-2: Data Set and Results for a Sample ATM Network

	OUTPUTS			INPUTS		RATING
ATM Site	Interchange Transactions (1000s)	Deposit Contrib. ($1000s)	Labor Contrib. (Hrs)	Working Capital ($1000s)	Maintenance Trips	Technical Efficiency
A1	2.0	300	150	15	12	1.000
A2	2.4	272	122	36	5	.862
A3	1.0	250	150	25	12	.785
A4	1.0	250	100	25	10	.583
A5	1.0	200	50	25	5	.858
A6	1.0	200	100	15	5	1.000
A7	2.0	150	150	15	8	.961
A8	2.0	150	100	15	8	.939
A9	3.0	100	200	15	10	1.000
A10	3.0	100	250	15	12	1.000
A11	2.5	300	200	30	6	1.000
A12	2.5	275	125	35	4	1.000
A13	2.4	273	125	37	5	.857
A14	2.6	225	215	24	7	1.000
A15	2.6	215	190	24	7	.944
A16	2.6	230	180	18	9	1.000
A17	2.7	125	160	23	11	.708
A18	2.7	125	162	25	12	.717
A19	2.9	130	75	19	4	1.000
A20	2.6	216	192	26	9	.820
A21	1.1	80	95	17	5	.952
A22	0.5	50	125	22	6	.869
A23	0.6	125	110	18	8	.778
A24	0.9	70	80	20	8	.700
A25	1.4	90	60	20	6	.780
A26	1.9	250	85	14	5	1.000
A27	0.6	225	115	16	9	.887
A28	0.8	220	120	17	10	.837
A29	0.9	160	130	15	11	.933
A30	1.2	110	155	14	8	1.000

Table 3-3: ATM Efficiency Results: Lowest Quartile

Observation	DEA Rating	Reference Set
A3	.785	A1,A11,A14,A26
A4	.583	A1,A14,A16,A26
A17	.708	A9,A14,A19,A26
A18	.717	A9,A14,A19,A26
A23	.778	A26,A30
A24	.700	A26,A30

good location in terms of business value. For example, ATM A4, with a rating of 0.583, is particularly inefficient. However, it is among the top ten ATMs in terms of deposit contribution. To sharpen management's insight, we need to determine if production is economically efficient, i.e., if ATM service production is profit maximizing. Since a manager can readily associate prices with each of the inputs and outputs we have submitted to DEA, our analysis can be extended to determine ATM profitability. This further helps management to identify ATMs which might be targets for closing.

4. Prescriptive Conclusions

At the outset we observed a business problem of apparent increasing concern and the dilemma it presents to management. IS budgets appear to be growing "out of control" and senior management worries that their firm is spending too much on unjustified "promises." But simultaneously, they are under constant economic pressure from competitive threats to exploit IT innovations for business conduct and "strategic opportunity" without regard to cost.

In this paper we discussed a new approach, DEA, and showed that it can provide comparative competitive measures of performance. Measures based on DEA can encompass shared costs and infrastructure and their analysis can generate benchmarks for IT cost control.

The approach is useful for gaining an understanding of the complexity involved, but DEA is not a "'surgeon's hammer' for IT assessment." It can't identify all of the outputs in some cases; for example, what is the value of a database management system or of electronic mail? The results from DEA are only as "good" as the data submitted by management for analysis.

Senior management is a necessary and vital participant in the assessment process and its role/contribution has been reasonably well-defined (see also Kriebel, 1986). Top management should emphasize the portfolio aspect of IT impacts, versus the evaluation of individual projects by defining multiple inputs and outputs. The DEA analysis can capture the interrelationship involved, but to be effective this requires ingenuity and insight by management in

Setting up the analysis (i.e., defining goals, inputs and outputs). The general problem every manager will face is defining the "business value linkage" for IT. As we argued, diffuse as well as focused impacts are possible and likely, and this will vary by type of IT. Moreover, not all outputs can be readily priced; for example, quality in an ATM context or information accuracy in a customer file: which prices should be assigned to these outputs? ITs with diffuse impacts will be the toughest to assess. For ATMs, as our example illustrated, the "business value linkage" is comparatively direct. The ATM is an IT with relatively focused impacts. The long term goal of this research and its application is to expand the range of ITs that can be assessed well.

Subject to the preceding requirements, the computational procedures for DEA are reasonably straightforward. That is, once the model is set up, computer programs exist for computing "frontiers" and performing sensitivity analysis. In executing DEA the approach can facilitate learning about consequences and formulation of policy with respect to IT.

But most importantly, this approach shifts management's focus from IT per se to business processes, linkages, contributions/value and organizational impacts.

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