

*An Electronic Businesses Balanced Scorecard and Digitization Metrics*

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## ABSTRACT

Business organizations are similar to living organisms. They need to adapt and react to changes within their environment. Similar to biological systems, business organizations need to have a system of “sensors” or metrics that will provide the necessary signals to the entity to react in a timely fashion. Thus, metrics are essential not only for measuring how the entity did in the past, and is doing at the present but also to provide some forward looking indications. Monitoring businesses are essential for mere survival, especially in this fast changing environment of E-Business and global economy. Since businesses and business activities are being conducted in the E-Business environment, existing measurements and techniques do not apply for today’ environment. In this paper we adopt a holistic view of the E-Business segment of corporations and develop a new comprehensive set of measurements. The main purpose of this paper is to discuss a balanced scorecard approach for the electronic environment. We also develop a unique innovative approach for evaluating the level of companies’ digitization, and provide an illustrative example and a description of the benefits associated with our model.

### **1. INTRODUCTION**

The advent of Internet technologies, hardware solutions, telecommunication networks, and computer applications has grown rapidly over the last two decades. This fast growth has resulted in a fast changing business environment and increased productivity. However, it also created new challenges for companies to adjust their business strategies, reengineer their business processes, increase their service offerings, and reduce their costs. Technology has opened up many new channels of communication

and commerce between companies and customers, companies and shareholders, and companies' employees. Trading partners can interact in a completely digitize environment and conduct many of their operations without any human intervention. Many forward-looking companies are leveraging new technologies to increase their productivity, reduce their cost and create more value for their shareholders. However, with the fast ever-changing technology environment and with the high cost of acquiring, integrating, and implementing new technologies, businesses have to learn how to invest their limited resources in technology while maintaining the focus on their core competency. Therefore, in order to effectively invest in new technologies to support electronic business (E-Business) a Balanced Scorecard approach needs to be developed for the firms operating in the digital environment. The main purpose of this paper is to develop a comprehensive set of metrics to evaluate the E-Business perspective of an organization. Further, we take one of our stated objectives and develop a measurement for the level of companies' digitization.

Kaplan and Norton [7,8,9,10] first introduced the concept of “Balanced Scorecard (BSC).” In the words of Kaplan and Atkinson ([6], p. 368), “The Balanced Scorecard translates mission and strategy into objectives and measures, organized into four perspectives: financial, customer, internal business process, and learning and growth.” Traditionally, businesses used to monitor and reward performances based on financial measures only, such as net income, earning per share (EPS), return on investment (ROI), etc. However, the Balanced Scorecard framework provides a comprehensive approach to planning and implementation of the business strategies for achieving the mission and

objectives of the company. The Balanced Scorecard concept is discussed in detail in Section II.

The recent surge in the use of technology, in particular Information Technology (IT), for improving the efficiency and effectiveness of the internal business processes has led some researchers to apply the Balanced Scorecard concept to IT investment to evaluate whether the IT investments are adding value to the company (Van Grembergen and Van Bruggen [28], and Van Grembergen and Timmerman [29]). Saull [21] and Van Grembergen [27] have extended the concept of Balanced Scorecard to IT governance. This topic will be discussed in further in Sections.

Corporations generate and use huge amounts of business data across the organizations and beyond organizational boundaries. More and more data is being used for decision-making, operation planning, channel integration, customer service, and administrative tasks. Advances in network computing technologies in recent years created a new environment for business, E-Business. E-Business may face a new value chain, where customers initiate the value creation process. Slywotsky [1] suggests that the following sequence of events may apply efficiently to digital businesses:

**Customers>Channels>Offering>Inputs>Assets,**

According to this model customers make their decisions and communicate them digitally to the business, thus enhancing the creation of value. This type of new information flow can be modeled for highly digitized companies, such as Dell Computers [1], where production and planning are triggered by customers' orders. New business models require businesses to respond promptly and accurately to customers' demand. Businesses which operate in the E-Business environment not only have to digitize their own operations and

information infrastructure but also to assure that their trading partners which are part of the integrated value chain are also digitized enough to meet their needs. Digitization of companies requires great investments in IT, which in turn may or may not result in the appropriate return. Although it may seem intuitive that IT increases productivity, discerning the effect of IT on productivity was proven to be a difficult task. The value of IT investment has been the subject of many research papers and will be discussed below.

### ***IT Productivity***

Information Technology imposes a great dilemma for management. On the one hand IT investments can lead to an increase in productivity, on the other hand IT investments can divert critical resources from the organizations' core competency. The issue of the value of IT has generated substantial interest among academics and practitioners. This interest was primarily triggered by the large investments in IT during the 80s and 90s. Since many of the benefits of using IT are intangible in nature, the productivity of IT is very hard to measure. IT is often viewed as a black box in which it is hard to separate the portion of productivity in a particular process due to IT and the productivity due to other factors. Brynjolfsson [2] presented the productivity paradox, which indicated that computers were not delivering the value promised. He raised some concerns regarding the measures used for the IT productivity estimation and listed four possible reasons for the failure to capture improved productivity, namely: measurement error, time lag, redistribution of activities among firms, and misallocation and over-consumption of information by managers. Kumar [20] used a model of real option valuations to show the value of improved responsiveness resulting from IT investments.

He was able to quantify the intangible benefit of IT through the improved responsiveness resulting from IT investments.

### ***IT Risk***

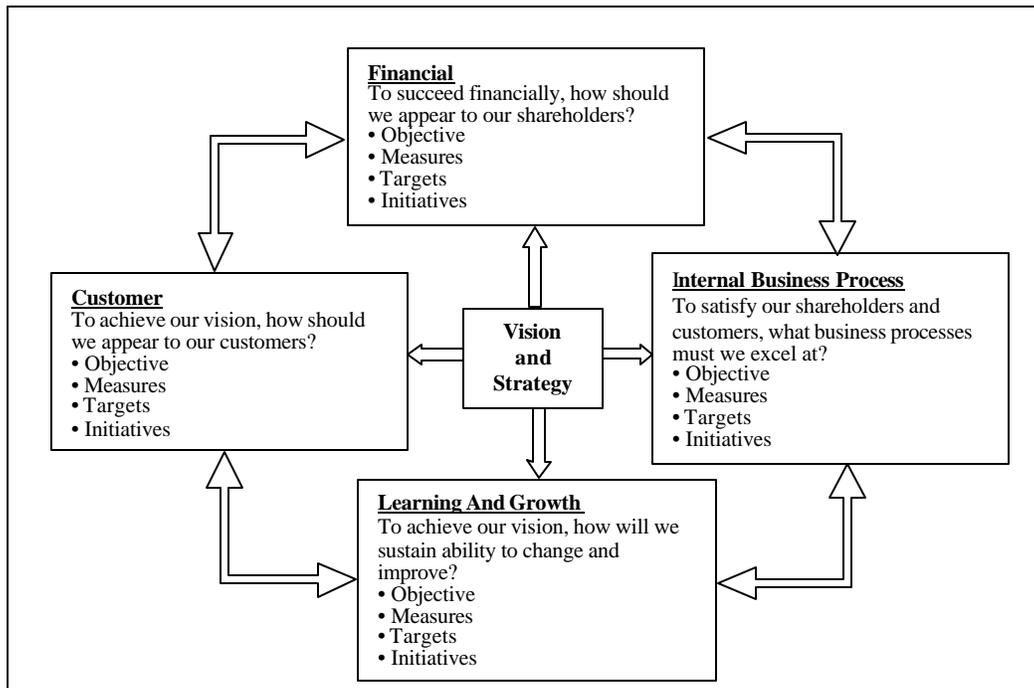
In additions to its benefits, IT introduces new risks to the organizations. The more companies rely on IT the more important it is to create the appropriate controls to maintain the reliability of the system. System reliability is defined by the AICPA/CICA [23] as follows: “A reliable system is one that is capable of operating without material error, fault, or failure during a specified period in a specified environment”. They included four principles to evaluate the reliability of the system: (1) Availability (2) Security (3) Integrity (4) Maintainability.

The ease of accessibility of information through the Internet has brought many problems of its own. It has become very easy to steal customers’ private information (name address, age, earnings, credit card numbers etc.) from the company’s files. Hackers have broken into US military computers. They have interrupted regular business functions. A common type of attack is the so-called “denial of service.” In early 2000, several US major business sites were attacked, and their normal activities were paralyzed for many hours. The most serious threat now being considered by the US government is not a nuclear attack or a missile attack, but it is a cyber attack. One can think of how serious it is. In a blink of an eye, one can paralyze the US Government, its communication system, its nuclear defense, utilities’ production facilities, etc. The same is true for a business entity. Security of information is important whether it is in transit, or in the entity’s computer.

## 2. BALANCED SCORECARD CONCEPTS

As mentioned earlier, Kaplan and Norton [7,8,9, and 10] first introduced the concept of “Balanced Scorecard.” The Balanced Scorecard translates mission and strategy into objectives and measures. In general, there are four perspectives (see Figure 1): financial, customer, internal business process, and learning and growth.

Figure 1: Balanced Scorecard



The financial perspective deals with the traditional objectives and measures outcomes such as the return on investment (ROI) and earning per share (EPS). These measures provide a way to assess how well the company has performed in terms of its

financial goals. However, these numbers represent the final results of the business performance. They do not provide a timely input in terms of what the management should do or could have done to achieve a better result. Under “Customer” perspective, a business entity establishes metrics that measure the customer’s satisfaction. A satisfied customer is a loyal customer and in turn creates more revenue for the entity. Under “Internal Business Process” perspective, a business entity attempts to excel in the internal business processes to stay profitable and compete well. Businesses have developed various metrics that measure the efficiency, effectiveness, quality, and other relevant factors associated with profitable strategies. Efficiency and effectiveness in the business processes results in quality products, lower costs of production, and faster delivery, which in turn results in satisfied customers, and thus higher revenues.

The Learning and Growth perspective deals with the preparedness of the workforce to meet the challenges of the changing environment. These metrics deal with the training and know-how of the workforce. Although these metrics, in general, serve as “sensors” for the business entity to monitor its environment, the existing literature on these metrics does not consider the ever-changing business environment of the Internet. We plan to focus our efforts in this paper on this dimension.

The Balanced Scorecard approach provides a mechanism to manage not only the tangible assets but also the intangible assets. The intangible assets, such as human capital, have become even more important than ever in this age of the Internet. Using the Balanced Scorecard approach, the companies can take full advantage of their tangible and intangible assets. Kaplan and Norton compare the Balanced Scorecard approach to a recipe (Kaplan and Norton [11] p. 10):

... Think how making a meal requires a combination of raw materials (the ingredients), tangible capital and assets (cooking implements, an oven, and a stove), and intangible, human capital (the chef). But a great meal requires a recipe to take advantage of all these tangible and intangible assets. The recipe is the critical soft asset. It transforms the raw ingredients, physical assets, and intangible assets—each with little stand-alone value—into a great meal, with considerable value. The recipe corresponds to a company strategy that combines internal resources and capabilities to create unique value propositions for targeted customers and market segments. The companies in our sample were successful with the Balanced Scorecard because they engaged all employees, not just the lead chef, to implement and improve the recipe.

Thus, the Balanced Scorecard<sup>1</sup> provides a general mechanism by which the management can align their strategy and goals with the objectives and measures that will provide a monitoring mechanism to evaluate how well the entity is doing in terms of achieving its goals and objectives. If there are any deviations, then corrective action can be taken in a timely manner.

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<sup>1</sup> See Kaplan and Norton (2000) for a list of companies who have implemented the Balanced Scorecard approach and benefited from it.

### 3. BALANCED SCORECARD FOR INFORMATION TECHNOLOGY

Saull [21] and Grembergen [30] and and Martinsons [13] have extended the Balanced Scorecard concepts to information technology (IT) for effective management of information technology. The information technology is perceived to be an enabler of achieving the corporate strategies and goals. In a recent article, Saull provides a conceptual mapping of the traditional BSC to the IT BSC and provides a list of key factors, performance indicators and benchmarks for the four perspectives related to the IT BSC. He suggests the following mapping from the traditional BSC to the IT related BSC:

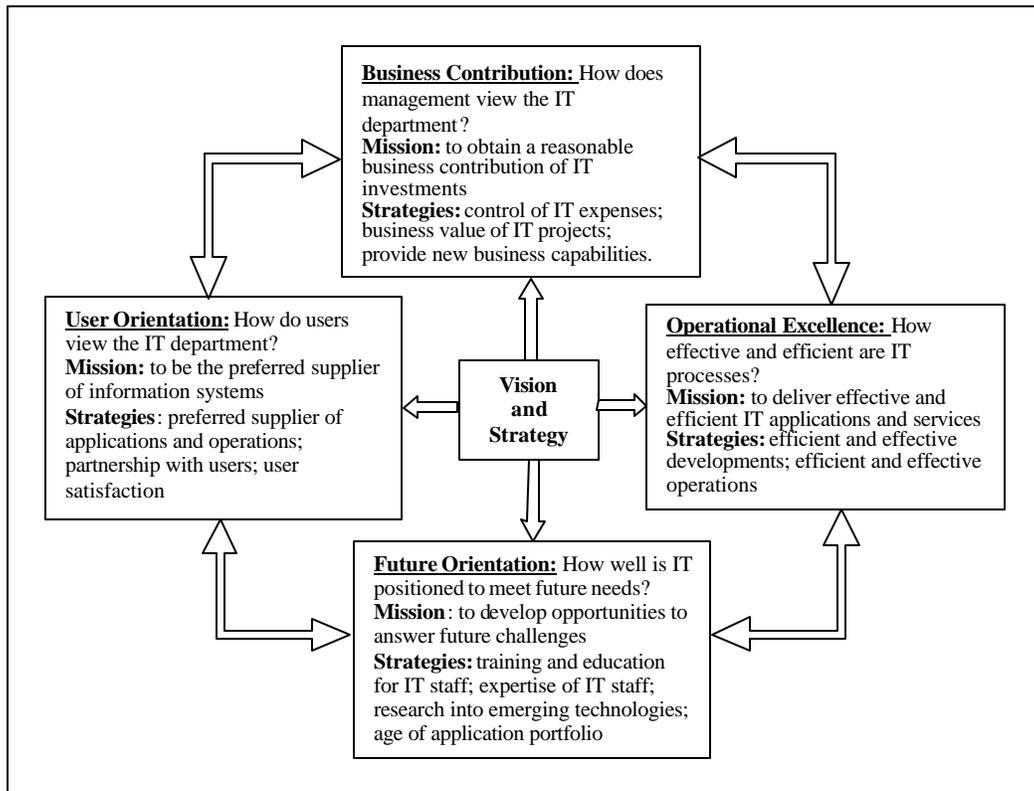
- Financial → Corporate Contribution
- Customer → Customer (User) Orientation
- Internal Business Process → Operational Excellence
- Learning and Growth → Future Orientation

Under the Corporate Contribution perspective, the main issue is whether the IT investment is creating value to the corporation and providing a reasonable return on the investment (ROI). Usually, the ROI for IT investments tends to be very high because of the expected short life of IT investments. On the customer side, there are several users of IT such as the board of directors, executive management committee, business management, audit and regulatory bodies, and the IT organization. Each customer type has its own key questions. For example, the board of directors would be interested in knowing what value IT provides to the corporation, whether it enables or retards growth, and whether it is well managed. From the audit perspective, one would be interested in

knowing whether proper controls are in place to protect the assets of the company and the key technology, and whether the business risks are properly managed.

Grembergen (2000) has provided another framework for the IT Balanced Scorecard very similar to the IT BSC by Saull (2000) discussed earlier. His framework is represented in Figure 2 below:

Figure 2: Standard IT Balanced Scorecard (Grembergen, 2000)



For each perspective, one has to develop a set of goals and objectives, and corresponding metrics to measure the current situation. It is important in IT that a cause-effect relationship be established between the outcome measures and the performance measures. The outcome depends on the performance drivers. Thus, it is essential to have the understanding of the performance drivers and to monitor them on a frequent basis in order to take corrective actions if the performance metrics deviate from the benchmarks.

Grembergen (2000) suggests that the relationship between the traditional Balanced Scorecards and the IT Balanced Scorecards can be explicitly expressed through a cascade of Balanced Scorecards (also, see Appendix III in COBIT, 2000; and van der Zee 1999). Under this concept, the traditional Balanced Scorecards are used to set the corporate goals, and the success is measured through the outcome metrics. These outcome metrics are related to IT enablers, i.e., IT strategies, through cause-effect relationships. The IT strategy scorecards measure the goals as outcomes of the strategies. However, the proper planning and organization (PO) of IT makes it possible to achieve the strategic goals. Thus, the IT PO serves as enabler of the IT strategies. However, the IT PO is achieved by the proper IT acquisition and implementation (IT AI scorecards) and the proper delivery and support of IT (IT DS scorecards). Along with the IT PO, AI and DS Balanced Scorecards, the monitoring (MO) scorecards provide the assurance as to whether controls are in place and IT processes are running effectively and efficiently. COBIT provides a comprehensive list of key success factors (KSF), key goal indicators (KGI), and key performance indicators (KPI) for each category of the IT BSC. KGI focuses on “what” to be achieved, the target, and KPI focuses on “How” to achieve it, the process. Table 1 below lists some KGIs and KPIs for IT processes.

Table 1: Examples of Key Goal Indicators (KGI) and Key Performance Indicators (KPIs) for IT processes (See COBIT 2000 for a detailed list of KGIs and KPIs).

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## **Key Goal Indicators (KGI)**

### Financial Perspective

- Achieved targeted return on investment or business value benefits
- Enhanced Performance Measurement (EPS, NI, etc.)

### Internal Business Process Perspective

- Reduced IT risks
- Productivity improvements
- Integrated supply chains
- Standardized processes

### Customer Perspective

- Reaching new and satisfying existing customers
- Creation of new service delivery channels
- Number of customers and cost per customer served

### Learning and Growth

- Adherence to industry standards
- Availability of bandwidth, computing power and IT delivery mechanisms, uptime and downtime

## **Key Performance Indicators**

### Financial Perspective

- Return on Investment (ROI)
- Economic Value Added measure (EVA)
- Earnings Per Share (EPS)

### Internal Business Process Perspective

- Reduced cycle times
- Increased quality and innovation
- Improved cost-efficiency of the processes
- Amount of errors and rework
- Benchmark comparisons
- Number of non-compliance reporting

### Customer Perspective

- Utilization of communication bandwidth and computing power
- Service availability and response times
- Satisfaction of stakeholders (survey and number of complaints)

### Learning and Growth

- Number of staff trained in new technology and customer service skills
  - Staff productivity
-

#### 4. BALANCED SCORECARD FOR THE E-BUSINESS ENVIRONMENT

As discussed in the introduction, business entities are similar to living organisms. Unless they adapt to the environment they are bound to become extinct. What does this mean to a business entity? This means that the business entity needs to be monitoring all the time the changes happening in its environment. This becomes more relevant in the current environment of the Internet, which is the topic of this section.

Sriram et al [22] have made an initial attempt to deal with e-commerce issues in the balanced scorecard framework. However, their approach is not comprehensive; they deal with only B2C (Business to consumer) environment and also they do not consider the risks involved in conducting the business in the Internet environment. We develop a conceptual framework similar to the one developed in COBIT [3] We expect that our framework would be a generic one that would be applicable to all types of E-Business (B2B, B2C, B2G, G2B, G2G, and etc.).

Our E-Business balanced scorecard approach stems from a broad definition of E-Business; E-Business is any process that a business organization conducts over a computer-mediated network. E-commerce on the other hand is defined as any transaction completed over a computer mediated network that involves the transfer of ownership or rights to use goods or services [24]. The investigation of E-Business processes can be viewed as a superset of E-commerce studies and will be used in subsequent sections. Our approach takes a holistic view of the E-Business projection of the organization. This approach looks at the adoption of Internet technology to conduct business in a digital environment. We do not limit ourselves solely to interaction through customers' oriented

web sites, but we look at the use of Internet technology as the enabler for accomplishing an integrated value chain. Papazoglou [14] extended Porter [15] view of the traditional value chain to an intra-organizational view. He presented a model in which each organization focuses on its core competency, and multiple organizations will contribute directly to each other's value chain. The author identified four key driving forces that would enable successful development and deployment of integrated value system applications: (1) new business models (2) cross enterprise interoperability (3) adoptable and flexible business processes (4) organization infrastructure. In the electronic environment, it is essential that both intra-organization and inter-organizational business processes' communication is digital. Another example for the use of information technology is the Merge-in-Transit (MiT) strategy, in this model shipments are collected from multiple origin points and are consolidated in transit to a single shipment to the customer. O'Leary [4] showed that the reengineered process of MiT requires timely digitized data interchange and results in the following benefits: Reduced transportation costs, improved customer service, lower obsolescence, and lower capital requirements. MiT and the integrated value chain are only two examples in which a digitized environment is essential. In subsequent sections we will introduce our electronic commerce balanced scorecard approach and a generic model for measuring the extent to which companies are digitized.

In Figure 4, we describe the four dimensions of E-Business Balanced Scorecard: E-Business Financial Contribution, User Orientation, Operational Excellence, and Future Orientation. Since a larger part of economic exchange, business processes and information processes is done digitally, it is important to evaluate the efficiency and

effectiveness of this projection. Again, E-Business includes any digital process that the organization conducts.

### **E-Business Financial Contribution**

The main purpose of E-Business Financials is to meet the company's financial objectives through E-Business.

- **Mission:** to achieve corporate objectives of financial performance through our E-Business operations.
  
- **Objectives:**
  - E-revenue growth
    - Meet e-sale targets
      - Compare expectations to reported e-sales
    - Increase E-Transactions
      - E-transaction/transaction ratio
      - # Of transactions
    - Introduce new E-products and services
      - # Of E-Products and services
  - E-cost management
    - Reduce cost per e-sale
      - $E\_cost\_per\_sale\_t/E\_cost\_per\_sale\_t-1$
    - Reduce cost per e-order
      - $E\_cost\_per\_order\_t/E\_cost\_per\_order\_t-1$
    - Reduce Cost per Customer enquiry

- E-Risk Management

***User Orientation –Internal users, and external users including value chain partners, customers and trading partners:***

The User Orientation deals with the mission to be the preferred provider of products and services through E-Business. In the information technology environment users are not necessarily external to the company such as customers, regulatory bodies and auditors, but also internal users such as the Board of Directors, CEOs, Managers at all levels, and the IT organization. Therefore the satisfaction of existing customers may be more important goal to achieve than building up market share or acquiring new customers [13].

- **Mission:** Be the preferred provider E-Business products and services
- **Objectives**
  - Preferred provider of digital data
    - Preferred provider of digital products
      - Number of E-products users
    - Preferred provider of digital information
      - Number of digital information enquiries
  - Attract E-customers
    - Increase our e-customer base
      - E-customer #
    - Gain market share in the e- marketplace
    - Maintain existing customers
      - E-customer retention rate

- Improve E-customer satisfaction
  - Improved Customer service
    - Time lag between service request and fulfillment.
- Preferred value-chain partner
  - Strategic agreements
    - # Of e-trading partners

***Operations- internal and external processes perspective.***

The Operational Excellence dimension deals with the mission to provide efficient and effective E-Business processes including manufacturing of products.

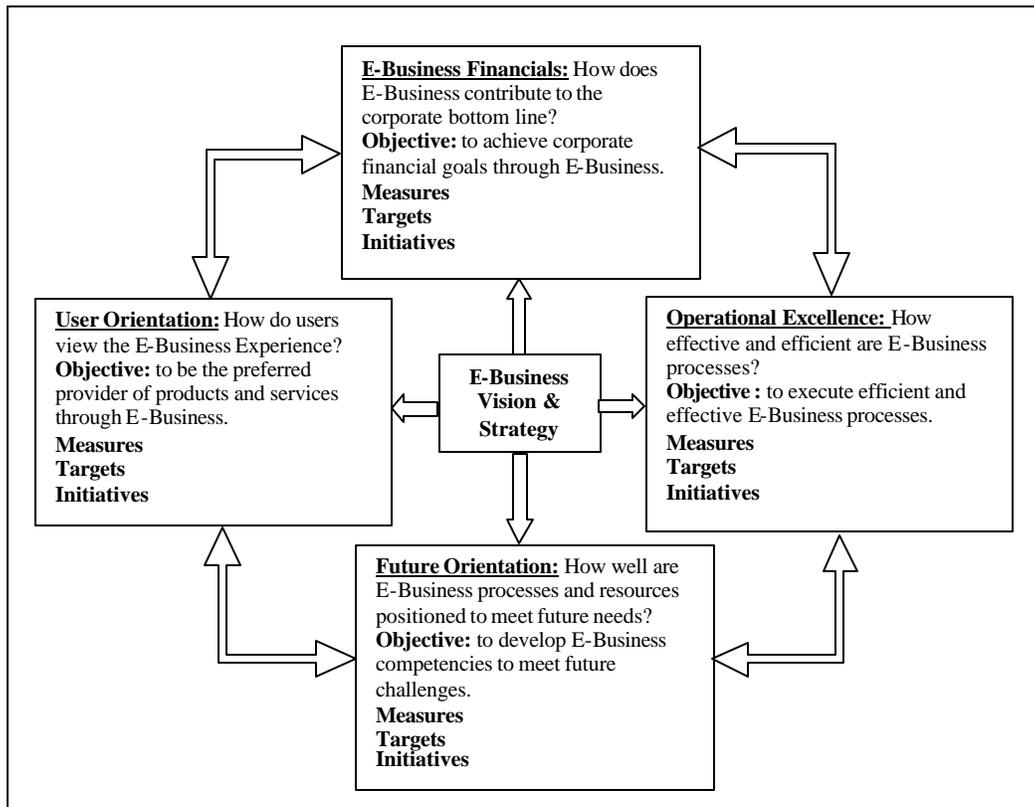
- **Mission:** Design and execute E-Business processes in the most efficient and effective manner.
- **Objectives:**
  - Digitize our business processes
    - Provide timely reliable information
      - Information degradation measure
      - Information latency measure
  - Reduce E-fraud
    - \$ Amount of E-fraud to projected e-fraud ratio
    - # Of risks addressed
  - Provide Continuous E-services
    - E-financial evaluation
      - Intervals of financial statements

***Future Orientation- flexible business processes, frictionless internal and external processing and communications.***

The fourth dimension deals with Future Orientation in which the mission is to develop E-Business competencies to meet future challenges by training and educating staff in E-Business, by researching emerging technologies, and questioning the age of application E-Business technologies, etc.

- **Mission:** Continuous evaluation of models and technologies to achieve frictionless business activities and commerce in the future.
  
- **Objectives:**
  - Seek new technological directions and standards
    - Alternative Solutions
      - # Of alternative solutions
  - Increase IT proficiency through continuous learning
    - Use e-learning platform
    - Encourage staff to participate in e-learning
      - % Of employees that took an e-learning class

Figure 4: Internet/E-Business Balanced Scorecard (IEB BSC)



## 5. DIGITIZATION METRICS

In this section we introduce a new innovative approach to measuring two of the most important E-Business balanced scorecard indicators in the Operation Excellence category. One of our stated objectives is to deliver and process information in the most efficient and effective manner. We believe that processing and delivering information in a digital way will result in reduced risk and cost. Non-digitized business processes will result in information degradation and latency, which in turn will be reflected in the bottom line financial performance.

The flow of information within and between organizations can be defined as "digitized" as long as there are no discontinuities in the real time flow of data, including the initial capture of information, information processing, information storage, and information communication. The digitization of companies can be evaluated based on the level of degradation and disruption in the initial capture of information, communication and information flow, and the processing of that information. Disruptive activities will occur by either capturing a narrowed limited scope of the data, a manual intervention, or the loss of timeliness (not real time communication). Disruptive flows of information can result in higher processing cost, time delay, and substantial increase in the potential risk to the organization. The flow of information within organizations will be modeled using a revised data flow diagram approach.

A data flow diagram graphically describes the flow of data within a system. It is used to document existing systems and to plan and design new ones. A DFD is composed of four basic elements: data sources and destinations (external processes), data flows, transformation processes (data transformer), and data stores. The DFD is a directed graph consisting of the four primitives mentioned above. In our model we look at a sequential system where we assume that data flows between two data transformers are direct in the sense that data transformers that use the data flow, as input cannot be called before the data transformer that uses the data flow as output.

- Data source- represents external entities (another department, business, person...) that are not part of the system but belong to the outside world. They are used to show where the input to the system is coming from and where the output of the system is going to.

- ❑ Data flows- data flows are represented as arrows connecting one data transformer to another. They represent a flow of data between the data transformers they connect. The flow of data in this case is unidirectional in the direction of the arrow.
- ❑ Data transformers- data transformers denote a transformation from an arbitrary number of input values to an arbitrary number of output values.
- ❑ Data stores- data stores provide a representation for storage of data.

Limitations of the traditional DFDs include (1) No indication of what event triggers a process, meaning that it does not indicate why a process begins. (2) A DFD represents only information flow processes and may exclude some business processes that do not require information flow. (3) In a DFD there is no way to represent the logic of the flow such as conditional events. However, the main advantage is that the flow of information can be diagrammed in various levels of detail. Following a top down approach, the diagram can be viewed from a general view to a specific view. Using the extended DFD model, we intend to drill down only as much as needed to categorize the data flow representation, processes and data storage.

The four basic symbols of the data flow diagram will be supplemented by additional representation of the digitization level. There are three main categories, which may be associated with the cost of un-digitized activities.

(1) The first category applies to the scope of the data. We assume that digital capturing of data will result in a broader scope of the captured data.

(2) The second category to examine is the probability of introducing corrupted data. Corrupted information is associated with data that is not captured, communicated, processed, and stored digitally (digitized information is assumed to be error free). We intend to estimate the probability for errors in each process by asking users to estimate the initial probabilities for errors in an un-digitized activity. This probability will be applied at the lowest DFD level in which each data transformer performs a simple operation that does not need to be further decomposed, probabilities will then be propagated through the system (following the uni-directional graph).

(3) The third component associated with unnecessary monetary cost is the loss due to delayed propagation, process, and extraction of un-digitized information. The loss of the timelines of information may result in production delays, customer dissatisfaction, idle machines and other additional costs. Again we assume that digitized data will result in a minimal cost through the use of continuous communication, online processing, and digital data stores. However, we also consider cases in which the use of digitized data is not optimized due to non-continuous communication and batch processing. The evaluation of the information delay will be calculated by comparing the calculated time lag to the alternative benchmark.

DFD research was primarily used for the purposes of software design and maintenance. Ward [18] introduced an extension to the DFD entitled a transformation schema. He introduced the ability to represent control and timing aspects of the system. He extended the model as followed:

- Transformation has two representations: data transformers and control transformation. Control Information controls the behavior of the data transformations by activating and deactivating them.
- Flows are divided into two subcategories: data flows and event flows. Data flows represent discrete or continuous data and event flows represent a signal, activation, or deactivation.
- Storage also has two representations, namely, data stores, and buffer. The distinction between the two is that a buffer represents a temporary fast storage and data stores represent a slow but permanent type of storage.

While the basic DFD is too simplistic for the evaluation of digitization of companies, we have decided to adopt the existing model and apply some necessary modifications.

- Data sources and data destinations will stay unchanged.
- The data flow representation is extended by introducing a representation for the digital flow of information vs. the physical flow of information, and a distinction between continuous and non-continuous connections.
- Processes will also be modified and will include a distinction between a manual vs. digital processes, and between online vs. batch processes.
- Data stores are also extended to allow for the distinction between digital and non-digital data stores.

Data Source (data capture process)	
Digitized	
Not-Digitized	

Data Flow	
Real Time Digital Flow	
Manual Information Flow	
Delayed (Not Continuous) Digital Flow	

Process (transformation)	
Digital Batch Process	
Manual Process	
Real Time Digital Process	

Data Store	
Digital Data Store	
Physical Data Store	

## DATA FLOW DIAGRAM ALGEBRA

### *Time Lag (information latency)*

As discussed, information latency resulting from information processing, and propagation may be very costly to an organization. We developed a method to measure the information latency in the following way: every flow, process, and storage of information will be given a latency value, which represents the time it takes to accomplish the task. These values are additive, and therefore will be added to one another to determine the total information latency for each outflow of a system represented in the level 0 diagram.

1. Latency values will be given to information flows at the level 0 DFD diagram (this is the level in which a system represented in the context diagram is represented by its processes). The latency values of information inflows and outflows are not expected to differ, and therefore will be used in the final aggregation of the information latency.
2. Each process in the context diagram will be drilled down to the extent to which a unified level of latency can be identified with the process. In other words, if a process that was drilled down to a certain level has ambiguity regarding the information latency of the data outflow we will keep drilling until this ambiguity is resolved. Unique information latency is identified when no process in the system has a different latency value contributing to the outflow of the data. Even if one unique latency value is identified in the process we may still need to drill down to a child level diagram to find out the value of that latency.

3. Once unique information latency is identified with each process, latency values are aggregated to the level 0 diagram. Since we are interested in identifying the information latency for each outflow of the level 0 diagram, different outflow latency values will be propagated to the aggregated diagram. The minimum value of each process' latency will be aggregated to the parent process where differences between minimum values of outflow latencies will be added to the outflows' latencies given at stage 1.
4. The values at the level 0 diagram will be added along the information flow and a latency value will be calculated for each outflow.

### ***Information Degradation***

The challenge of calculating the information degradation is great. As mentioned above information degradation can occur at the initial capturing point, during the flow of the data, and during the processing stage of the data. It is important to note that information degradation may be of three broad types: no information degradation, partial information degradation (which may or may not have associated costs), and fatal information degradation, in which information is degraded in one of the nodes, information was degraded to the extent that it becomes completely erroneous and a definite unexpected cost is incurred. It is apparent that our scheme cannot measure any information degradation outside its scope, e.g., corrupted information supplied by a customer whose system is not modeled by us. An example for partial information degradation is that an order that was placed by a customer was only partially delivered. In

this illustration, information was partially degraded, resulting in additional processing, machine-setup and customer dissatisfaction costs.

### ***DFD Motivating Example***

Figure 1 displays an illustration of the context diagram of the FilmMagic Video Rental stores presented by Kendall [12]. The context DFD represents the entire view of the video rental system including four external entities to the system: Video purchase system, customer, management, and accounting. Figure 2 presents the level 0 DFD where main processes are illustrated. The latency values will be aggregated to the level 0 diagram from child processes. At this stage we assign latency values to the information inflows and information outflows. Information inflows in this illustration are generated by the customer and the video purchase system, while information outflows are directed to the customer, management and the accounting entities.

Since process 1 in figure 2 has 4 information outflows, we cannot identify a unique latency value that will apply to all. Therefore we drill down into process 1 and get the level one diagram illustrated in figure 3. Process one results in the following outflows: cash transaction, rental receipt, and rental information, and an update to the customer record.

- The "Cash Transaction" outflow latency can be uniquely identified by adding: "Find Customer Record" process latency (30 sec), "Customer Record" flow latency (2 sec), "Rental Information" flow latency (5 seconds) to the "Get Consumer Payment" (10 seconds) process. (total latency of 47 seconds)

- The "Rental Receipt" outflow latency is the aggregation of: the "Cash Transaction" outflow (47 sec) the "Update Customer Record" process (7 sec) , the " Rental Information" flow (4 sec), and the "Produce Customer Receipt" process (20 sec), resulting in the total of 78 seconds.
  
- The "Rental Information" outflow latency is the aggregation of the "Cash Transaction" outflow , the "Update Customer Record" process (7 sec), and the "Rental Information" flow (4 sec) latency, resulting in a total of 58 sec.

The next stage involves the aggregation of the above latency results. The latency that will be applied to process 1 at the level 0 DFD is the  $\text{MIN}(47,58,78)$ . The outflows of process 1 will be the aggregation of original outflow delays (shown in figure 2), and the difference between the minimum values as shown in figure 4.

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Figure 1

