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Defining Meaningful Measures of IT Productivity with the Balanced Scorecard

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ABSTRACT

The accurate and timely measurement of an organisation's information technology (IT) productivity is a critical tool to control the strategic and operational aspects of any firm. This paper describes the validation and integration of productivity measures through the application of the Balanced Scorecard. Developing measures of IT productivity that are not skewed by methodological or data collection anomalies, shifting usage of communication and workflow channels, negated utility of knowledge management, quality versus quantity trade-offs, and differences in individual skill levels and performance is difficult yet essential. The Balanced Scorecard as a strategic measurement framework is applied to assist in determining the appropriate matching of what we intend to measure and to what we assign numerical values.

INTRODUCTION

Measuring productivity has been a central preoccupation of industry and government. Historically, a production census was conducted on a global scale and determined the economic standing of nations based on their ability to produce goods and services with added value beyond the sum of the cost of the raw materials. The twentieth century has seen a meteoric rise in the investment of computers and telecommunications technologies with the intent of dramatically improving productivity and retaining competitive advantage. The technology sector fueled this investment with promises of productivity gains that would result from either requiring fewer workers or by allowing the replacement of highly specialized labor with semi-skilled labor. The resulting productivity as measured for industries or economic sectors did not live up to the promised benefits. This has surrounded IT investment by controversy. The standard measures used for economic utility and productivity were unable to capture the shifting paradigm of the information economy.

The fundamental complexity of measuring productivity in information sector organizations is typically underestimated. The pitfalls that frequently skew measures of IT productivity include methodological or data collection anomalies, shifting usage of communication and workflow channels, negated utility of knowledge management, quality versus quantity trade-offs, and differences in individual skill levels and performance. We address each one of these issues, as it would apply to a single firm or from the enterprise perspective. Government data on industry sectors is not discussed, as it is not under the power of the firm to change or control this view. We introduce the common pitfalls of measurement of IT productivity as described by Attewell and then present how to apply the Balanced Scorecard to overcome them.

Methodological or Data Collection Anomalies

Productivity measurement may be impeded by methodological or data collection anomalies that arise from various sources. Methodological or data collection anomalies refer to the corruption of the integrity of the data. A common productivity measurement pitfall occurs when firms scrutinise personnel productivity. When people feel they are being monitored and measured they naturally become suspicious and may supply poor-quality data, thus subverting the accuracy of measurements. A more subtle issue is that productivity must be measured in context. This is due to the interdependency of entities productivity with how they conduct their work and the type of work product being produced. We are unable to measure the productivity of labour (personnel) without engaging indirect measurement of the specific work process (designing, coding, testing, and reviewing) and the work product produced (intermediate or final products). At the enterprise level productivity is measured as an aggregate of personnel effort, resource utilisation, and the final work products. This aggregation often conflates the issues by combining offsetting increases and decreases in productivity across sub-processes of the overall workflow.

Shifting Communication and Workflow Channels

Productivity measurement may be hindered by a resultant shift in usage of communication and workflow channels when technology is introduced into the work process. A textbook example of this phenomenon occurred with the introduction of email. Managers stopped using Dictaphones and composed their own memos on-line. A verbal communication is 5 times faster to produce than a written communication. Recent studies are revealing that managers are now spending an alarming percentage of their time answering email. Much of the work in technology focused organisations require the application of complex modes of cognitive information processing. New technologies that are intended to increase productivity often shift how information is transmitted, the accuracy or clarity of the transmission and the difficulty in making a meaningful interpretation from the transmission. Global software development and distributed product manufacturing have resulted in an increasing dependence on Internet technologies to distribute and manage information and work products. These changes can result in not only a change in the activities required to perform work, but also shift responsibilities and accountability from one type of personnel to another. Another aspect of this shift is a change in the indexicality of communications, particularly in global settings of production. Indexicality is a term from sociolinguists, which refers to the degree of compression that can be applied to a communication because of a shared knowledge base among participants. This aspect as applied to global software development makes the need for formal specifications and complete documentation quite apparent, it can be assumed that no shared knowledge will exist and all pertinent information must be documented.

Quality Versus Quantity Trade-Off

Productivity measurement should measure not only how much product is produced but also the quality of the product produced. The quality versus quantity trade-off can exhibit itself in many forms and undermine not only productivity measurement but impinge on the organisation's productivity. This is a particu-

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larly thorny problem for IT as quality as defined for software and systems is highly subjective. In addition, quality is truly multidimensional, as the system may possess properties that exhibit as multiple qualities such as, safety, reliability, usability, etc. To further complicate the issue of quality organisations focus on the number of faults or defects found in the product and measure this as number of defects per lines of code written. This measure on surface captures the essence of quality versus quantity for software. The source of the difficulty is that the number of defects or faults in the software has no demonstrated relationship with the system properties that result for the product. Therefore, enormous amounts of effort may be expended removing defects from software with no noticeable improvement in the final product. This is an open area of research in the metrics community and strides are being made to identify relationships between types of defects, when and how they are revealed, and the final product quality.

Dynamism of the Information Revolution

Productivity measurement has become complicated by inherent dynamism of the information revolution. The requisite skills and retention of employees that possess not only current skills but also an ability to learn the next set of required skills is a chronic problem faced in IT and telecom sectors. Skills obsolescence is an ongoing problem requiring that labour be retrained in an ongoing and aggressive fashion. This is particularly true when new technology is introduced or standardisation of technologies is required. The impact on productivity is to diminish individual productivity while new skills are acquired through training. The greater the change the greater the potential immediate negative impact to productivity. Major change is typically sought as a means to improve productivity thus providing a double-edged sword to early adopters; the initial result will be a decrease in productivity followed by incremental increases over time. A more difficult aspect of measuring productivity arises from the shift that results when a measurement focuses on individual or team effort. Technologies are introduced that are thought of as saving hours of effort. This is a common occurrence because line managers focus on the staff hours under their direct supervision. Technologies that reduce staff hours are viewed as improving productivity. Unfortunately, at the enterprise level the organisation measures productivity as the utilisation of capital as well as labour. Technologies thought to improve productivity often improve individual productivity while shifting the cost of production to shared resources such as centralised data repositories or on-line processing through an intranet. These are categorised by economists as principal/agent issues. The disconnect occurs through the dissemination of the applied labour effort using a technology that distributes costs of using that technology disjoint from the effort. The resulting overall productivity decreases due to negative impacts on resource utilisation are not visible to the individual. In fact, the individual may see a localised rise in productivity that is negated by an overall decrease in productivity. Due to the nature of many information technologies the true measure of productivity may not be visible except at the enterprise level.

This section described the pitfalls that frequently skew measures of IT productivity:

- methodological or data collection anomalies,
- shifting usage of communication and workflow channels,
- negated utility of knowledge management,
- quality versus quantity trade-offs,
- differences in individual skill levels and performance.

Although, it would seem that given the complexity to measuring productivity that organisations would be unable to overcome the seemingly insurmountable barriers described here. However, finding conceptualisations that manage the complexity by decomposing it to tractable measures of productivity provide the keys to success. To effectively measure productivity, we need to begin by defining what we are measuring. Then we can manage the complexity of how to measure productivity with greater clarity.

Definition of Productivity

Defining productivity requires we identify the productive entity or subject of interest, do we want to measure productivity of labour, resources, or processes? Depending on the point of focus quite different measures would be required. However, with careful planning a set of measures may be used to provide distinct views of productivity. This is made clear through examples. First, it is instructive to look at the typical equation for productivity. Equation (1) might be considered the most rudimentary of templates for productivity measures.

$$\text{Productivity(P)} = \text{Output/ Input} \qquad \text{Equation (1)}$$

To evaluate the problem it is good to provide more concrete examples that are of general interest. We draw again from the software development community and initiate our discussion with the standard equation for software productivity.

$$\text{Productivity(P)} = \text{100 SLOC/ Person Day} \qquad \text{Equation (2)}$$

This would seem reasonable as we can count how many hours are expended in a day to write a software program and how many lines of source code were written in that period of time. However, a simple example demonstrates the shortcoming of this simplistic and naïve approach to measuring productivity. If a programmer called (P1) produces the first software system at 100 SLOC/day and then produces a second system at 200 SLOC/day, equation one would tell us that the programmer (P1) had doubled his productivity. But is this really the case? Does the second system provide greater functionality and therefore increased amounts of value for the same amount of effort?

Additional information is required. What percentage of the lines of code produced is actually providing the required functionality? If only 50 lines of code are required, total productivity has actually decreased, as additional resources to manage and compile 200 lines of code are required. This illustrates a shift of cost due to a diminished utilisation of capital resources without a visible shift in effort. Let's look at another example. A programmer (P2) comes across the second program and notices that only 50 SLOC are actually used in the execution of the program, if this programmer removes 150 SLOC, but adds 50 more lines of code that doubles the functionality and value of the software, is he (P2) less productive? Programmer (P2) has a net decline of 100 SLOC/ day, yet improved efficiencies of resource utilisation (compilers and repositories) while doubling the value of his output.

Table 1. Programmer productivity profiling				
Productive Entity		Process	Product	Resource(s) Required
Programmer	P(1)	Coding	Set of Programs	Editor, Compiler
Programmer	P(2)	Designing/ Code Generating	Set of Programs	CASE tool, Code Generator
Programmer	P(3)	Integrating	Set of Programs	COTS, Editor, Code Generator
Programmer	P(4)	Product Line Reuse	Set of Programs	Reuse Repository, Specification

Measuring productivity in contexts that are shifting processes, personnel and resources through standardisation, automation, and integration of technologies face the greatest challenges in understanding and controlling their productivity. How can we identify these complex relationships, measure their interactions for positive and negative impacts, and prevents impediments to improving productivity? We begin by viewing productivity as a multi-faceted set of interactions, not as a singular measure based solely on the quantity of product produced. We tabularize a set of activities that are typically measured for productivity using the same measurement focus of SLOC/effort. These activities are drawn from the domain of software development organisations see Table 1.

It is of value here to take time to discuss our four hypothetical programmers P(1), P(2), P(3), P(4). If all four programmers deliver a set of programs with 1000 SLOC expending the same number of days of effort to do so, are they equally productive? What if the defect densities for their code respectively are; 28/1000, .007/1000, 567/1000, 22/1000. Is programmer P(3) less productive? Is the reported defect density the result of a defect laden COTS product? Has programmer P(3) provided an essential feature to the system despite a very difficult integration? SLOC/effort and defect density fail to capture the relationship of how much value was produced through this combination of resources that were used.

Productivity must implicitly capture the value add of the output (product), based on the inputs (labour as well as capital resources required) to build that product. To measure productivity we must construct a value chain that maps the process used, resources required, and the productive entity engaged in the process, to the final product as measured by those characteristics that provide added value, (i.e., features, reliability, availability, safety, performance). This definition inherently requires a set of equations that capture productivity. It is the specification of this set of equations that may be subsequently used as a template and parameterised for a given productive entity under specific productive processes. Productivity is defined as a value chain that maps the process used, resources required, and the productive entity engaged in the process, to the final product (or service) as measured by those characteristics that provide added value. The multiple attributes that compose a measure of productivity result in an inherent complexity. This complexity when faced with the common pitfalls for IT productivity measures require that the complexity of the measure as well as the barriers to measurement be addressed concurrently.

Approaches to Measuring Productivity

It is apparent that IT productivity is a complex measure. We use Thorp's critical dimensions of IT complexity; linkage, reach, people and time, to categorise the aspects of IT productivity. The following sections provide a discussion and concrete examples of Thorp's IT complexity categories, see Figure 1. We then integrate the four pitfalls of measurement with the four complexity factors and identify their respective roles in documenting value and measuring productivity effectively.

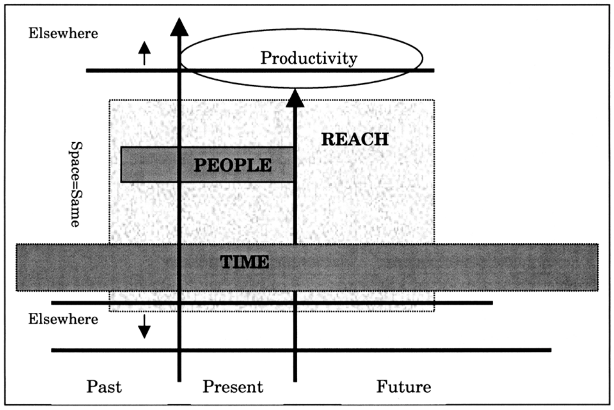
Linkage refers to three key elements. The mapping and alignment of a {productive entity, resource, process} with the business strategy. The demonstration of the contribution to benefits or value by the productive entity while using resources to engage in the productive process. The integration of the measured productivity of {productive entity, resource, process} with organisational initiatives or programs.

Reach or scope refers to two key elements. The evaluation of the scope or areas of the organisation affected by {productive entity, resource, process}. The extent or size of the impact based on {productive entity, resource, process} interactions.

People refers to four key elements that address disparate aspects of accountability, organisational culture and behavioural attitudes, technology adaptation requirements, and skill obsolescence and training. Accountability requires that the people that are involved in the productive process {productive entity, resource, process} have defined roles and responsibilities. Organisational culture and behavioural attitudes reflect how people are motivated in an organisation to improve productivity. People as productive entities, must improve by reducing or optimising resource utilisation. An improved process might achieve this or advanced technologies that substitute manual labour for automated activities, or through standardisation across an enterprise, the choice is often a factor of how people are rewarded. Technology adaptation refers to the technology life cycle and the degree of effort to improve and the readiness to adopt new technologies. This typically refers to the people as productive entities using a new resource or conducting work using a new process or both. Skill obsolescence and training refer to providing for the necessary skill set based on the unique combinations of {productive entity, resource, process}. Learning to avoid hand coding defects is not of value if all code is to be generated from detailed design specifications.

Time refers to two key elements that are difficult in practice but essential to meaningful measures. The time horizon required managing all the above dimensions and realising the desired benefit. This aspect focuses on setting achievable and realistic expectations. This inherently includes time lags between changes in {productive entity, resource, process} and the realisation of benefits. The second key element is critical. The changes in dimensionality linkages, reach, people, and time over the expected time horizon. This second aspect assumes a non-steady state of an organisation. An organisation undergoing change must re-evaluate measures to check and verify that assumptions made about the linkages, reach, people and time relative to productive entities the resources they use and the process applied to produce, are still valid measures of productivity.

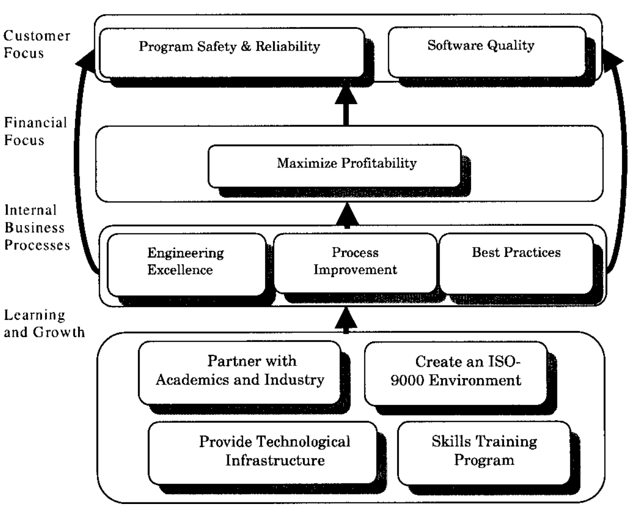
Figure 1. Productivity complexity factors: time, reach, people and the relations that create linkages among the factors.



Balanced Scorecard

This section demonstrates how Thorp's complexity categories can be ameliorated through the use of the BSC. By doing so we discover how to approach productivity measurement while avoiding common pitfalls. The BSC is not the organizational strategy but rather a measurement paradigm to provide operational and tactical feedback. The organizational strategic vision and goals are the foundation upon which the measurement framework is constructed. The BSC is segmented into a four-tier hierarchy for measurement: financial, customer, internal business processes and learning and growth segments. There are objectives associated with each tier of the hierarchy.

Figure 2. Four tier hierarchy with objective's focus



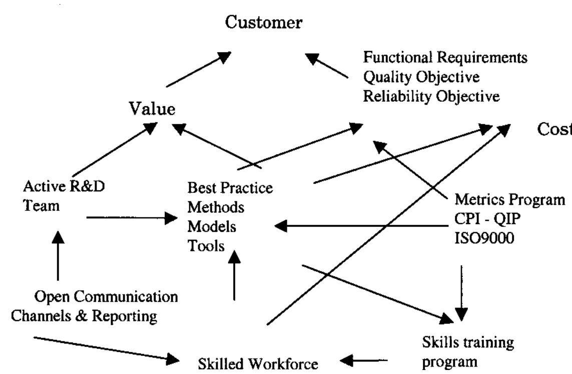
There are two categories of measures used in the BSC the leading indicators or performance drivers and the lagging indicators or outcome measures. The performance drivers enable the organization to achieve short-term operational improvements while the outcome measures provide objective evidence of whether *strategic objectives* are achieved. The two measures must be used in conjunction with one another to *link measurement throughout the organization* thus giving visibility into the organizations progress in achieving strategic goals through information resource management and process improvement initiatives.

The three principles of building a balanced scorecard that is linked through a measurement framework to the organizational strategy include:

(1) Defining the cause and effect relationships,
(2) Defining the outcomes and performance drivers,
(3) Linking the scorecard to the financial outcome measures

The initial steps of cause effect graphing for the BSC engage in the construction of a set of hypotheses concerning relationships among objectives for all four perspectives of the balanced scorecard. These relationships are diagrammed using influence diagrams. The measurement system makes these relationships explicit therefore, they can be used to assess and evaluate the validity of the BSC hypotheses. Further the hypothesis are mapped to a set of objectives concerning the necessary and sufficient factors to creating value for the organization in terms of the strategic vision and goals.

Figure 3. Influence diagram of organizational linkages to identify required measures.



Financial

The core financial measures for the Balanced Scorecard include return-on-investment, economic value-added, profitability, revenue growth/mix and cost reduction productivity. Financial performance is only one indicator of success. The financial objectives must be linked with the overall scorecard through cause and effect mappings documented by objective measurements.

Customer Measures

The core measures for the customer include market share, customer retention, customer acquisition, and customer satisfaction and customer profitability. These five core measures are used in conjunction with one another to evaluate and profile the status of the customer base of an organization. Many of the core customer measures are not applied in the same context.

Process

The internal business process measures have focused on key factors of process definition and improvement paradigms. Process improvement frameworks have included Total Quality Management TQM, the Software Engineering Institute's Capability Maturity Model CMM, and more recently ISO-9000 Certification. All of these efforts share a customer focus of measurable business process improvements that result in cost reductions and cycle time improvements. This foundation is used by organizations as a starting point for developing the additional framework of strategic measures from multiple perspectives. A key resource in deploying effective business processes is information and information technology.

Infrastructure (Learning and Growth)

The learning and growth objectives are the drivers for achieving desired results in the other three areas of the scorecard. This is the BSC category that supports the creation of the necessary infrastructure to achieve the strategic goals of the organization. Three key factors in this perspective of the strategy are identified as employee capabilities, information systems capabilities and employee motivation, empowerment, and alignment.

Developing Measures of Productivity

The act of constructing the BSC provides a foundation for the identification and exploration of the linkages as described by Thorp. Specifically, the mapping and alignment with the business strategy and the demonstration of the contribution to benefits or value by the productive entity using resources to engage in the productive process.

The BSC requires that linkages be identified and then tested through a series of hypothesis testing activities. This prevents measuring the productivity of a resource or class of personnel that are *not relevant* to the specific context or goals of the organisation. Classes of personnel must be present to meet organisational needs. Employee capabilities require that the strategic skill base necessary to meet organizational objectives be well documented and understood. Employee's personal goals are aligned with organizational goals to allocate retraining, skill enhancement, job enrichment, and promotion opportunities. Information systems capabilities provide the necessary infrastructure to allow employees to see their personal linkages to organizational goals.

The identification of infrastructure in the learning and growth segment of the BSC defines resources that are shared across organisational units. These highlight reach and scope of interactions that signal special handling for inputs relative to outputs in productivity measures. The process segment of the scorecard identifies processes and sub-processes that are interdependent. The evaluation of the scope or areas of the organisation affected by the changing of the allocation and utilisation of resources or the standardisation or optimisation of processes. The extent or size of the impact based on resource or process interactions is highly dependent on availability and accuracy of information. Information is a key resource to create an employee base that can make informed decisions concerning operational efficiencies. The CMM provides infrastructure to support key processes in the creation or management for the software engineering process improvement through the SEPG, software metrics groups and software quality assurance groups. These structures focus support efforts on key functional areas for continuous process improvement. The measures used to enumerate employee skills and numbers include staffing levels, strategic job coverage, strategic information availability and dependability. The core measures for learning and growth focus on the employee. There are three measures employee satisfaction, employee retention, and employee productivity. The relationships among these measures are hierarchical with employee retention and productivity dependent on degree of employee satisfaction. The enablers to employee satisfaction include employee skill base of core competencies, technological infrastructure, and the general work climate.

The process tier of the BSC defines the measures for process improvement and control. By having well defined processes it is possible to predict with accuracy the time to achieve productivity gains and lag between when benefits would be realisable. This process visibility and control is not readily achieved in IT making predictions of the time horizon required to manage all the above dimensions and realise the desired benefit difficult. Thus setting achievable and realistic expectations is not straightforward but must be watched and re-evaluated. The BSC requires that measurement be linked from operational activities to high level strategic goals.

Finally the measures of the process and learning and growth tiers are linked to customer measures of satisfaction, retention and profitability. The customer measures readily translate to financial measures. This approach has multiple benefits but the most significant arises from using the Balanced Scorecard not as a static measurement tool like a yardstick, but as a dynamic monitoring device that alerts managers and employees when they are engaging in counter productive behaviours.

SUMMARY AND LESSONS LEARNED

The Balanced Scorecard (BSC) strategic measurement framework provides the necessary structure to evaluate quantitative and qualitative information with respect to the organization's strategic vision and goals. There are two categories of measures used in the BSC the leading indicators or performance drivers and the lagging indicators or outcome measures. The performance drivers or leading indicators enable the organization to quantitatively track whether or not the organization is achieving short-term operational improvements. The outcome measures or lagging indicators provide objective evidence of whether *strategic objectives* are achieved and to what degree. The two measures must be used in conjunction with one another to link measurement throughout the organization thus giving visibility into the organizations progress in achieving strategic goals through multiple organizational initiatives. The development of a core set of metrics for implementing the Balanced Scorecard is the most difficult aspect of the approach. Developing metrics that create the necessary linkages of the operational directives with the strategic mission prove to be fundamentally difficult as it is typical to view organizational performance in terms of outcomes or results rather than focus on metrics that address performance drivers that provide feedback concerning day-to-day organizational progress. The Balanced Scorecard provides the necessary framework for decomposing the IT complexity and addressing measurement barriers. Table 2 reading from left to right aligns the IT complexity with the corresponding segment of the BSC. This separation of concerns allows common barriers to be more readily seen and addressed.

Table 2. Summary: IT Complexity, BSC, Common Pitfalls

Table 2. Summary: IT Complexity, BSC, Common Pitfalls

IT Complexity Factors	Balanced Scorecard	Overcoming Measurement Pitfalls
Linkage ✓ tie to strategy ✓ value chain ✓ tie to organisational objectives	Balanced Scorecard is based on a 4-tier hierarchy that is tied to specific objectives. Value chain is created linking desired ***Customer*** base to ***Financial*** objectives.	The BSC is constructed by hypothesis testing of relationships (linkages) among the 4 tiers. A rigorous scientific approach minimises data anomalies.
Reach ✓ organisational units affected ✓ degree of impact	***Process*** objectives tie how work gets done to target measures for production and quality.	Cross-functional interdependencies are dynamic and reforming to meet changing resource allocations and business goals. Measures of how many units are produced in the context of its utility or value add.
People ✓ accountability ✓ cultural barriers ✓ skills required ✓ technological flexibility	***Infrastructure (Learning & Growth)*** is a measure that the right people with the right skills are assigned to the right tasks with the authority and technological flexibility to remain competitive.	Technological changes redirect communications channels and workflow responsibilities, negative impacts are monitored using leading indicators.
Time ✓ time horizon for payback ✓ dynamic linkages	BSC ***leading and lagging*** indicators proactively measure current state of the organisation and past-present-future trends.	Dynamism of the information economy is creating a destabilisation that is accounted for in our BSC.

To achieve meaningful measures of productivity it is clear that simplistic or naïve approaches are at best not suitable. In the worst case, they would be misleading, potentially resulting in net decreases in productivity and organisational viability. To address the high degree of complexity inherent in measuring productivity a measurement framework that allows the creation of "productivity measurement templates" is desirable. This supports an orderly decomposition of complexity with a concurrent ability to aggregate measures to achieve a broad view without sacrificing accuracy and relevance of the measurement.

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