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Sox Compliance with OEE, Enterprise Modeling and Temporal-ABC

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ABSTRACT
The Sarbanes-Oxley (SOX) Act 2002 resulted from the mounting accounting and corporate scandals in the late 1990s and early 2000s. Since the passage of the SOX Act, companies are facing even greater challenges to meet raised expectations to provide accurate, visible, and timely information for SOX compliance. This research puts forth a systems design framework to achieve a real time, accurate, consistently traceable and easily verifiable SOX compliant technology. Our multidisciplinary and integrative systems design incorporates Overall Equipment Effectiveness (OEE) to ensure effective business performance within a knowledge represented company modeled as Enveloped Activity Based Enterprise Model (EABEM) that facilitates Temporal-Activity Based Costing (ABC) so as to effectively lead to accurate, traceable and verifiable operational cost transparencies necessary for SOX compliance.

KEYWORDS
Overall Equipment Effectiveness (OEE); Sarbanes-Oxley Act (SOX); Enterprise model; Enveloped Activity Based Enterprise Model (EABEM); Temporal-Activity Based Costing (T-ABC); Ontology; Knowledge representation; Resource cost units; Cost fluents

1. Introduction

The Sarbanes-Oxley Act (SOX) of 2002 was intended to prevent potential scandals and to re-establish investor assurance (Miller & Pashkoff, 2002). Following high-profile fraudulent financial reporting cases such as Enron, which obliterated investor confidence, SOX is a crucial piece of legislation to comply with by companies. Therefore, to provide accurate, visible, and timely information for SOX compliance, organizations should seek new ways to improve enterprise wide communications, streamline operational processes, finance and accounting activities while monitoring business performance (Drawbaugh & Aubin, 2012). These new ways should incorporate a multidisciplinary and integrative approach to ensure effective business performance of a company while automatically leading towards traceable transparency to assist that company towards SOX compliance. To *establish such a multidisciplinary and integrative framework towards SOX compliance,* the four corner-stones (Tham & Madni, 2014) are: (i) Overall Equipment Effectiveness (OEE); (ii) Compliance sections of Sarbanes-Oxley Act; (iii) Enveloped Activity Based Enterprise Model (EABEM); (iv) Temporal-Activity Based Costing (T-ABC).

2. Overall Equipment Effectiveness

OEE, the overall equipment effectiveness, is a measure of the efficiency and effectiveness of the manufacturing processes (i.e. machines, cells, assembly lines, processes, etc.). OEE is a simple and powerful metric for tracking and improving a plant's efficiency (De Ron & Rooda, 2006). OEE works by breaking down the reasons for productivity losses into three main factors: *Availability, Performance and Quality.*

Availability (A): This factor measures productivity losses resulting from downtime. Downtime is any event that stops planned production for a period of time. Availability is determined by dividing actual production time by planned production time and is typically denoted by A.

Performance (P): This is a factor that measures a loss in productivity due to slow cycles. Slow cycles occur when the manufacturing process is running at less than optimum speed. When you divide the current production rate by the ideal production rate, the result is the performance ratio, simply referred to as performance and is typically denoted by P.

Quality (Q): This factor measures losses from manufacturing subpar products—those that do not meet minimum requirements. The Quality ratio is calculated by dividing the number of good units by total units started and is typically denoted by Q.

OEE is a concept utilized in a lean manufacturing implementation. For example, OEE is becoming a commonly utilized maintenance metric within lean organizations. *The OEE concept normally measures the effectiveness of a machine center or process line, but can be utilized in non-manufacturing operations also.*

The high level equation for OEE is:

$$\text{OEE} = A \times P \times Q \tag{1}$$

The Availability portion, A, of equation (1) measures the percentage of time the equipment or operation was running compared to the available time. For example, if a machine was available to run 16 h, but was only run for 12, then A is 75 percent (12/16). The 4 h when the machine did not run would be setup time, breakdown or other down time. The number of hours the company did not plan to run the machine is rarely used in the calculation.

The Performance portion, P, of equation (1) measures the running speed of the operation compared to its maximum capability, often called the rated speed. For example, if a machine produced 80 pieces per hour while running, but the capability of the machine is 100, then P is 80 percent (80/100). The concept can be used multiple ways depending on the capability number. For example, the machine might be capable of

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producing 100 pieces per hour with the perfect part, but only 80 on that particular order. When the capability of 100 is used for the calculation, the result is more a measure of facility OEE. For example, the sales department may take an order for a part that can only be produced at 80 per hour, which negatively affects OEE.

The Quality portion, Q, of equation (1) measures the number of good parts produced compared to the total number of parts made. For example, if 100 parts are made and 90 of them are good, then Q is 90 percent (90/100). Combining the above example into the OEE equation (1), the OEE is: OEE = A x P x Q = 75% x 80% x 90% = 54%

An OEE of 100 percent would require a machine to produce good quality every second of the available time at its top rated speed. The key to using OEE is in the analysis. For example, if the "Availability" is 70 percent, the 30 percent of time for breakdowns, setup and downtime should be analyzed for improvement opportunities. The most effective use of OEE is to break down the losses into smaller buckets of "opportunity". A 54% OEE does not mean much without any detail.

The OEE goal depends on the process, setup times and order quantities. For example, a machine that produces 10 orders per day with a 30-min per order setup time would have 300 min reduced from the Availability equation. Conversely, a machine that runs one order all day would only have 30 min of setup time. These facts make it difficult to compare two machines'

OEE numbers. The value is in the analysis and comparison of a machine's OEE in one period vs. another. The comparison may also become meaningless if the order quantities vary significantly day to day. Knowing the complete OEE breakdown, one is able to see the opportunities for improvement (Muchiri & Pintelon, 2008) become apparent. The largest opportunities should be improved first, working down the list until all opportunities are improved. The improvement opportunities are always in one of the following "buckets": (i) Breakdown, (ii) Setup, (iii) Downtime, (iv) Speed Loss, (v) Small Stops, and (vi) Quality.

The OEE is an excellent way of communicating the improvement opportunities to everyone including operators, maintenance technicians, sales representatives, engineers and managers.

Most lean manufacturing tools work together to create value in the system and eliminate "waste". OEE is a prime example of this integration of tools.

Summarily, every enterprise can improve on efficiency, and one of the best measures of efficiency is OEE. If one does not know one's OEE, then one does not truly know how efficient one is. More importantly, without knowing OEE, one does not know how efficient one could be.

3. Sarbanes-Oxley Act

The Sarbanes-Oxley Act (SOX) came into force in July 2002 and introduced major changes to the regulation of corporate governance and financial practice. It is named after Senator Paul Sarbanes and Representative Michael Oxley, who were its main architects, and it set a number of non-negotiable deadlines for compliance (Beasley & Elder, 2004). This Act was intended to reduce fraud and failure in corporate reporting. The scope of these actions is all encompassing, affecting audit firms, Wall Street analysts, boards of directors and corporate executives. The Act led to the most sweeping compliance and procedural requirements since financial regulations of the 1930s. Some have shown the Act in a negative light due to the high costs of compliance, where the costs of meeting the standards imposed by SOX can range from $1 million to over $10 million (Jain & Rezaee, 2010). Therefore, one of the most important requirements for companies for SOX compliance is the necessity to employ internal controls to prevent, detect, and deter fraud (Hooper & Fornelli, 2010; Moffett & Grant, 2011). Since the passage of the SOX Act in 2002, IS professionals are facing even greater challenges to meet raised expectations to provide accurate, visible, and timely information while ensuring their company's information assets are secure (Damianides, 2005), *hence, the need for this research.*

The Sarbanes-Oxley Act is arranged into eleven 'titles'. As far as compliance is concerned, the most important sections within these eleven titles are sections 302, 401, 404, 409 and 802 (Verleun, Georgakopoulos, Sotiropoulos, & Vasileiou, 2011).

3.1. SOX Title III Section 302

This section is listed under Title III of the act, and pertains to "Corporate Responsibility for Financial Reports". Summarily, periodic statutory financial reports are to include certifications that:

(1) Signing officers have reviewed the report.
(2) Report does not contain any material untrue statements or material omission or be considered misleading.
(3) The financial statements and related information fairly present the financial condition and the results in all material respects.
(4) Signing officers are responsible for internal controls and have evaluated these internal controls within the previous ninety days and have reported on their findings.
(5) A list of all deficiencies in the internal controls and information on any fraud that involves employees who are involved with internal activities.
(6) A list of any significant changes in internal controls or related factors that could have a negative impact on the internal controls.

Organizations may not attempt to avoid these requirements by re-incorporating their activities or transferring their activities outside of the United States.

3.2. SOX Title IV Section 401

This section is listed under Title IV of the act (Enhanced Financial Disclosures), and pertains to "Disclosures in Periodic Reports". Summarily, financial statements are published by issuers are required to be accurate and presented in a manner that does not contain incorrect statements or admit to state material information. These financial statements shall also include all material off-balance sheet liabilities, obligations or transactions. The Commission was required to study and report on the extent of off-balance transactions resulting transparent reporting. The Commission is also required to determine whether generally accepted accounting principles or other regulations result in open and meaningful reporting by issuers.

3.3. SOX Title IV Section 404

This section is listed under Title IV of the act (Enhanced Financial Disclosures), and pertains to "Management Assessment of Internal Controls". Summarily. Issuers are required to publish information in their annual reports concerning the scope and adequacy of the internal control structure and procedures for financial reporting. This statement shall also assess the effectiveness of such internal controls and procedures. The registered accounting firm shall, in the same report, attest to and report on the assessment on the effectiveness of the internal control structure and procedures for financial reporting.

3.4. SOX Title IV Section 409

This section is listed within Title IV of the act (Enhanced Financial Disclosures), and pertains to "Real Time Issuer Disclosures". Summarily, issuers are required to disclose to the public, on an urgent basis, information on material changes in their financial condition or operations. These disclosures are to be presented in terms that are easy to understand supported by trend and qualitative information of graphic presentations as appropriate.

3.5. SOX Title VIII Section 802

This section is listed within Title VIII of the act (Corporate and Criminal Fraud Accountability), and pertains to "Criminal Penalties for Altering Documents". Summarily, this section imposes penalties of fines and/or up to 20 years imprisonment for altering, destroying, mutilating, concealing, falsifying records, documents or tangible objects with the intent to obstruct, impede or influence a legal investigation. This section also imposes penalties of fines and/or imprisonment up to 10 years on any accountant who knowingly and willfully violates the requirements of maintenance of all audit or review papers for a period of 5 years.

4. Identifying Systems Integration Hooks from Sox and OEE

Two significant aspects of SOX Section 409 are to be noted:

(1) The need for real time enhanced financial disclosures.
(2) Issuers of these disclosures are required to disclose to the public, on an urgent basis, information on material changes in their financial condition or operations (Chorafas, 2009).

The above two significant aspects of SOX inherently call for financial disclosures that MUST be verifiable and validated through real time costs of activities performed in the enterprise seeking SOX compliance. Hence, the need for the system design to incorporate a generic knowledge representation of activities in an enterprise so as to facilitate the capture of temporal activity costs while activities are being performed in the real world.

In our prior discussion of OEE, the improvement opportunities are always in one of the following "buckets"—Breakdown, Setup, Downtime, Speed loss, Small stops and Quality. With the exception of Quality, the foregoing "buckets" are time or temporal related metrics occurring in the course of any day that will have an impact on costs of activities performed in the enterprise.

For example, if an activity, "fabricate plug_on_wire" uses an "injection molding equipment" to produce a finished unit, "plug_on_wire", then it is logical and reasonable to conclude that a breakdown of the injection molding equipment would impact or effect the time and cost of the "fabricate plug_on_wire" activity to produce the finished unit, plug_on_wire, (discussion later on this example with Figure 1).

4.1. Identifying the Systems Integration Framework

- From SOX, the explicitness for the need of real time disclosures of changing financial conditions or operations in a manner that is easily understood with qualitative graphical presentations.
- From OEE, the potential opportunities to monitor and improve a plant's efficiency or enterprise operation effectiveness.
- The need for a generic knowledge representation of activities of an enterprise (later referred to as Enveloped Activity Based Enterprise Model—EABEM).

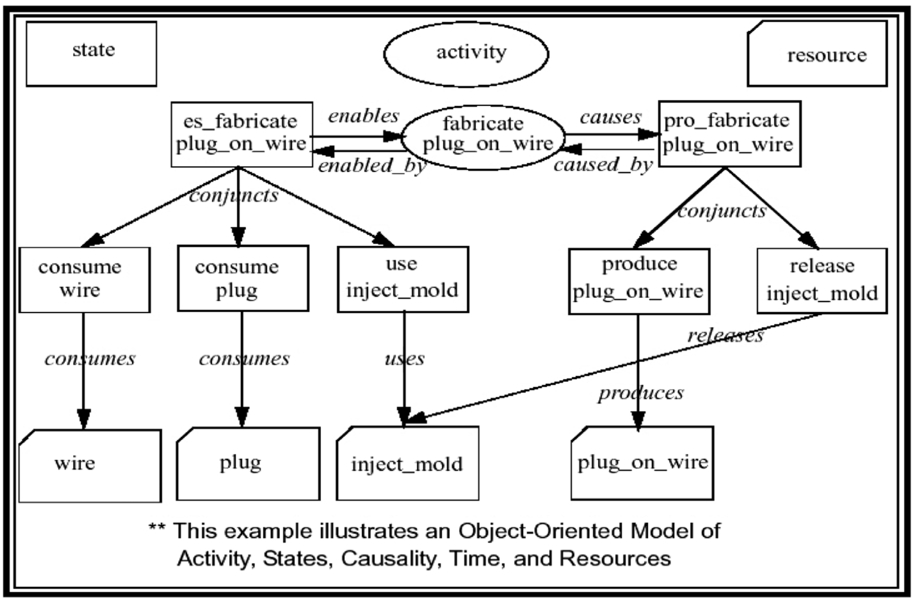

Figure 1. Activity-State Resource Cluster.

- Within the knowledge representation of activities, resources and the changing states of resources of an enterprise, we recognize that the “buckets” for improved opportunities in an enterprise as discussed in OEE effect the performance time of the activities and the cost associated with those activities.
- The ability to reason and compute temporal activity costs (later referred to as Temporal-ABC or T-ABC) of enterprise activities with the changing temporal states that occur with resources as activities are performed in the real world would be a much desirable contribution to enhancing the importance of OEE from a cost perspective, i.e., T-ABC costs at a given point in time give a corresponding cost dimension to the OEE computation at the corresponding point in time.
- From a common sense standpoint, the T-ABC cost metrics should serve as the reliable base for the verification and validation of real time disclosures of changing financial conditions or operations (i.e., activities) called for in SOX. That is, if a disclosure of a changing financial condition is unexplainable through the T-ABC cost of enterprise activities as performed in the real world, then that financial condition must be “red flagged” or there is a high potential for “non-compliance of SOX”.

5. Ontology, Micro-Theory, Advisor, and Enterprise Model

Ontology is a data model that “consists of a representational vocabulary with precise definitions of the meanings of the terms of this vocabulary, plus a set of formal axioms that constrain interpretation and well-formed use of these terms”. Vocabulary, definitions, and axioms that describe the enterprise are formally represented using ontologies, and prescriptions for achieving goals are formally defined using ontology representations. A *micro-theory* is formalized knowledge constructed upon an ontology so as to solve a problem in a domain such as costing. An *advisor* is a software tool, which encapsulates, and enables performing tasks using ontologies and micro-theories. In particular, our proposed system design is directed towards developing a SOX-OEE advisor, which encapsulates and enables performing tasks to trace, compute, verify and validate real time costs of enterprise activities pertinent to SOX compliance and the OEE metric. An *enterprise model* is a computational representation of the structure, activities, processes, information, resources, people, behavior, goals and constraints of a business, government, or other enterprise. It can be both descriptive and definitional spanning what is and what should be. The role of an enterprise model is to achieve model-driven enterprise design, analysis and operation. To represent and reason about costs using an enterprise model, the model should be descriptive, i.e., it should represent key entities, structures and concepts needed to describe the enterprise’s activities, resources, products, information flows and costs. The model should also be prescriptive. It should be possible to prescribe the costs of activities, resources and products of an enterprise using this model. Vocabulary, definitions, and axioms that describe the enterprise are formally represented using ontologies, and prescriptions for achieving goals are formally defined using ontology representations. By doing so, Tham (1999) formalizes enterprise activity-based costing, or more precisely, Temporal-Activity Based Costing (T-ABC) as it reflects temporal states of resources and activities, and prescribes to strategic cost management. Parts of these models can be shared and re-used by others with minimized interpretational ambiguity, because they are modeled formally.

6. Constructing Enterprise Activity Based Enterprise Model

The Activity-State Resource Cluster (Figure 1, in short, activity-cluster) is the basic construct (Fox & Gruninger, 1998) in modeling an Enveloped Activity Based Enterprise Model (EABEM) for any organization, company or enterprise.

Action is represented by the combination of an activity and its corresponding enabling and caused states. An activity is the basic transformational action primitive with which processes and operations can be represented. An activity specifies a transformation of the world. Its status is reflected in an attribute called status. The domain of an activity’s status is a set of linguistic constants:

- Dormant - —the activity is idle and has never been executing before.
- Executing - —the activity is executing.
- Suspended - —the activity was executing and has been forced to an idle state.
- ReExecuting - —the activity is executing again.
- Completed - —the activity has finished.

“Being a resource” is not an innate property of an object, but is a property that is derived from the role an object plays with respect to an activity (Fadel, 1994). Hence, the resource ontology includes the concepts of a resource being divisible, quantifiable, consumable, reusable, a component of, committed to, and having usage and consumption specifications.

An enabling state defines what has to be true of the world in order for the activity to be performed. A caused state defines what will be true of the world once the activity has been completed. An activity along with its enabling and caused state is called an activity-state resource cluster (Figure 1) or simply activity cluster.

The status of a state, and any activity, is dependent on the status of the resources that the activity uses or consumes. All states are assigned a status with respect to a point in time. There are five different status predicates:

- committed - a unit of the resource that the state consumes or uses has been reserved for consumption or usage;
- enabled - a unit of the resource that the state consumes or uses is being consumed or used while the activity is executing;
- disenabled - a unit of the resource that the state consumes or uses has become unavailable and the activity is suspended;
- re-enabled - a unit of the resource that the state consumes or uses is re-available for the activity to resume or reExecute;
- Completed—a unit of the resource that the state consumes or uses has been consumed or used and is no longer needed.

Resource requirements that enable an activity are specified through the consumption specification (consume_spec) and use specification (use_spec) of the resources required to enable the activity; whereas, the causal effects of an activity are

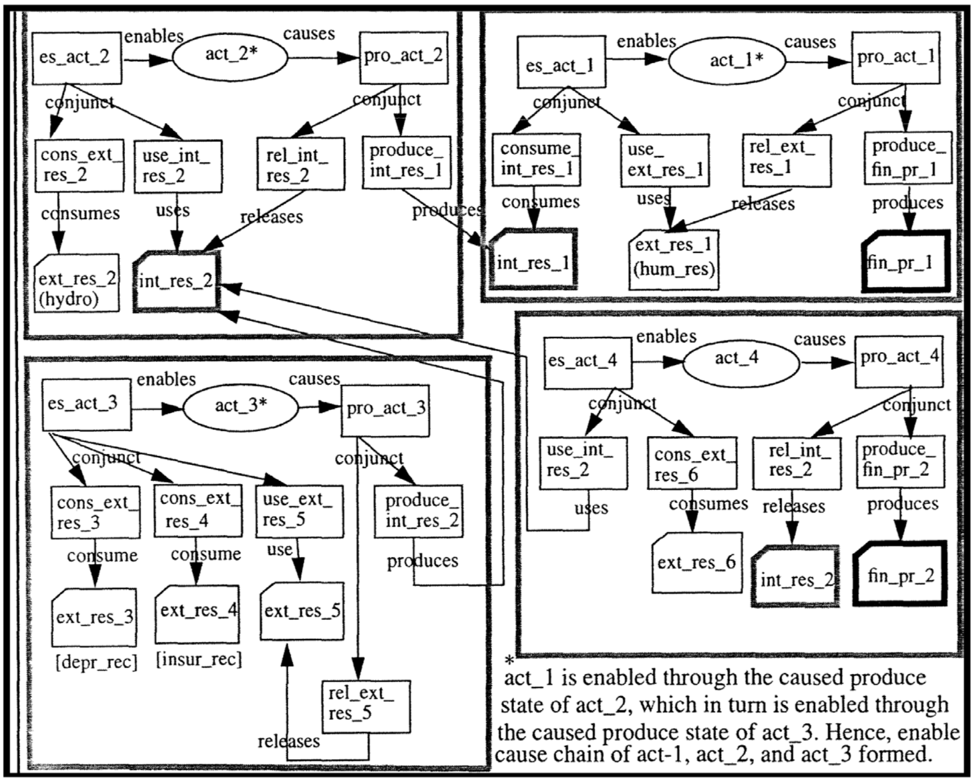

Figure 2. Linked Activity-Clusters representing an Enterprise Process (Activity Clusters Boxed).

specified through the produce specification (produce_spec) and release specification (release_spec) of the resource produced or released on the completion of the activity. A resource may be consumed or used by an enabling state in continuous mode at some rate or discrete mode as some quantity. For inventory purposes, a resource point (rp) of a resource specifies the quantity of resource at some time point and unit of measure.

The resource cost unit of a resource is the cost of a unit of the resource in the state that it exists in the real world at some time point. The commit-resource- cost-unit, the enabled-resource-cost-unit, the disenabled-resource-cost-unit and the re-enabled -resource-cost-unit are respectively associated with the commit, enabled, dis-enabled and re-enabled states associated with a resource.

In Figure 1, the real world enabling state to fabricate a plug_on_wire product is the consumption of wire and plug and the usage of the inject_mold equipment (note: wire, plug and inject_mold equipment are resources). On completion of the activity, Figure 1 visually represents the real world caused state, i.e., the plug_on_wire is produced and the inject_mold equipment is released as it is no longer required by the fabricate_plug_on_wire activity. Hence, Figure 1 is a graphical, visual and knowledge representation for the activity, fabricate_plug_on_wire.

Typically, in any enterprise, there are several activities that are linked to one another in some sequence(s) that are intrinsically tied to the work flow of processes that bring forth revenue generating products and/or services pertinent to the business model of the enterprise. These linkages depicting processes may be visually displayed with consistency, easily verifiable accuracy and minimal ambiguity through the deployment of activity-cluster linkages as shown in Figure 2.

Figure 2 models activities of an enterprise process through the activity-cluster representation. As illustrated in Figure 2, the activities of the process are formed through the linkages of the activity clusters. By way of explanation, the activity, act_1, consumes a resource, int_res_1. The activity, act_2, produces int_res_1. More precisely, the enabling state of act_1 is linked to the caused state of act_2, thereby forming an enable_cause link between act_1 and act_2. However, the activity, act_2, requires the resource, int_res_2. The resource, int_res_2, in turn is produced by the activity, act_3. We now have an enable_cause link between act_2 and act_3. Thus far, the two links form the enable_cause chain to consist of three activities sequenced as (act_3, act_2, act_1). In order to produce the resource, int_res_2, the activity, act_3, requires resources, ext_res_3 and ext_res4 and ext_res_5. For this illustration, assume that ext_res_3, ext_res_4 and ext_res_5 are resources that are supplied from sources (or companies) external to the enterprise modeled.

6.1. Practical Guidelines for Constructing EABEM Deployments in Real World Applications

If an enterprise with a multitude of processes is to be modeled with a network of linked activity-clusters, some obvious questions come to bear:

(1) Do all activities need to be considered in enterprise processes?
(2) Do all resources need to be considered in the enabling state of an activity?
(3) Can an enterprise model be bounded? That is to say, what is the extent or frontier boundary for the enterprise model?

In practical terms and with intuitive common sense reasoning, one must construct an enterprise model with the following definitional guidelines:

- *Significant Resource* is one that has a high imputed cost to attain and/or has an appreciable cost impact on the cost of the activity that requires the resource. [In practice, the unit cost specified by an enterprise in respect to a significant resource may be based upon some arbitrary cost management and control policy or upon some past historical experience with the particular resource. For example, all resources that have a book value of $10,000 or more may be considered significant resources for a particular enterprise.]
- An *Internal Resource* is one that is produced by within an enterprise activity-cluster. For example, from Figure 1, if the plug_on_wire product produced is eventually used in an assembly activity, the plug_on_wire would be considered an internal resource.
- An *External Resource* is one that is produced by activities deemed external to the enterprise. For example, in Figure 1, if we were to include that electricity (hydro) is consumed by the injection_mold equipment then hydro would be an external resource as hydro is typically supplied by a "utility company" through activities external to the enterprise being modeled.
- A Significant Activity is one that is enabled by at least one Significant Resource.
- An Internal Activity is one that is enabled by internal resources only.
- A Frontier Activity is one that is enabled by external resources only.

With these definitional guidelines in mind, we limit the proliferation of representing insignificant activities and insignificant resources in constructing an EABEM (E) for any enterprise.

A Formalized Schema for EABEM (E) is defined by Tham (1999) using Set Theory as equation (2) below:

$$E \equiv \left[\sum \textit{internal resources} \cap (\xi sig)\right] U \left[\sum \textit{external resources} \cap (\xi sig)\right] U \left[\sum \textit{activities} \cap (\eta sig)\right] U \left[\sum \textit{frontier activities}\right] \quad (2)$$

Where,

- $[\sum \textit{internalresources} \cap (\xi sig)]$: *set of sentences defining significant internal resources*
- $[\sum \textit{externalresources} \cap (\xi sig)]$: *set of sentences defining significant external resources*
- $[\sum \textit{activities} \cap (\eta sig)]$: *set of sentences defining significant activities*
- $[\sum \textit{frontieractivities}]$: *set of sentences defining frontier activities*

From a Knowledge Representation (KR) perspective, constructing an EABEM most fundamentally provides a consistent, agreeably accurate, traceable, and non-ambiguous surrogate, a substitute for the enterprise, to determine consequences by thinking rather than acting, i.e., by reasoning about the world rather than taking action in it. EABEM is founded on ontological commitments and provides a medium for efficient computation by the guidance a representation provides for organizing information so as to facilitate the making of recommended inferences.

7. Sox Considerations, Cost Fluents, Taxonomies, and Temporal-ABC

Any systems design working towards assisting SOX compliance must be capable of effectively representing entities such as building and equipment depreciation, property tax, rent, and similar expenses that our incurred by enterprises. These expense entities are the commonly identified traditional time period related overhead cost categories. From a knowledge representation and artificial intelligence (AI) standpoint, these expense entities are represented as resources that are consumed with the passing of time.

In AI, a fluent is a condition that can change over time. For real time financial disclosures related to SOX, we concern ourselves with cost fluents, i.e., costs that change with time or over a period of time. For example, equipment depreciation cost changes within a period of time. From a technical AI perspective, cost fluents may be represented in first-order logic (FOL, i.e., a formal language, which supports expressing propositions as well as predicates, where predicates may have quantified variables as arguments) by predicates having an argument that depends on time.

7.1. Cost Fluents Applicable towards SOX Compliance

To reason and compute costs pertinent to SOX, *Period Cost External Resources* are defined as nonactivity cost fluents f based upon "traditional time period related overhead cost categories" such as building depreciation, equipment depreciation, property taxes, borrowed capital interest, insurance, salaries, wages, management supplemental benefits, and union supplemental benefits (refer Table 1), where:

- *f* is a predicate denoting class of nonactivity cost fluent for the overhead cost;
- *tps* denotes the time period under study (e.g., 1 year, 6 months, etc.);
- *tc_ext* is an externally given total nonactivity based cost applicable to tps (e.g., if the fixed overhead of depreciation is under study for tps = 1 year, then tc_ext would be the annual depreciation cost);
- *tt_act* is a total actual time or total estimated time for the number of instances that occur in tps;
- *r* is the name of the external resource (e.g., equipment depreciation) associated with the nonactivity cost fluent.

Note that employees' salaries and wages are considered as Period Cost External Resources as the physical presence of an employee for an activity requirement is viewed as a discrete and re-usable resource per se, but wages or salaries expended on the job are consumed as resources that have an economic value expressed in terms of $ per unit time. From a KR and cost perspective, an activity that requires a human operator has two conjunctive enabling states: One that uses the operator as a re-usable, discrete resource; and the second that consumes the wages/salaries of the operator as a consumable rated resource.

Table 1. Defined Non-activity Cost Fluents Associated to Commonly Identified Traditional Time Period Related Overhead Cost Categories.

Period Overhead Cost	Nonactivity Cost Fluents
Building depreciation	*bldgDepCost(tps, tc_ext,tt_act, r)*
Equipment depreciation	*eqDepCost(tps, tc_ext,tt_act, r)*
Property taxes	*propTaxCost(tps, tc_ext,tt_act, r)*
Borrowed capital interest	*borCapCost(tps, tc_ext,tt_act, r)*
Insurance	*bldgDepCost(tps, tc_ext,tt_act, r)*
Salaries	*salaryCost(tps, tc_ext,tt_act, r)*
Wages	*wageCost(tps, tc_ext,tt_act, r)*
Management benefits	*mgtBenCost(tps, tc_ext,tt_act, r)*
Union benefits	*unionBenCost(tps, tc_ext,tt_act, r)*
In-Process inventory	*inprocInvCost(tps, tc_ext,tt_act, r)*
Finish Goods inventory	*finishGoodsInv(tps, tc_ext, tt, act,r)*
Leases	*leaseCost(tps, tc_ext,tt_act, r)*

Example: Given that the operator wage is $20/hour, the enabling state of an executing activity using the operator (i.e., discrete re-usable resource) for 2 h would consume wage (i.e., consumable continuous resource) of $40 (= 2 h x $20/hour).

The period overhead costs of Table 1 are not exhaustive. However, if an enterprise has other overhead cost entities to be considered, e.g., training, safety, carbon footprint, etc., a corresponding class of nonactivity cost fluent of the form *f(tps, tc_ext, tt_act, r)* may be defined.

Non-period Cost External Resources are defined as cost fluents f based upon traditional non-period overhead cost categories such as material costs, and utility costs like hydro, heat and water. Similar to Table 1, the non-period nonactivity cost fluents are shown in Table 2 where tc_ext denotes a specified nonactivity-based total cost parameter distributed over the total quantity parameter tqty_ext associated with the particular cost category.

Non-period cost external resources are defined as cost fluents f based upon traditional non-period overhead cost categories such as material costs, and utility costs like hydro, heat and water. Similar to Table 1, the non-period cost fluents are shown in Table 2 where *tc_ext* denotes a specified nonactivity-based total cost parameter distributed over the total quantity parameter *tqty_ext* associated with the particular cost category.

The nonactivity cost fluents presented in Table 1 and Table 2 enable reasoning, visualization, verification and validation of "overhead costs" pertinent to SOX compliance in the EABEM environment.

7.2 Resource Taxonomy for EABEM and SOX

Our foregoing discussions lead us to conclude that, for purposes of effective and efficient enterprise wide real time cost management conducive towards SOX compliance, each known resource, [rknown (r)], in EABEM should be a significant resource [significant_res(r)].

Each internal_res(r) is either a period cost internal resource [period_cost_int_res(r)] or a non-period cost internal resource [non_period_cost_int_res(r)]. Similarly, each external_res(r) is a period cost external resource [period_cost_ext_res(r)] or a non-period cost external resource [non_period_cost_ext_res(r)]. Hence, from concurrent perspectives of EABEM development and real time cost perspectives for SOX compliance, Figure 3 shows a Resource Taxonomy for EABEM and SOX.

8. Temporal- ABC & Cost Behavior during Activity Instance for Temporal-ABC

The traditional activity-based costing (ABC) principle includes the assignment of costs to activities based on their use of resources, and the assignment of costs to "cost objects" (i.e., products or services) based on their use of activities (Turney, 2005). ABC implementations depend on the selection and number of cost drivers used to assign overhead and indirect costs through cost pools to cost objects. Owing to lack of overhead cost traceability and hence its accountability, companies form overhead cost pools for allocation to activities. Consequently, cost object costs are often grossly distorted due to allocation. To overcome the shortcomings of traditional ABC, Tham (1999) introduced the Principle of Temporal-ABC as follows:

- *A cost object, i.e., a product or service, is the reason why activities are performed. The assignment of costs to activities is based upon their requirements of resources and the possible changing temporal states of those resources, thereby resulting in temporal costs for activities. The cost of a cost object is based upon the temporal costs of activities that produce it.*

To understand cost behavior in Temporal-ABC, resource cost units of a resource are explained as follows:

(1) *Committed resource cost unit:* A resource that is committed to an activity may be viewed as "inventory committed to the activity". Money invested or sunk into the committed resource is not available for use in other areas of the enterprise, and, in fact, may have to be borrowed money. From a costing standpoint, the cost of borrowing the money or the cost of "foregone investment opportunity" from using this capital in other areas of the enterprise must be charged as the cost of capital against the activity to which the resource is committed.

(2) *Enabled resource cost unit:* A resource is usually committed to an activity for future use. We consider an instance of an activity as being instantiated at the time point when a resource is committed to the activity. The committed resource enables the activity to execute. At the time point when the activity begins execution, the enabled resource is used or consumed by the enabling states of the executing activity. From a cost perspective, the enabled resource cost unit metric is taken to be equivalent to the committed resource cost unit metric as each unit of resource required by the executing activity costs an amount equal to its commit resource cost unit.

(3) *Disenabled resource cost unit:* A resource that becomes disenabled brings about the suspension of an executing activity that requires it. Though the cost value of the resource has not changed in this state, the enterprise loses opportunities during the time period the activity is suspended due to the disenabled resource. While the resource is disenabled, we must consider the notion of lost opportunity cost, viz., the return that could have

Table 2. Defined Non-activity Cost Fluents Associated to Commonly Identified Traditional Time Non-Period Related Overhead Cost Categories.

Non-Period Overhead Cost	Non-Period Cost Fluents
Hydro	*hydroCost(tc_ext, tqty_ext, r)*
Heat	*heatCost(tc_ext, tqty_ext, r)*
Water	*waterCost(tc_ext, tqty_ext, r)*
"indirect materials"	*indMatlCost(tc_ext, tqty_ext, r)*

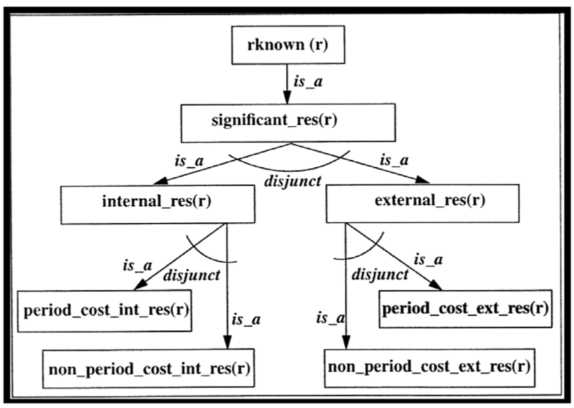

Figure 3. Resource Taxonomy for EABEM and SOX.

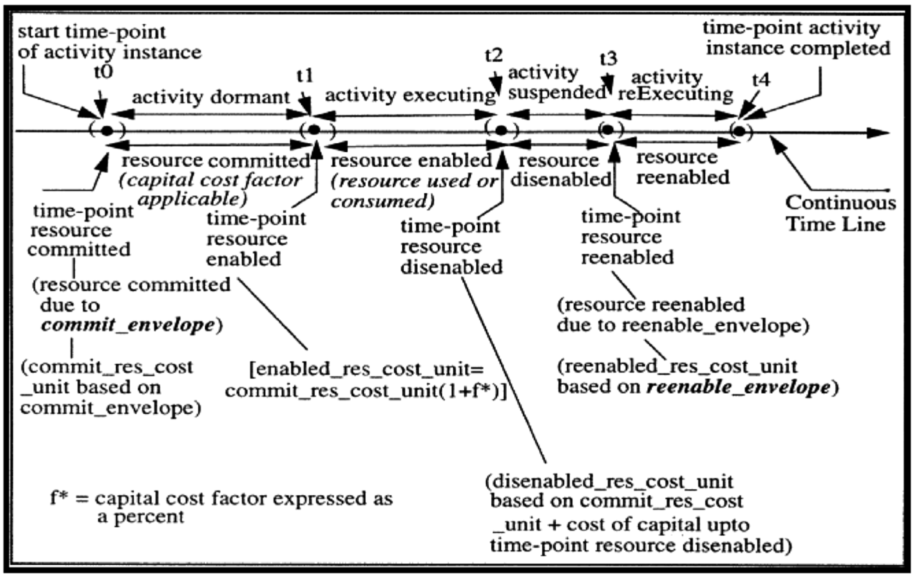

Figure 4. Activity Instance on Continuous Time Line.

been realized if the resource state was enabled and the activity executing. Hence, from a costing standpoint, a lost opportunity cost factor (usually expressed as some percentage factor) must be taken into consideration when computing the disenabled resource cost for an activity that has been suspended due to the disenabled resource.

(4) *Re-enabled resource cost unit:* Typically, a disenabled resource is re-enabled by the execution of activities that bring about the "repair" of the dis-enabled resource so that the suspended activity due to the dis-enabled resource may resume execution. Therefore, we consider the cost value of a re-enabled resource as being greater than that of the initial enabled resource simply because the cost of "repair" activities must be sunk into the dis-enabled resource before it is re-enabled. An enterprise may consider cumulatively incrementing the value of the re-enabled resource cost unit with each iteration that a resource is dis-enabled and then re-enabled.

In Figure 4, the status of an activity instance changes with the passing of time due to the status value of the used or consumed terminal states associated with the resource required by the activity instance. The activity status at time point's t0, t1, t2, t3, t4 may be dormant, executing, suspended, reExecuting or completed respectively corresponding to the status value of the state for the required resource being committed, enabled, dis-enabled or re-enabled respectively, and overall completion of the activity. The resource cost units of a resource is the cost of a unit of the resource in the state that it exists in the real world at some time point. The commit- resource-cost-unit, the enabled-resource-cost-unit, the dis-enabled-resource-cost-unit and the re-enabled-resource-cost-unit are respectively associated with the commit, enabled, dis-enabled and re-enabled states associated with a resource to give granular insights into costs.

For example, assume company X has a capital cost factor of 6 percent per annum on borrowed capital of $10,000 used to buy a machine, i.e. a resource for a machining activity. In this case, assuming that [t0, t1) represents a time interval of 4 months then the prorata capital_cost_factor for X would be 2 percent. Assuming the machine was acquired for $10,000 from some external supplier, the commit-resource-cost unit for the machine is $10,000. To compute the committed resource cost for the machine (resource) or the dormant activity cost for the machining activity for the committed resource interval or dormant activity interval of 4 months would be $200, i.e. 2% x $10,000 = $200. This $200 may be looked upon as real costs sustained by company X as part of the "cost of borrowing" total in the general ledger for X traceable to the 4 months the machine was committed to the machining activity that was never performed perhaps due to scheduling problems. Note that, if the resource committed period or the activity dormant period of [t0, tl) is reduced to a null period, the dormant_act_cost or the committed_res_cost would be zero instead of $200. In essence, just-in-time (JIT) planning strives to reduce or minimize the resource committed period. Temporal-ABC costs are real and help reveal activities and their corresponding costs against items of the general ledger for a company.

9. Conclusions

The changing states of a resource relevant to Temporal-ABC within EABEM facilitate the tracking of resource availability pertinent to OEE. The enabled resource cost unit lends a direct cost perspective towards the availability of an equipment (or resource); whereas the committed, dis-enabled and re-enabled resource cost units lend direct cost perspectives towards the "buckets"—breakdown, setup, downtime, speed loss, and small stops—for OEE improvements. Our systems design framework makes it possible to achieve improvements in enterprise wide operational processes through facilitation of OEE computations as an effectiveness percentage while providing corresponding cost metrics directly related to the "buckets" for improvement. The real time computations involved in Temporal-ABC associated with activities and resources of an EABEM provide relevant cost metrics pertinent to real time financial disclosures called for by SOX. Tracing with resources and activities in EABEM enables one to assign costs based on specific data making traceability, verification and validation more direct for SOX compliance.

Disclosure statement

No potential conflict of interest was reported by the authors.

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