Representing and Reasoning About Costs Using Enterprise Models and ABC

By

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Doctor of Philosophy (1999)

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Abstract

The well accepted Activity-Based Costing (ABC) Principle includes the assignment of costs to activities based on their use of resources, and the assignment of costs to end products and services based on their use of activities. Since ABC assigns costs to activities based on their use of resources, the logical formulation of ABC must be premised upon the existence of some given or identifiable unit resource cost that must be associated with each resource required by an activity. Notwithstanding this obvious rationale for unit resource cost being absolutely essential for ABC, there has been little or no development in the field of ABC to solve two fundamental problems relevant to ABC:- *(i) What unit resource costs are associated with a resource? (ii) How does one deduce unit resource costs so that direct, indirect and overhead costs are accounted for within the costs of a resource?* The solving of these two fundamental problems relevant to ABC is the central focus of this research.

Though centered within the cost domain, this research presents a holistic solution by crossing over several fields which, in themselves, are expansive and highly specialized areas. More specifically, the perspectives integrated are from the fields of:- (a) Computer Science and Artificial Intelligence for the development of knowledge-based information systems and the deductive reasoning of solutions in a distributed agent environment; (b) "New Industrial Engineering" that applies the capabilities of information technology to analyze, engineer and re-engineer business processes on an enterprise wide basis;

(c) Strategic Cost Management that seeks accurate and consistent solutions for product and service costs to formulate strategies for competitive advantages.

First, based upon real cost related problems put forth as common sense queries posed by industrial partners, this research presents the analysis and design of a Cost Ontology for Enterprise Modelling that identifies and reasons with Resource Cost Units of a resource. A Formalization of ABC and a Micro-theory of ABC are established based upon the Cost Ontology. Secondly, it develops the Principle of Resource Probing, the Principle of Activity Probing, a Formalization of Overheads, and a Micro-theory of Resource Cost Units that collectively form a Theory of Resource Cost Units. This theory establishes the framework of axioms and concepts that enables one to deduce costs with ABC so that direct, indirect and overhead costs are included in the Resource Cost Units.

The theories and developments of this research are tested for practical applicability by finding solutions to real world scenarios as presented by corporate partners - deHavilland Inc. (Bombardier, Canada) and BHP Steel (Broken Hill Proprietary, Australia) for purposes of strategic cost management.

Dedication

This research is dedicated to my dearest wife, Shuyee, our loveable twins, Jason and Karen, my caring parents, and my late elder brother, Monchu, who passed away suddenly while this endeavour was in progress.

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CHAPTER 1 Introduction

1.1 Executive Summary

The 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"[1] based on their use of activities [Brimson 91]. Since ABC assigns costs to activities based on their use of resources, the logical formulation of ABC must be premised upon the existence of some given or identifiable unit resource cost that must be associated with each resource required by an activity. Notwithstanding this obvious rationale for unit resource cost being absolutely essential for ABC, there has been little or no development in the field of ABC to solve *two fundamental problems relevant to ABC:-* **(i) What unit resource costs are associated with a resource? (ii) How does one deduce unit resource cost(s) so that direct, indirect and overhead costs are accounted for within the costs of a resource?** The solving of these two fundamental problems relevant to ABC has been the motivating drive and central focus of this research.

1. Within the ABC literature, the term "cost objects" refers to the reasons for which activities are performed in enterprises.

The holistic **solution** provided consists of 3 interdependent parts:-

1. *A Cost Ontology for Enterprise Modelling* that promotes a precise and unambiguous understanding of temporal cost behaviour of resources and activities for a formalization of the ABC Principle. It is based upon the TOronto Virtual Enterprise (TOVE) Model that is founded upon the TOVE Core Ontology for activity, state, resource and time. This part identifies and associates costs for a resource and their effects on the cost of an activity requiring the resource.

2. A *Theory of Resource Cost Units* that provides a logical and formalized framework to deduce the basic unit costs of a resource identified in 1, so that conventional concepts of direct, indirect and overhead costs are accounted for in the unit costs of a resource.

3. A *Prototypical Demonstration of a Cost Advisor* that encapsulates axioms, principles and theories of the two previous parts in an IT environment referred to as the TOVE Testbed. It provides a visualization of the "activity-based" enterprise modelling infra-structure and a work-bench to deduce solutions to some cost related queries, referred to as informal competency questions, as posed by our corporate partners - deHavilland Inc. (Bombardier), Toronto; Broken Hill Proprietary (BHP), Melbourne, Australia.

The thesis of this dissertation, then, is: **Costs within an organization can be described by representing them in an enterprise model to provide a Formal Model and a Micro-theory of ABC; and costs of a resource can be objectively deduced to include direct, indirect, and overhead costs for a populated enterprise model by applying a Micro-theory of ABC and a Theory of Resource Cost Units.**

The term "populated enterprise model" refers to the population of activity instances for an enterprise. In particular, the thesis is focused upon representing, deducing and reasoning with the costs of activity instances to achieve an activity-based analysis of the costs in the production of a product or service. It *assumes* that a "complete activity model" is provided for an activity instance. Secondly, that given this assumption, i.e., the completeness of the

activity model, the identification of cost drivers is no longer relevant to the analysis. A forensic or predictive activity-based analysis of costs in the production of a product or a service is dependent upon the "complete activity model" representing activity instances that have occurred in the past or that will occur in the future respectively. Thirdly, it is imperative to note that the forensic or predictive activity-based costs of a product will depend on the time period of analysis. That is to say, for example, if the time period considered for the analysis is one year, as is normally done, the cost of a product based on the annualized analysis would be different from the costs of the product based on a quarterly or monthly basis, and vice versa.

The thesis is supported by the development of the following models:

- a formal, re-usable, descriptive model of enterprise costs, called a Cost Ontology for Enterprise Modelling in TOVE,
- a formal, re-usable, prescriptive model called a Micro-theory for ABC,
- a formal, re-usable, descriptive model called a Formalization of Overheads,
- a formal, re-usable, prescriptive model called a Micro-theory of Resource Cost Units.

1.2 A Need for this Research

According to the ABC concept, costing of "cost objects" proceeds with the assignment of cost to activities based on their use of resources, and the assignment of costs to "cost objects" based on their use of activities. Within the ABC literature, the term *"cost objects"* refers to the reasons for which activities are performed in enterprises. Products, services, and customers are considered cost objects as there may be reasons why activities are performed. This concept towards costing has gained wide and favourable acceptance in all sectors of industry in the US, UK and Canada [CMA 93].

First, the question is: From where and how does one get the costs of resources for ABC? Second, ABC emphasizes the need to obtain a better understanding of cost behaviour and

thus ascertain what causes the overhead costs [Drury 89]. However, towards solving the question and fulfilling this need, there are some problems that influence the feasibility of the ABC Principle being applied to enterprises.

Let us examine the current costing process in ABC. According to Turney [92], ABC is accomplished in a two stage process. In the first stage, the cost assignment of resources to an activity is accomplished through a resource cost assignment phase through "resource drivers". In the second stage, the cost assignment of activities to cost objects is accomplished through "activity drivers". Resource drivers are the links between resources and activities. They take cost from the general ledger and assign it to activities. An activity driver is a factor used to assign cost from an activity to a cost object. According to Turney [92(A)]:

- "Various factors, referred to as resource drivers, are used to assign cost to activities."
- "Activity drivers are methods for assigning the cost of activities to cost objects. ..... Cost objects are costed accurately when activity drivers measure the use of activities directly or correlate closely with their use. ..... The objective is to pick the right number and type of activity drivers. Enough of the right type are needed to report accurate costs - though too many may be costly and may create a system that's too complex to understand."

Based upon the selection of *resource drivers* and *activity drivers*, "overhead and indirect costs" get assigned and included into the cost of a cost object through cost pools [Turney 92]. In other words, traceability and cost assignment of "overheads and indirect costs" to cost objects is dependent on resource drivers and activity drivers. Presently, this is the state of the art in ABC with regard to "overheads and indirect costs".

Therefore, given that there can be several different resource drivers and activity drivers, the cost of the activity is only as good as "a resource driver", and the cost of the cost object is only as good as "an activity driver".

In other words, the operationalization of the process, and the computation of the cost of an activity and the cost of a cost object are in themselves open to inconsistencies and inaccuracies. Does this reduce ABC to being an art, rather than a science? Maybe it does, as is implied in the following excerpts from [Babad & Balachandran 93]:-

> "An ABC system achieves improved accuracy in estimation of costs by using multiple *cost drivers* to trace the cost of activities to the products associated with the resources consumed by those activities. In this respect, a cost driver is an *event*, associated with an activity, that results in the consumption of the firm's resources."
>
> " 'The art of designing an ABC system can be viewed as making two separate but interrelated decisions about the *number of cost drivers needed* and *which cost driver to use*. These decisions are interrelated because the type of cost drivers selected changes the number of *drivers* required to achieve a desired level of accuracy' (Cooper 1989a, 1989b)."

In short, there is a need to operationalize the resource cost assignment and the activity cost assignment with better consistency, better accuracy, better traceability of "overheads and indirect costs", and less ambiguity. With regard to ambiguity, notice the confusing usage of the terms - *resource driver, activity driver, cost driver, event* and *drivers.*

This research demonstrates that the Formalization of ABC and the Theory of Resource Cost Units founded upon the Cost Ontology for TOVE is a major step towards fulfilling this need in the ABC field. First, the approach adopted towards formalization consists of Enterprise Modelling and Ontological Engineering. This approach enables us to communicate the ABC Principle as a formal model, where formal refers to a data model expressed using a logic language, not an analytical model expressed in mathematics. Unlike most English sentences, and like an equation written in mathematics, a logic language expression can be interpreted unambiguously, as long as the terms that comprise the expression are precisely defined. Second, the solution provides a clear mapping of resource drivers to resource cost units (i.e., cost of a unit of resource depending upon its state of existence in the world) for the resource cost assignment; and the mapping of an

activity instance to an activity driver for the activity cost assignment. Third, the solution provides a Formalization of Overheads so that traceability, accountability, and assignability of "fixed overheads" (e.g., depreciation, property taxes, etc.) and "variable overheads" (e.g., cost of utilities- hydro, heat, water) is achieved with better consistency, better accuracy, and less ambiguity. Fourth, the solution provides a logical framework that encapsulates a Micro-theory of ABC and a Micro-theory of Resource Cost Units so that an objective deduction of resource cost units of a resource can be made to include direct, indirect and overhead costs directly to activities and to cost objects. Fifth, the cost of specifying an activity for a cost object is given consideration to be included in the cost of an activity called for by a cost object. It is noteworthy that cost of specifying an activity for a cost object is given little or no consideration in ABC developments to date. And lastly, based upon the logical framework presented, it is possible to automate the deductive reasoning of the resource cost units of significant resources of significant activities in a populated enterprise model.

1.3 The Costing Problem

The costing problem arises in that traditional cost systems themselves have major shortcomings. This problem is exacerbated in that existing enterprise modelling frameworks provide a modelling infrastructure that tend to support traditional cost systems [Tham & Fox 98]. Traditional cost systems use volume-driven allocation bases such as direct labour hours, direct machine hours, direct labour dollars, direct material dollars, and sales dollars as the primary means of assigning organizational expenses and overheads to individual products, services and customers. However, many of the resource demands by individual products and customers are not proportional to the volume of units produced or sold. Thus, traditional cost systems do not measure accurately the costs of resources used to design, to produce, to sell and to deliver products to customers.

The traditional cost systems may have proved adequate for providing product costs when the overhead costs and costs of indirect activities was a small percentage relative to the direct labour consumed by the products. However, modern enterprises are mostly

operating in a *capital intensive and automated environment* with direct labour as a percentage of total operating cost being typically around 8 percent [Zhuang & Burns, 91]. A survey of electronic firms indicate a cost profile breakdown as being 13 percent for materials, 8 percent for direct labour, and 79 percent for overhead [Hawks et al., 1992]. Significant overhead costs such as equipment depreciation, cost of monies borrowed, property taxes, employee supplementary benefits, and insurance costs are apportioned amongst product lines using volume related rates such as direct labour hours. Therefore, by using direct labour as a primary apportioning device to distribute significantly high overhead and indirect costs to products, can cause significant distortions in product costs and poor strategic decisions.

In general, *the apportionment of indirect and overhead costs to products and service products based on volume related units such as direct labour or machine hours according to traditional cost systems provide irrelevant costs for decision making and for the determination of product or service profitability* [Cooper 89] [Kaplan 88].

Kaplan and Cooper of Harvard Business School have developed an approach to product or service costing called activity-based costing (ABC) as a means to overcoming some of the problems with traditional costing systems.

Traditional costing methods were designed primarily to satisfy the need for inventory valuation as defined by GAAP (Generally Accepted Accounting Principles) in manufacturing organizations. The objectives of traditional or conventional cost accounting systems are to provide historical cost information to serve two primary masters: first, government regulatory agencies, especially the tax bureaus such as Revenue Canada and the Internal Revenue Service of the USA; and second, the owners of the corporations, namely, the stockholders. Tax and other regulations such as GAAP specify very rigid rules for handling cost data so that quarterly and annual reports of corporations provide information in formats well understood by stockholders, financial analysts and potential buyers of a company. These systems are properly referred to as "financial accounting systems". Therefore, traditional costing systems narrowly focus on using cost information

as a means to achieving financial accounting through the preparation of a variety of financial statements for external users.

We are faced with the issue that traditional cost systems use cost information to serve external users (i.e. non-company personnel); but they do not serve the needs of internal users (i.e., company personnel), especially the needs of managers and operations' personnel. According to Turney [92(A)], managers are reluctant to accept indirect costs from traditional cost systems as they provide "no information about activities". In order to make the assignment of indirect costs more acceptable to managers, Turney implies that the strategy should be for a cost system that provides relevant activity information that is traceable and timely.

The needs of managers and operations' personnel approximately fall into two areas in which cost information is used:-

1. The development of product costs that support pricing and strategic planning. This includes the identification of relevant costs as well as the distribution of indirect costs.
2. Management control systems that help in planning and reviewing. Included here is variance analysis arising from budgets and standard costs, as well as a variety of issues relating to measurement and evaluation of managerial performance.

The above two areas form the domain of "managerial accounting systems" in that the relevant rule or test becomes the usefulness of cost information for the management of the enterprise. Presently, the needs of managers and operations' personnel are not considered specifically in the traditional cost accounting systems. Cost information for their two areas of needs stated above must be dug out or "guesstimated" at best from the various monthly, quarterly or annual financial reports. This has left managers swamped with data while still starving for information that assists them in decision making.

The deficiencies in the traditional cost accounting systems for management decision making show up vividly and are most damaging in profit margin data for individual

products or cost objects. Indirect or overhead costs are assigned arbitrarily to cost centres processing components of many varieties of products and involving mixtures of high and low cost activities that may require simple manual labour and expensive automation equipment. Profit margins using such costs allocated to individual products based on their direct labour content become not only absurd and meaningless, but are misleading when direct labour has diminished to less than 10 percent of total factory cost.

Traditional cost accounting systems have not given credence to the reality of high overhead or indirect costs as being non-volume related costs. In contemporary manufacturing enterprises, many significant indirect costs such as set-up, procurement, and quality control are all examples of costs where variations relate to such factors as diversity, complexity and degree of customizing of output. Therefore, to unitize costs such as these on a volume related basis, such as direct labour hours, introduces systematic bias into the resultant cost information; and, if the process is examined, it places the accountant in an indefensible position.

Two actions must be taken by enterprises facing these rising overhead costs: they must be attacked and reduced substantially in order for the company to remain competitive. To do so, new methods that promote the traceability and the assignment of overhead costs to individual products must be found and used.

1.4 ABC: Objectives and Issues

Traditional cost accounting allocates costs to products based on the attributes of a single unit of a cost object, a typical attribute being the number of direct labour hours expended to manufacture the unit. Allocations therefore vary directly with the number of units produced. In contrast, ABC focuses on the activities required to produce each product or to provide each service, based on activities consumed by the product or service.

Therefore, the ABC approach to costing is radically different from the traditional cost approach that tends to only measure direct labour and machine hours used for products; and then distributes a pool of indirect and overhead costs based on the direct labour and/or

machine hours used for the products. The ABC concept of directing resource costs to activities (referred to as *resource cost assignment*), and the assignment of costs to cost objects based on their use of activities (referred to as *activity cost assignment*) is intuitively more appealing to one's common sense in terms of deriving costs of products effectively, efficiently and accurately [Turney 92(B)].

ABC has two primary objectives:-

1. to obtain more accurate data on product, process, and service costs;
2. to identify the costs of activities and the reason those activities are undertaken.

In both cases, the value of the information lies in its potential application by managers to help in everyday decision making. Decisions that are affected by cost information include pricing, new product introduction or abandonment, and the identification of productivity improvement opportunities.

The survey put forth by the Society of Management Accountants of Canada (CMA 93) indicates that the ABC concept has been widely and favourably accepted by all sectors of industries - manufacturing, retail, food, resource, commercial, energy, transport, and finance. It has been emerging as a widely accepted technique for general economic understanding of all overhead or indirect costs. However, notwithstanding the wide and favourable acceptance to the ABC concept over the last eight years, current ABC systems have had limited success in the US, UK and Canada. According to the survey [CMA 93] there have been very few implementations of ABC systems in these three countries - approximately 14 percent in Canada, 6 percent in the UK and 36 percent in the US based on a total sample size of 5,422 companies in the three countries over the period of 1991 to 1993 inclusive.

Even for those companies that have adopted ABC, there is the recognition that the potential scope of ABC extends beyond purely the production overhead category [Innes & Mitchell, 1991] in that ABC should include activity based information that *"comprises any relevant information about activities across the entire chain of value - design,*

engineering servicing, production, distribution, marketing and after sales service" [Johnson 88]. Consequently, there is a need for new methods that provide information about the costs attributable to "indirect functions". [Borjesson 97].

According to Innis & Mitchell [91], within the ABC developments thus far, there is a *need* for the inclusion of 'overhead resource' and non-production overheads for activity based analysis. This is fully supported by others who emphasize the need for selling, distribution and service costs to be integrated within the ABC environment [Johnson & Kaplan 87] [Jeans & Morrow 89].

The lack of a "comprehensive cost unitization" of resources [Innes & Mitchell 91] *"across the entire chain of value"* makes it almost impossible for companies to achieve fully the decision oriented, control and 'scorekeeping' purposes for ABC based information towards the "balanced scorecard" [Kaplan & Norton 92].

Owing to lack of overhead cost traceability and hence its accountability, companies attempting to implement ABC form overhead cost pools for allocation to activities. Too often, different types of costs are combined into one diffuse overhead pool, so *product costs are often grossly distorted due to allocation* [Borjesson 97]. Tracing enables one to assign costs based on specific data, whereas allocation from pools often involves indirect assignment of costs to activities [Turney 92(A)].

The Emerging Practices in Cost Management [Brinker 96] indicates that, for ABC, if products are to be costed in a manner which reflects their actual consumption of resources, then there is a need for "overhead resources" to be formalized in a manner such that the costs of "overhead resources" can be traced to activities and allocated to products on the basis of time.

1.5 Enterprise Modelling Issues

According to Fox & Gruninger [97]:-

> "An Enterprise Model is a computational representation of the structure, activities, processes, information, resources, people, behaviour, 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.
>
> From a design perspective, an enterprise model should provide the language used to explicitly define an enterprise. .....
>
> From an operations perspective, the enterprise model must be able to represent what is planned, what might happen, and what has happened. It must supply the information and knowledge necessary to support the operations of the enterprise, whether they be performed manually or by machine. It must be able to provide answers to questions commonly asked in the performance of tasks."

One way to effectively access and share information [Konsynski & McFarlan 90] towards costs of products, services, processes and systems of an enterprise is to represent and reason costs using information-systems based enterprise models [Kosanke 97].

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. The ABC Principle is an appropriate cost prescription because:-

- it prescribes costs to products and services that give confidence to the enterprise regarding better accuracy and usefulness of information [CMG - IMA 94];
- it can address costs across activities and resources in all sectors of enterprises [O'Brien 90];
- it is one of the more important, widely accepted and publicized cost techniques towards Strategic Cost Management [Foster 96].

Chapter Section: Enterprise Modelling Issues

The models developed in this thesis are intended to be descriptive and prescriptive in that they represent knowledge data bases from which solutions to queries, referred to as competency questions, are prescribed through deductive reasoning.

A number of issues exist concerning the design of Enterprise Models [Fox 93]. The issues are:-

1. Reusability: it is concerned with the large cost of building enterprise-wide data models. Is there such a thing as a generic, reusable enterprise model whose use will significantly reduce the cost of information system building?
2. The Consistent Usage of the model: given the set of possible applications of the model, can the model's contents be precisely and rigorously defined so that its use is consistent across the enterprise?
3. Accessibility: given the need for people and other agents to access information relevant to their role, can the model be defined so that it supports query processing so that answers to common queries in an agent's domain (e.g., costing) may be obtained.
4. Selectivity: how does one know which is the right Enterprise Model for one's application?

Some of the major enterprise modelling frameworks are:-

1. Enterprise-Wide Data Model (EDM) [Scheer 89],
2. CIM-OSA (Computer-Integrated Manufacturing - Open-Systems Architecture) [ESPRIT 91],
3. Purdue Enterprise Reference Architecture (PERA) [Williams 92],
4. DoD (Department of Defense) Enterprise Model [DoD 93], and
5. CAM-I [Berliner et al. 88].

EDM, CIM-OSA, PERA and DoD tend to provide a modelling infrastructure that support traditional cost systems, whilst CAM-I provides principles for cost management in an advanced manufacturing technology (AMT) environment that sets the stage for ABC [Tham & Fox 98]

1.6 The TOVE (TOronto Virtual Enterprise) Project

At the Enterprise Integration Laboratory (EIL) of the University of Toronto, it is our belief that the issues of reusability, consistent usage, accessibility and selection can best be addressed by taking a more formal approach to enterprise modelling. *By formal, we are not referring to analytical models as found in Operations Research, but to logical models as found in Computer Science.* Towards this end, the TOVE (TOronto Virtual Enterprise) Project at EIL includes two major undertakings: the development of an Enterprise Ontology and a Testbed [TOVE92] [Fox et al. 93].

An ontology "consists of a representational vocabulary with precise definitions of the meanings of terms of this vocabulary plus a set of formal axioms that constrain the interpretation and well-formed use of these terms" [Campbell & Shapiro 95].

Ontologies are introduced in TOVE as a basis for modelling enterprises. The TOVE ontologies at the EIL currently span core knowledge about the enterprise such as activity [Gruninger & Pinto 95], time, causality, resource [Fadel et. al. 94], and organization [Fox et. al. 95]. These ontologies are collectively referred to as the TOVE Core Ontologies.

According to Fox [92], the objective of the TOVE (TOronto Virtual Enterprise) project is to create an enterprise ontology that has the following characteristics: (i) provide a shared terminology for the enterprise that every application can jointly understand and use; (ii) define the meaning (semantics) of each term in a precise and as unambiguous a manner as possible using First Order Logic; (iii) implements the semantics in a set of Prolog axioms that enable TOVE to automatically deduce the answer to many "common sense" questions about the enterprise; and (iv) define a symbology for depicting a term or the concept constructed thereof in a graphical context.

According to Fox et al.[93]:

> "We are taking what can be viewed as a "second generation knowledge engineering" approach to constructing our Common Sense Enterprise Model. Rather than extracting rules from experts, we are "engineering ontologies". The approach to engineering ontologies begins with defining an ontology's requirements; this is in the form of questions that an ontology must be able to answer. We call this the competency of the ontology. The second step is to define the terminology of the ontology - its objects, attributes, and relations. The third step is to specify the definitions and constraints on the terminology, where possible. The specifications are represented in First Order Logic and implemented in Prolog. Lastly, we test the competency of the ontology by "proving" the competency questions with the Prolog axioms. The TOVE ontologies constitute an integrated enterprise model, providing support for more powerful reasoning in problems that require the interaction of multiple ontologies."

The TOVE Enterprise Ontology provides a generic, re-usable ontology for modelling enterprises. The Core TOVE Enterprise Ontology spans knowledge of activity, state, resource, causality and time. The Core TOVE Ontology constitutes an integrated enterprise model, providing support for more diversified and powerful reasoning in problems that require the interaction of multiple ontologies that may span domain specific knowledge in the areas of organization, supply-chain management, quality and activity-based costing (as developed in this thesis report).

The TOVE Testbed provides an environment for analyzing enterprise ontologies. The Testbed provides a model of an enterprise (a lamp manufacturing plant), and a graphical user interface software tool called Oak [EIL94] developed in the Enterprise Integration Laboratory (IE Dept., U of T) for building, browsing, editing and visualizing a ROCK knowledge base [ROCK 92]. [ROCK: Representation of Corporate Knowledge; Carnegie Group's knowledge representation software tool developed under the IMKA - Initiative for Managing Knowledge Assets - project]. Oak also facilitates the deductive processing of queries input in Quintus Prolog [Quintus 91].

The data model for the lamp manufacturing plant pertaining to the core TOVE ontology is implemented on the TOVE Testbed on top of C++ using ROCK.

1.7 Proposed Contributions

The Cost Ontology for TOVE, the Micro-theory of ABC, and the Theory of Resource Cost Units directly contribute towards providing the solution to a fundamental question in ABC - From where and how does one get the costs of resources for ABC? In providing the answer to this fundamental question with a logical framework, this research provides the opportunity to automate the deductive reasoning of resource cost units to include direct costs, indirect costs, overhead costs, and the cost of specifying an activity for a cost object. This leads to better consistency, better accuracy, less ambiguity and promotes "open book accounting"[Foster 96].

The Cost Ontology for TOVE and Micro-theory of ABC provides a Formalization of ABC in terms of precise terminologies and axioms that enable us to deduce the temporal cost behaviour of resource, activity and cost object in a consistent manner compatible with the ABC Principle.

The Theory of Resource Cost Units enables us to deduce the costs of a resource. These costs are based upon the intrinsic state that the resource exists in. The theory enables us to deduce the resource costs with improved traceability and accountability of direct, indirect and overhead costs.

The Cost Ontology and Micro-theory of ABC serve as a foundation to establish an ABC Cost Advisor - a software that provides graphical and deductive solutions to cost related questions in a consistent manner compatible with the ABC Principle. The ABC cost solutions provided include direct, indirect and overhead costs that have direct traceability and accountability towards the costing of cost objects.

From the perspective of Enterprise Modelling, the Enveloped Activity Based Enterprise Model (EABEM) provides the infrastructure of the activities, states and resources of any

enterprise based on the TOVE Core Ontology. The formulation of EABEM is made possible through the Principle of Resource Probing, the Principle of Activity Probing, and a Formalization of Overheads to represent, as "virtual" resources, entities associated with traditional notions of overhead. Unlike several other enterprise modelling efforts, EABEM provides the enterprise infra-structure that makes it possible to integrate and implement several of the Cost Management Principles of CAM-I for Activity-Based Management (ABM) and Strategic Cost Management.

From the perspective of successful ABC implementation, this research eliminates the need and confusion companies face in attempting to determine "the right cost drivers and the right number of cost drivers" to make the ABC system manageable and conducive for change management in an organization.

Finally, based upon the literature reviewed re: SAVILE (Ch. 2) from PricewaterhouseCoopers, the largest Accounting Firm according to Forbes Magazine, the formal models developed in this research may serve as some of the "rigid underlying models" that help generate the thousands of numbers typically summed up in their Financial Modelling Practices at that company.

1.8 Outline of Thesis

This chapter has provided an insight into the two fundamental problems with ABC **-(i) What unit resource costs are associated with a resource? (ii) How does one deduce unit resource cost(s) so that direct, indirect and overhead costs are accounted for within the costs of a resource?** It identifies the need for this research. It provides the 3 interdependent parts of a holistic solution. It has pointed the issues related to traditional costing and ABC. It briefly provides a description of the TOVE project and the enterprise modelling approach taken in the development of the solution. Finally, the proposed contributions of this research have been indicated.

Chapter 2 is titled Literature Review. It provides a review of enterprise modelling efforts undertaken over the past decade and the cost perspectives of these models. Cost

management requirements are reviewed in the light of the Cost Management Principles of CAM-I that tend to support activity-based costing (ABC). Problems and issues relating to ABC are also reviewed. Other cost models such as Target Cost and Throughput Accounting are reviewed in the context of ABC. A more detailed overview of the TOVE Project is presented. The chapter also includes key points of four major ABM (Activity-Based Management) software packages, viz., Activa from PricewaterhouseCoopers, Profit Manager PLUS from KPMG Peat Marwick, EasyABC Plus from ABC Technologies, and NetProphet II from Sapling Corporation. In order to provide the reader some insight into "formal works" in the domain of cost accounting that may connect with contributions from this research, the chapter includes a review of the knowledge-based system SAVILE (PricewaterhouseCoopers), that is based upon a specific ontology appropriate for several reasoning tasks in accounting and auditing.

Chapter 3 puts forth the Methodology and Core Ontologies towards the development of the proposed solution presented in this research.

Chapter 4 details the design of the Cost Ontology for TOVE and a Micro-theory of ABC. It shows a clear mapping between the ABC concept and the Cost Ontology for TOVE.

Chapter 5 formalizes a Theory of Resource Cost Units. This is composed of a Principle of Resource Probing, a Principle of Activity Probing, the development of an Enveloped Activity Based Enterprise Model (EABEM), a Formalization of Overheads, and a Micro-theory of Resource Cost Units. It concludes with a logical framework for the objective deduction of resource costs in a populated enterprise model so that direct, indirect and overhead costs are consistently and accurately accounted for.

Chapters 6 and 7, demonstrates the implementation of the Cost Ontology and Micro-theory for ABC towards a Cost Advisor that is tested with case studies in deHavilland Inc. (Bombardier, Toronto, Canada) and Broken Hill Proprietary (BHP, Melbourne, Australia) respectively. The deHavilland case study is presented as a Forensic Cost Analysis with ABC in Ch.6; while the BHP case study of Ch. 7, titled Enterprise Modelling and ABC,

demonstrates the manner in which the Cost Advisor provides forensic and "predictive what-if" solutions to several cost related competency questions.

In Chapter 8, the re-usability of the Cost Ontology is demonstrated in the light of the ABM functionality of the NetProphet II software package from the Sapling Corporation.

Chapter 9 provides the summary and contributions of this research, and outlines directions for future research that build upon the contributions of this thesis.

CHAPTER 2 Literature Review

2.1 Introduction

The focus of the thesis dissertation involves enterprise modelling and activity based costing. Its research directive is a Formalization of ABC in an Enterprise Model. The objective of this formalization is to lay the foundation for a holistic solution towards obtaining the costs of resources so essential for ABC. The term "holistic" implies that requirements and solutions are considered from a variety of viewpoints. To this end, the literature reviewed in this chapter gives coverage to the areas most pertinent for this holistic solution - enterprise models and their cost perspectives, cost management, ABC/ ABM, costing problems faced by enterprises, other cost models such as Target Costing and Throughput Accounting, an approach to enterprise modelling and integration, and ABC/ ABM software.

2.2 Enterprise Models & Their Cost Perspectives

Due to rapid changes of economic, geo-political and technological conditions, enterprises must be able to adapt to change with ease and quickness. This is called agility. To achieve

an agile response to change, enterprise systems must be engineered, implemented and integrated in a systematic way very similar to approaches developed for software engineering. This has given rise to the emerging discipline - Enterprise Engineering [Vernadet 97]. According to Williams [97], Enterprise Integration is the coordination of the operation of all elements of the enterprise working together to achieve the optimal fulfillment of the mission of the enterprise as defined by enterprise management.

Enterprise modelling is a predominant activity in Enterprise Engineering and Integration. The 'Enterprise', in this context, is described as a socio-economic organization. It is comprised of a set of elements with a highly complex set of interactions. To be able to understand, improve and control the Enterprise, modelling techniques are required to deal with the complexities. Models provide a simplified representation or abstraction of reality. The model may include the representation of physical objects or concepts that help organize and unify knowledge. [Smart et al. 97]

According to Fox & Gruninger [97], an Enterprise Model is a computational representation of the structure, activities, processes, information, resources, people, behaviour, 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.

Over the last decade, to improve enterprise integration, agility and competitiveness in the global markets, there have been several efforts in enterprise modelling to establish comprehensive representational frameworks of corporate knowledge with the expectation that a better understanding of shared corporate knowledge by diversified participants or agents of the enterprise would yield better costs and profits or "a better bottom line" as is commonly referred to.

Included in these enterprise modelling efforts are the more significant ones such as:-

1. Enterprise-Wide Data Model (EDM) [Scheer 89],

2. CIM-OSA (Computer-Integrated Manufacturing - Open-Systems Architecture) [ESPRIT 91],
3. Purdue Enterprise Reference Architecture (PERA) [Williams 92],
4. DoD (Department of Defense) Enterprise Model [DoD 93], and
5. CAM-I [Berliner et al. 88].

EDM, CIM-OSA, PERA and DoD provide insights into representational frameworks of corporate knowledge, whilst CAM-I provides principles for cost management in an advanced manufacturing technology (AMT) environment that sets the stage for ABC.

The modelling efforts - EDM, CIM-OSA, PERA and DoD - have concentrated on capturing the functionality or activity aspects of the enterprise being modelled without regard to addressing the problems in the management of costs for their products or services as put forth by CAM-I. They tend to support traditional cost accounting as opposed to strategic cost management which evaluates opportunities for repricing, the redirecting of resources to more profitable ends, and the re-engineering of processes in the production of products or the delivery of services as outlined by CAM-I. The methodology of the modelling efforts towards the representation of enterprise functionalities or activities have not provided the infrastructure to support strategic cost management promoted by CAM-I [Tham & Fox 98]

2.3 Scheer: Enterprise -Wide Data Modelling (EDM)

The enterprise-wide data modelling contribution by Scheer [85] was initiated in Germany in the mid 1980s and undertakes to construct data structures for typical functional areas (departments) such as production, engineering, purchasing, human resources, sales and marketing, accountancy and office administration that are generally encountered in an industrial enterprise with the aim of supporting planning, analysis, and traditional accounting systems in general.

Scheer uses the Entity-Relationship Model (ERM) [Chen 76] to systematically develop the *data structures* for the enterprise in terms of *entities* (something that can be identified in the users' work environment), *attributes* (characteristics/properties of an entity) and *relationships* (the association of entities with one another). The *temporal* (time) *aspects* [Allen 83] [Ladkin 86] of data structures are recognized in a rudimentary fashion through the identification of key attributes of entities as calendar time related, such as date, year, (fiscal) period and time-table-number. The temporally dependent processes, which are typically transaction data, are defined by their links with the special entity type TIME.

Knowledge representation is achieved through the identification of entities, their key attributes, and relationships with other entities from the areas of accountancy and/or from the other function areas. Entities, relationships and attributes are linked using Chen's ERM to construct a semantic network for data structures within accountancy. The abstraction mechanism of generalization, which enables an entity type to be thought of as a more generic entity type, is used to organize enterprise entities into a hierarchy through a partial order relationship, often referred to as the IS-A relationship [Brachman 85].

2.3.1 Cost Perspectives in EDM

Scheer's EDM view of *accountancy identifies five functional areas - Financial Accounting, Cost Accounting, Accounts Payable, Accounts Receivable, Payroll Accounting - that have connected entity relationships with one another and other functional areas of the enterprise.*

Scheer illustrates a sectorial integration principle [Scheer 85] whereby the sectors of purchasing, invoicing, and production data collection are related to Accounts Payable, Accounts Receivable, Fixed Asset Accounting, Payroll Accounting, and Inventory (Material) Accounting to achieve the General Accounting function for the EDM in the CIM environment [Scheer 91]. Scheer's EDM provides the infrastructure to fully support traditional cost accounting.

2.4 CIM - OSA: Enterprise Modelling

CIM-OSA is the acronym for Computer-Integrated Manufacturing - Open-Systems Architecture. The objective of Computer-Integrated Manufacturing (CIM) is the appropriate integration of enterprise operations by means of efficient information exchange within the enterprise with the help of information technology; and the Open-Systems Architecture (OSA) defines an integrated methodology to support all phases of a CIM system life-cycle from requirements specification, through system design, implementation, operation and maintenance, and even system migration towards CIM-OSA solution [Jorysz and Vernadat 90].

The European Strategic Programme for Research and Development in Information Technology (ESPRIT) supports a number of CIM related projects. CIM-OSA is the outcome of one such ESPRIT project, code number 688 with code name AMICE, the reverse acronym for European Computer Integrated Manufacturing Architecture.

2.4.1 CIM-OSA Enterprise Modelling Paradigm

CIM-OSA provides an architecture to describe the real world of the manufacturing enterprise by providing a unique set of advanced features to model functionality and behaviour of CIM systems at three distinct levels - *requirements definition, design specification and implementation description.* This description is used to control the enterprise operation and to plan, design and optimize updates of the real operation environment.

The CIM-OSA modelling methodology is more *descriptive than prescriptive*. In order to satisfy the needs of particular enterprises, CIM-OSA *does not provide* a standard architecture to be used by the whole manufacturing industry, but rather a Reference Architecture from which Particular Architectures may be derived. To facilitate this derivation of Particular Architecture from a Reference Architecture, CIM-OSA brings together a number of architectural principles and employs several structuring concepts [ESPRIT 91].

2.4.2 Cost Perspectives in CIM-OSA

CIM-OSA recognizes the importance of Enterprise Activities within the Business Processes of an enterprise. *CIM-OSA falls short* of adequately guiding the user, for example, in costing a product or supporting an investment decision based on a cost related criteria like profit. Perhaps the lack of a cost perspective of an enterprise may have been overcome if the developers of CIM-OSA included a view called the Cost View.

In summary, *much remains to be done or extended* in CIM-OSA in providing cost contents to the underlying concept of decision support across the centrally recognized construct Enterprise Activities within Business Processes. All CIM-OSA can do is to provide the Reference Architecture and its structuring means for organizing the different aspects of the enterprise. It is still up to the individual user to apply it in a *creative way* to improve the cost-effectiveness and efficiency of his/her enterprise and thereby make it more competitive in the marketplace.

2.5 The Purdue Enterprise Reference Architecture (PERA)

In December, 1990, PERA was particularly developed as an endeavour in enterprise modelling for a CIM factory by the Purdue Laboratory for Applied Industrial Control at Purdue University, West Lafayette. As early as mid 1986, the CIM Reference Model Committee of Purdue for Industrial Computer Systems had recognized *the need to establish a basis for the treatment of human-implemented functions* in a CIM enterprise. This need formed the focal point in initiating the PERA endeavour.

2.5.1 The Modelling Paradigm in PERA

PERA centres around representation of Information Systems Tasks, Manufacturing Tasks and the Human-based Tasks of the enterprise being modelled. The knowledge representation schema for each of these task modules is very similar to the Integrated DEFinition (IDEF) modelling approach [ICAM 81].] The generic representation schema incorporates Inputs with Time, Enabling Parameters, Transformation Process, Outputs and