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FORMAL ANALYSIS OF INTERNAL CONTROL - AN INTRODUCTION

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FORMAL ANALYSIS OF INTERNAL CONTROL
AN INTRODUCTION

Abstract - The paper examines a new approach to internal control analysis. A formal linguistic model, rather than prevalent flowcharting procedures, is used. Advantages of the formal linguistic approach include the automatic synthesis of a firm wide internal control description from descriptions by individuals of their duties. Automated consistency and completeness checking, and a querying system that can utilize the vast capabilities of computers to analyze the firm model based on adequate internal control criteria are significant features of the model. The system is capable of addressing a wide variety of internal control issues using the computer, and also performing analysis concerning machine processed documents. We believe these capabilities provide a strong new tool for accountants and auditors. The concepts developed should permit students in accounting to develop an understanding of the potential use of computers in aiding the auditor in evaluating the internal control system of a company.

Résumé - Cet article aborde l'analyse de contrôle interne sous un nouvel angle. La procédure usuelle employant le "Flowcharting" est remplacée par un modèle de linguistique formelle. Cette méthode de linguistique formelle offre l'avantage de synthétiser les descriptions des différentes tâches de tous les individus en une description de contrôle interne de toute l'entreprise.

Les éléments significatifs de ce modèle sont :

- "automated consistency"
- "completeness checking"
- un système qui, en employant les vastes capacités de l'ordinateur, analyse le modèle de l'entreprise basé sur des critères de contrôle interne adéquats.

Le système peut s'adresser à une grande variété de problèmes concernant le contrôle interne.... et peut aussi analyser les documents traités en machine.

Nous sommes convaincus qu'un nouvel et puissant instrument est offert aux comptables et experts comptables. En employant les concepts développés dans ce papier, les étudiants en comptabilité pourront mieux comprendre et apprécier toutes les applications que l'ordinateur leur offre. Spécialement, ils comprendront comment l'ordinateur peut aider un expert comptable à évaluer

Introduction

The research challenge addressed in this paper is to develop a representation of an office environment that offers at least the same descriptive power as the traditional flowchart approach. Besides representation, we need the capability of carrying out a reasoning process in a way that handles the types of questions that an auditor would raise. In order to effectively deal with realistically complex offices the representation must be computer recognizable. This then permits the reasoning process to be automated.

In the teaching of internal control and auditing, virtually no consideration has been given to the potential of data processing support of an auditor in attempting to satisfy professional requirements on the validity of the corporate internal control system. Thus, a teaching challenge is to integrate information systems concepts with accounting and auditing requirements. Students should recognize that professionally set auditing and control standards may require large investments by the company in data processing support. A secondary area of interest for students is the development of office automation concepts and their implications for accounting and auditing.

This paper presents a formal approach to internal control evaluation, with the intention of permitting a large amount of internal control verification, currently executed by auditors using flowcharts, to be done on a computer. This complex task requires formal analytic procedures, such as an Artificial Intelligence (AI) problem solving capacity, to be combined with, or applied to, standard auditing practices for internal control evaluation.

This had led us to the development of an internal control description guage, or ICDL. The first requirement of an ICDL is standardization. processing to be done automatically, all terms must have fixed, standard nings. Thus, the ideal ICDL is entirely unambiguous, and yet must be ficiently flexible to permit modelling the complex firm procedures rently studied by auditors. It should be stressed that an ICDL is not programming language like COBOL, but a system description language, mitting the modelling of internal control procedures.

TICOM II provides an example of such an ICDL. One may view TICOM II an introduction of AI concepts into internal control evaluation. Most systems are composed of (i) a knowledge base, (ii) a set of productions, operations, on the knowledge base, and (iii) a control strategy for using e productions. In traditional internal control analysis, the knowledge se is the model of the firm, constructed as a flowchart. The set of ceptable operations is the knowledge the auditor brings to the analysis sk, for example, his ability to follow a path checking for violations of ternal control. In addition, there is a procedure directing the analytic tools he uses.

In order to use machines to assist the auditor in his evaluation task, art or all of the above must be written in a computer acceptable method. ward this goal, the authors have constructed TICOM II, consisting of an CDL for the knowledge base, analytic procedures to simulate the analysis tools f the auditor, and a control strategy comprised of methods of deducing whether given internal control violation is possible within the firm description.

The Internal Control Description Procedure

The object of the internal control description is to capture all of the information processed by auditors with no loss of generality. Internal control analysis is normally executed by flowcharting the actions of a firm's agents [1], and is exemplified by the description of a purchasing system in Figure 1. The important characteristics of internal control can be imputed from these graphical models. It is clear that files, documents, document transfers and comparisons are important internal control features, as they are included in the flowchart models. In general, the significant characteristics of internal control are deduced from the flowcharts used in the modelling process. This observation was employed to provide a foundation for our modelling process.

The major aim of this new modelling process, as discussed in the introduction, is the computer analysis of the internal control system. This introduces the first restriction on the description process, that it must be formally recognizable. The second restriction on the modelling process requires only that all the actions of the flowchart are available in the language.

Another important aspect of the description procedure is its modularity. Individuals in a firm know their own duties, but in a large firm one person cannot connect all the individuals' duties. As a result, it is necessary that some piecing of the individuals' duties occurs. This is tedious and best done by a machine. The analysis system will do this through a matching scheme that connects transfers of documents with statements indicating which recipient possesses the document subsequent to the transfer.

A wide range of internal control and security issues can be analyzed by the machine, assisting in validating the procedures the firm uses. Typical issues that this system can analyze include: 1) The existence or absence of the segregation of duties at both the aggregate and individual levels; 2) the order of access and processing of documents; 3) the existence of particular processing steps at any given stage of system operation; 4) comparison of job description with actual duties; 5) the existence of necessary conditions for internal checks and comparisons deemed valuable and described by auditors; 6) the necessary and sufficient conditions for a given set of actions to occur.

It is perhaps important to note that both the flowchart method and the formal linguistic approach may be used as a systems design tool. Both approaches can effectively be used in a similar way toward making internal control systems satisfy external criteria. This will become apparent later in the paper, when systems analysis is discussed. It is significant for the reader to understand that no aspects of the flowchart approach inherently contain more information than the formal methods.

The Language

To summarize, the following issues were involved in developing the language representation presented in this section: (1) a language of sufficient power to include at least as much information as in a traditional flowchart; (2) a computer recognizable language; (3) reasoning ability within the

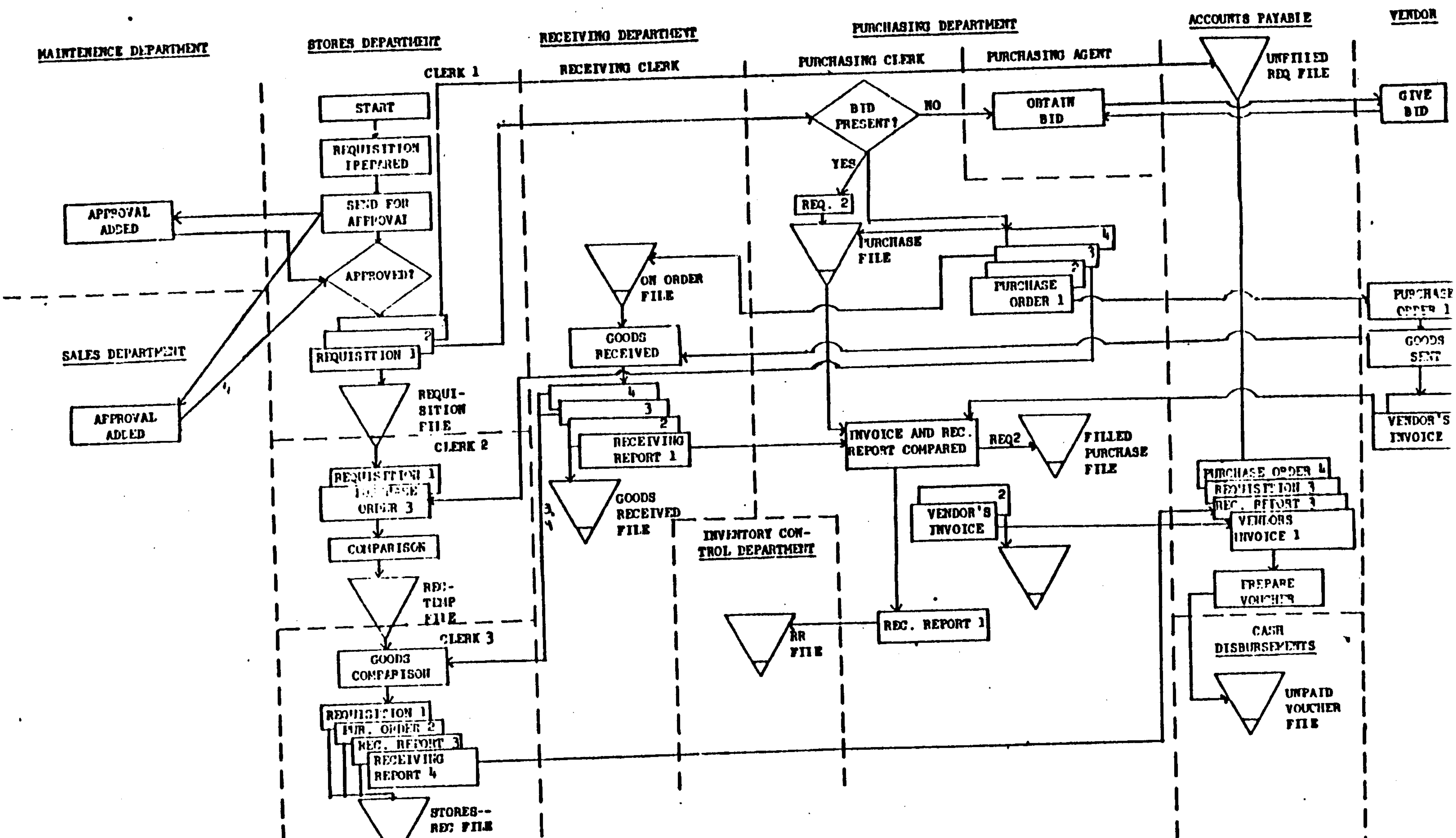


FIGURE 1 PURCHASING SYSTEM

Figure 2 The Commands

Command	Description
ASSIGN field-list OF object;	Specifies which fields of a particular data object are to be assigned values.
MODIFY field-list OF object;	Specifies which previously assigned fields of a particular data object are to be reassigned values.
DESTROY object-list;	Specifies which data objects are to be destroyed.
IF boolean-expression THEN true instructions ELSE false instructions END IF; IF boolean-expression THEN true instructions END IF;	Specifies a simple or compound boolean expression, whose truth determines which disjoint set of instructions are to be performed next.
TRANSFER object-list TO agent;	Specifies that the data objects listed are to be transferred to the designated agent.
WAIT object-list;	Specifies that the agents' processing is blocked until he receives the data objects listed.
PUT object-list INTO repository;	Specifies that the data objects listed are to be placed into the designated repository.
GET object-list FROM repository;	Specifies that the data objects listed are to be retrived from the designated repository.
COPY target-object GIVING duplicate object-list;	Specifies that the target object is to be copies creating the designated duplicate objects.
END TASK;	Specifies the end of a task.
REVIEW	Signifies the entrapment of an error or a discrepency.

language; and (4) the ability to handle concurrent events. The auditing language is two tiered, i.e., it is divided into objects and actions on those objects. Objects are people, files, documents, goods and other physical items. Actions are changes in the state of objects, e.g. transfer of a document from a desk to a file, destruction of a copy of a requisition. Of the two, actions are by far the easiest to formulate, so we will begin with action descriptions.

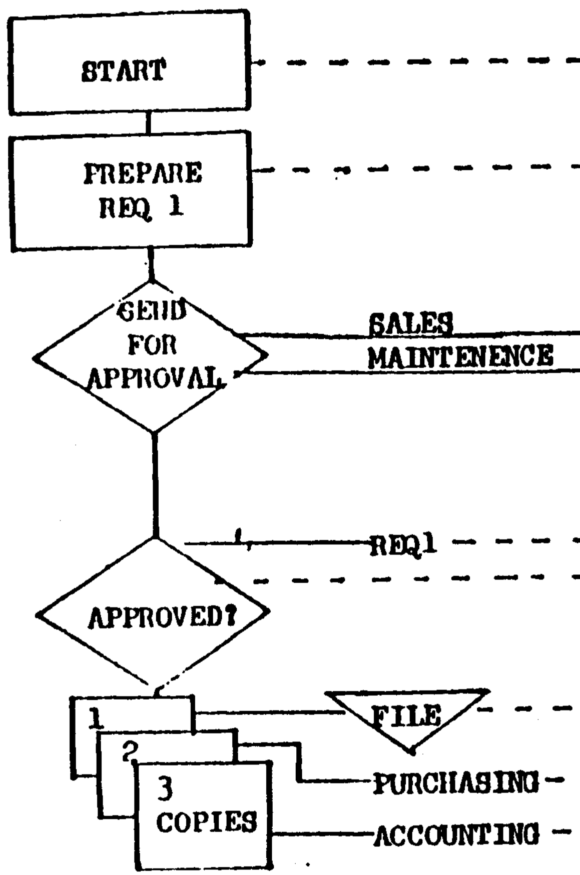
As we mentioned, the actions of the system are founded in the actions employed in flowcharts. It was necessary to use only eleven different actions to completely model the different flowcharts found in accounting works. The collection of actions, called commands, are listed in Figure 2, with a brief explanation of their use.

Figure 3 illustrates the correspondence between flowchart notation and TICOM code. The dotted lines indicate where the code corresponds to the flowchart. When one result of an "If" is not described, the code places it under the catchall "Review". Reviews result from an incomplete system description. If the result of this case were defined by the flowchart (such as what occurs when a requisition is not approved) then this could easily be included in the corresponding ICDL code. Because the system modelled does not deal with these eventualities, these circumstances were described as "Review" in order to provide for closure on all "If" statements.

Analytic Procedures

The preceding sections suggest that the TICOM-II language is a viable medium for describing the operations of systems subject to internal control analysis. From the descriptions of the system components, TICOM-II builds a knowledge base from which it can make inferences concerning the internal

Figure 3 Clerk 1

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GET REQ1 FROM CLERK 1-DESK-DRAWER;

ASSIGN SOURCE-DEPT, DATE, PROP-DESC, PROF NUM
    QTY OF REQ1

IF REQ1. SOURCE-DEPT = "SALES" THEN
   TRANSFER REQ1 TO SALES. MANAGER
IF REQ1. SOURCE-DEPT = "MAINTENCE" THEN
   TRANSFER REQ 1 TO MAINTENCE. MANAGER
ELSE REVIEW; END TASK; END IF; END IF;

WAIT FOR REQ1
   IF REQ1. APPROVAL IN DEPT-SUPER-APPR THEN

COPY REQ GIVING REQ2, REQ3;
PUT REQ1 INTO REQUISITION-FILE;

TRANSFER REQ2 TO RPUCHASING. AGENT
TRANSFER REQ3 TO ACCOUNTING. ACCOUNTANT

ELSE REVIEW;
END IF;
END TASK;

END CLERK 1.
```

control behavior of the system. The knowledge base is comprised of definitions and classifications of the systems; objects and agents, and an internal representation of the internal control model. Conceptually, the internal control model can be depicted by a precedence graph. Each node of the graph uniquely corresponds to an instruction in the system description and vice versa. The nodes are interconnected with precedence arcs which specify the order in which the commands are to be performed. Precedence arcs are labeled to indicate the truth of conditional branches.

The first principle employed in TICOM-II deductive analysis is called a contraction. A contraction is a procedure for eliminating an instruction from the system without destroying any of the relative properties of the other instructions. In order to establish the relationship of some set of instructions C, all of the other instructions in the system may be contracted out. Intuitively, contraction is performed by removing a node from the precedence graph by combinatorally connecting the input arcs of the node with the output arcs of the node. In addition to contraction, TICOM-II possesses simplification rules for reducing the complexity of precedence graphs.

This process is roughly analogous to an auditor studying the cycles of an internal control system independently. By examining one cycle, he has contracted all other parts of the system out. Similarly, an auditor who studies each department of the system separately has contracted the other departments out. The contraction gives TICOM-II a similar facility. Contractions permit TICOM-II to evaluate the relation of operations in the system by simplifying the system with respect to other operations. The above procedures contribute to our ability to establish the internal consistency of the described internal control system and to establish state achievability conditions within the system.

Current research has so far led to the development of seven simplification rules and extensions of the precedence graph concept to include constructs that permit a node to perform its task if and only if one of a set of conjunctions of nodes have first completed their operations. Other analytic capabilities being developed include a deductive logic for analyzing the effects of parallelism.

The Query Language

The query language is a language that invokes certain searches and subroutines, such as contraction, in a fashion designed to resolve the query. It is perhaps best illustrated by an example.

In the query language, objects and agents are grouped into useful categories. For example, the agents of the firm are identified by both department and by job titles (clerk, vice president, etc.). Objects are classed by whether they are assets, physical or nonphysical, which department they belong to, and so on. This classification must be done before querying begins. It is impossible for any computer to recognize the term STORES unless the individuals comprising STORES are identified at some time. This permits a query to be posed about general subclasses of things. For instance, a question about any STORES Personnel and any requisition would include the class identifiers:

STORES (p) and REQUISITION (r)

which the computer would interpret as p is in stores and r is a requisition. An example of a query would be:

(IS THERE) [TRANSFER r TO p and STORES (p) and REQUISITION (r)]?

which asks if any stores personnel p is ever transferred a requisition r.

The computer answers this by examing all transfers and seeing if, under any circumstances, they go to an individual who is in the STORES class and the object is in the requisition class. There is also a command to have the machine print all of the possible occurrences, and another command to cause the computer to print the circumstances under which the query could be true. If the query involves two or more commands, a complex matching scheme becomes necessary.

The query system should prove an effective tool for internal control system design. Although the query system cannot actually design such an internal control structure, it can answer complicated questions about a tentative structure, thus permitting alterations by the designer, accountant or auditor before implementation or use. In this way, an auditor can use the system to uncover potential internal control failures and adjust accordingly. Using this system, management could quickly discover who had access to some embezzled asset, or find out where missing forms were supposed to be. Moreover, with some fairly simple modifications, the existence of potential collusive groups and the capabilities of the collusive groups can be evaluated. The automated internal control analyzer can answer questions equally effectively about hypothetical or actual systems.

One final feature of the query system as it now stands should be elucidated. It is relatively inexpensive for the system to estimate the scope of the search required to answer a given query. As a result, the computer can give an estimate of worst case cost and time involved in answering a query before it has gone very far on its search. For this reason, the auditor need not worry about sending the machine on an overly costly search. The auditor himself can decide whether the question is worth the estimated cost, and in this way save both time and money.

The internal control description language is far more general than a flowchart description. The language can incorporate not only the basic flows most often presented, but with little expansion in effort, substanially more detail and precision is possible. Factors often noted in various "off the chart" methods such as memos can be directly incorporated in the description. Further, the ability to analyze and question characteristics of the described system is enhanced substantially. We believe that any existing, documented query can be analyzed by the system in greater depth and with greater assurance as to the correctness of the response than is now possible.

The computerization of the basic internal control description opens the way to developments beyond our current grasp. As accounting control systems become more computer dependent, this language will form a compatible integrated part of the systems operation and security, without fundamental alteration in concept. The auditor will be in a position to query the characteristics of these more advanced control systems. The current movement toward automated office systems requires a computer based data flow description process. Our model meets that need with auditability criteria at its center, something not often considered by other approaches to office automation.

We believe that the effort spent in developing this new concept in internal control description and analysis methodology has potentially high payoffs in application. Once the automated analysis system is operating, altering the model for firm changes becomes relatively easy. Furthermore, the analysis itself, being done by a computer, approaches the desirable goal of a continuous audit. Finally, the automated analysis is the first step in the pragmatic goal of auditing the office of the future, where much of the processing is done by machines [2].

TICOM II, when fully implemented, could serve as an excellent instruction tool for auditors and accountants. Because TICOM II can logically deduce internal control weaknesses in firm designs, students working with such a tool can gain invaluable insight into the auditing task in general and control theory in particular. One possible use is for the student to suggest potential remedies for internal control flaws. These would be analyzed by TICOM, providing students with instant feedback on the results of their proposed remedies.

BIBLIOGRAPHY

[1] Robertson, J.C., Instructor's Guide to Accompany Auditing, Revised Edition, Business Publications, Inc., 1979, p. 213.

[2] Bailey, A.D., Jr., Gerlach, J., McAfee, R.P. and Whinston, A.B., "Office Automation" Handbook of Industrial Engineering, Salvendy Ed. (John Wiley & Sons, Inc. New York, Forthcoming)