Causal Relationships between Improvements in Software Development Processes and Final Software Product Quality

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Abstract: A main assumption of software process improvement (SPI) is that improvements in a software development process result in higher quality software products. In other words, SPI assumes the existence of causal relations between process and product characteristics. To what extent have these causal relations, however, been explored? Which specific process improvements have which particular impact on which particular product quality attributes?

In this paper an overview is given of these "software process and product dependencies" (PPD). This overview comprises of a list of SPI-techniques and the associated product quality attributes that are addressed with these techniques. The extent of the causality is investigated and whether there is a possibility to identify more or less effective strategies for product quality improvement. The overview is based on a literature study and expert evaluation.

The research is summarised in a matrix of both software process elements and associated software product quality characteristics. This matrix contains both satisfactory and unsatisfactory results. On the one hand, a promising extensive base of publications on techniques and methods was identified. On the other, a disappointing deficiency of empirical validation regarding the actual impact of those techniques on product quality is also prominent. As it is, we remain with an inadequate and incomplete indication of the product characteristics that particular software process improvement techniques intend to ameliorate. This article, therefore, hopefully, also provides a basis for discussion on the need to make process-product dependencies more explicit.

Keywords: software development, software process improvement, learning, product-process dependencies, PPD.

1. Introduction

Software engineering is a relatively young discipline in which control over process, products and resources appears to be difficult (Humphrey 1989). Time and cost overruns frequently occur, leading to all sorts of product quality problems. These quality mishaps may cause dangerous situations in all kinds of areas. Well-known examples are airplane accidents, space-project failures, and automobile malfunctions all due to quality problems with software (Gibbs 1994; Glass 1998).

A number of 'good software engineering practices' have been defined, which should result in a higher probability of success (Humphrey 1989). These practices particularly refer to elements of the software development process that need to be fulfilled. The underlying assumption here is, that in order to make a high quality product, one requires to have a high quality development process. Consequently, the process depends on the requirements of the product. Improvement of software processes with the aim to improve the product, are grouped under the name 'product focused SPI' (PROFES 1998; 1999).

In the recent years software engineering has a tendency to move towards standardization of models, techniques and approaches. All models, techniques and approaches are packaged in state-of-the-art practice methodologies to support and enhance the software engineering industry. The general notion is that standardization and a methodological approach with structured steps and progress metrics will lead towards improvement of software-products. In this paper an overview is presented of the relationships between these best-practices and particular product quality characteristics. This overview should provide insight in which improvement to the development process is more suitable to improve which quality characteristic of the software product.

The overview is described according to the following steps:

1. Developing a process/product matrix. In this matrix the impact of actions in a development process and on a software product is illustrated. The axis of the matrix are defined as well as the scale on which impact can be measured (Section 3).

2. Surveying literature for process actions and identifying the impact of these actions on product quality (Section 4). An expert panel supports this identification.

3. Drawing conclusions from the matrix (Section 5).

The research was performed as part of the quality management initiative at Tokheim Industries and the EEC PROFES project.

2. Defining a process-product relation matrix

In order to support decision making regarding process-product relations, there needs to be a kind of representation that links these two dimensions (Hamann *et al.* 1998; Solingen 2000)[1]. Questions that should, for example, be answered are:

- What actions can be taken to improve software usability?

- When a particular working method is improved, what are the consequences for, for instance, maintainability?

- What alternative actions are there for unit testing that might have similar effects?

The information on the process side of the matrix indicates what (type of) process actions are available in the software engineering domain. The information on the product side indicates which product quality characteristics are influenced by one or more process actions. The cells express the extent of this influence. The resulting matrix of process actions and quality characteristics will then indicate what the impact of a certain process action will be on a certain quality characteristic or a set of quality characteristics, or indicate what process actions are influencing a certain product quality characteristic.

The product life cycle has been used to define the process side of the matrix. This is, because techniques can be applied in different phases of the development life cycle and may have different effects in different phases. For example 'reviews' have different effects depending on the life cycle phase: during requirements their impact is primarily on improvement of the 'functionality', while during 'coding' their impact is primarily on 'reliability' and 'maintainability'.

After studying sources of available product life cycle definitions and available processes, the following life cycle definition was used (based on: Bicego et al 1994; PROFES 1998; Pfleeger 1991):
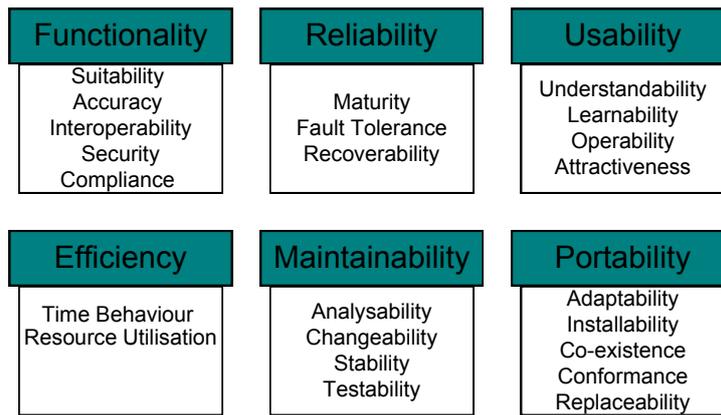
- Product Requirements Specification

- Product Architecture Development

- Design & Implementation

- System Integration and Testing

- Product Maintenance

- Product Improvement

All process actions that were identified in the literature, were categorised in the above life cycle stages. The detailed sub-phases of this life cycle model are listed in Appendix B.

The product side of the matrix is organised along a subdivision of software quality characteristics. Many subdivisions have been published in the past (e.g. (Boehm 1978; McCall *et al.* 1977). In this research we decided to select the ISO 9126 classification for software product quality (ISO/IEC 1994). The software quality characteristics are illustrated in Figure 1. More detailed definitions of the quality characteristics and sub-characteristics are listed in Appendix A.

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[1] A working example of a repository of product-process dependencies can be found in the PROFES PPD Repository (PROFES 1999).

Functionality	Reliability	Usability
Suitability Accuracy Interoperability Security Compliance	Maturity Fault Tolerance Recoverability	Understandability Learnability Operability Attractiveness

Efficiency	Maintainability	Portability
Time Behaviour Resource Utilisation	Analysability Changeability Stability Testability	Adaptability Installability Co-existence Conformance Replaceability

Figure 1: ISO 9126 software quality characteristics (ISO/IEC 1994).

A qualitative scale is used to express the extent of a process-product dependency, being:

+++ Highly positive impact, implying that the process action is expected to have a strong positive impact on a particular product quality characteristic.

++ Medium positive impact, implying that the process action is expected to have a significant positive impact on a particular product quality characteristic.

+ Low positive impact, implying that the process action is expected to have a modest impact on a particular product quality characteristic.

0 No Impact, implying that there is no impact expected (not to be confused by "unknown").

– Low negative impact, implying that the process action is expected to have a modest negative impact on a particular product quality characteristic.

–– Medium negative impact, implying that the process action is expected to have a significant negative impact on a particular a particular product quality characteristic.

––– High negative impact, implying that the process action is expected to have a strong negative impact on a particular product quality characteristic.

For instance: n-version programming is expected to have a high positive impact on 'reliability', a high negative impact on 'maintainability' and a medium negative impact on 'efficiency'.

3. Searching for literature on process-product relationships

A literature study is used to identify the various process-product relationships. The search for literature was performed in several ways:

- Top-Down. In the top-down approach the software product life cycle model was used to find process actions for each phase within the life cycle model. As the breakdown of the model indicates, the life cycle model was broken down into activities for each phase. In this approach, process actions were identified, which could be applied in the according phase for the completion of some activity (as defined in the list of activities).

- Bottom-Up. In the bottom-up approach the software product quality model was used to find process actions that contributed to, or had had an impact on, a certain quality characteristic. In this approach, process actions were sought which could be applied throughout all phases of the life cycle model.

- Middle-both-ways. In the Middle-both-ways approach a certain software engineering technique or method, also known as process action, is selected to identify its impact on a certain set of quality characteristics and its place in the life cycle. In this approach, process actions can be selected from experience and the literature can give an indication of the impact of the process action and the placement of the process action. This approach is most effective when the impact of a certain process action needs to be identified without any prior references.

Studies of best-practices appeared to be most suitable. Although, the amount of research on software engineering is, of course, enormous, it was surprising to us, that in only few publications the effectiveness of new methods is validated (for instance, through case studies). It was even more surprising that so few publications indicate to which specific quality characteristic a technique contributes. Most publications stated that their approach 'largely increased product quality', without indicating what this actually meant and how significant this increase was. For the detailed outcomes of the literature survey we refer to (Soerjoesing

1999). Notable publications were (Wichmann 1997; Peng & Wallace 1993; Vliet 2000; Gilb 1988; Lyu 1996; Paul et al. 1993). In a publication by the Software engineering Institute (1997) several error detection techniques are presented, including their impact on quality characteristics. This guide also includes a preferred set of techniques to improve processes. Overall, more than 100 publications were reviewed to complete the matrix of Appendix C.

Due to the absence on information about the detailed process-product dependencies in the existing literature, we had to use an alternate approach to filling the PPD matrix: expert judgement. An expert panel interpreted the publications with respect to the matrix of Appendix C. This expert panel consisted of two business experts and one academic expert. On basis of their (embedded) software development background, they assessed the information provided with the various techniques and scaled the expected impact on a particular software product characteristic. This assessment was essential, because many of the papers provided insufficient information for an unambiguous placement in the matrix.

The experts all had an extensive background in embedded software development, however, primarily in one particular industry (Tokheim Industries). Consequently, this could cause a bias in the matrix making the results to some extent industry specific. We would like to challenge other organizations to validate the matrix in their organization and report on their experiences. It is not our intention to post the PPD matrix as the industry-wide externally valid model for product-process dependencies. The model is intended as a more detailed approach for particular companies to assess product quality by addressing specific process aspects. Usage of this PPD matrix in one specific organization for product quality estimation (based on the process model and project plan) is described in (Solingen 2000).

The PPD matrix of Appendix C contains 467 PPD's. From these PPD's, 424 PPD's have a positive effect and 43 a negative effect. All product characteristics are addressed by process actions. The smallest number is 3 (for instance, Functionality-Compliance). The largest number is 69 (Maintainability-Analysability). The following number of improvement actions refers to the following software product characteristics:

- Functionality: 103;
- Reliability: 85;
- Usability: 63;
- Efficiency: 51;
- Maintainability: 142;
- Portability: 23.

This implies that suggestions for improving particular software product characteristics can derived from the PPD matrix for every software product characteristic. Furthermore, possible additional effects of particular improvement actions can be derived from the matrix, These additional effects may, of course, be welcome or undesired.

As such, the PPD matrix turned out to be an excellent check list for improvement actions and an effective way to communicate the effects of software process improvements among the involved engineers.

4. Conclusions

In this paper an overview is provided of process improvement actions and their most likely effect on specific software product quality attributes. This overview is summarised in the matrix of Appendix C. This matrix should enable researchers and practitioners to identify more (and less) effective strategies for software process improvement on basis of particular product quality weaknesses. The relationships are based on an extensive literature review and assessed by an expert panel.

The matrix can be used as a checklist, however it should also be usable as a kind of knowledge base. In this case, the software engineers of an organization complete the various relations in the matrix on the basis of new experiences.

The proposed framework is also suitable for the validation of new techniques. Researchers that propose new techniques are encouraged to find practical evidence that their approach actually affects particular process and product relationships. We consider the identified disappointing empirical evidence of existing methods and techniques as a major improvement action for software engineering researchers.

Acknowledgements

References

Bicego, S., Koch, P., Kuvaja, A., Krzanik, A., Mila, L., Saukkonen, G. (1994) "Software Process Assessment and Improvement: The BOOTSTRAP Approach", Blackwell Publishers.

Boehm, B.W., Brown, J.R. Kaspar, H., Lipow, M., McLeod, G., Merritt, M. (1978) "Characteristics of Software Quality", North Holland.

Curtis, B., Chrissis, M.B., Paulk, M.C., Weber, C.V. (1993) "Key practices of the Capability Maturity Model", Software Engineering Institute, Version 1.1. SEI-CMU-93-TR-25

Gibbs, W.W. (1994) "Trends in Computing: Software's Chronic Crisis", Scientific American, Vol. September, pp.86-100.

Gilb, T. (1988) "Principles of software engineering management", Addison Wesley.

Glass, R.L. (1998) "Software Runaways", Pearson Education POD.

Hamann, D., Järvinen, J., Oivo, M., Pfahl, D., (1998) "Experience with explicit modelling of relationships between process and product quality", Proceedings of the 4th European Software Process Improvement Conference, Monte Carlo, Vol . December.

Humphrey, W.S. (1989) "Managing the Software Process", Addison-Wesley.

ISO/IEC, (1994) Information Technology -Software quality characteristics and metrics- "Quality characteristics and subcharacteristics", part 1.

Lyu, M.R. (1996) "Software Reliability Engineering", IEEE CS Press, McGraw-Hill.

McCall, J.A., Richards, P. K., Walters, G. F. (1977) "Factors in Software Quality", National Tech. Information Service, Springfield, AD/A-049-014/015/055, Vol. 1,2 and 3

Peng, W.W., Wallace, D.R. (1993) "Software Error Analysis", National Institute of Standards and Technology, Gaithersburg, NIST Special Publication, March, pp 500-209.

Pfleeger, S.F. (1991) "Software Engineering: the production of quality software", McMillan Publishing, New York.

PROFES PPD (1999) Repository [online]: http://www.vtt.com/, PROFES Consortium.

PROFES User Manual (1998) [online]: http:/www.vtt.com/, PROFES Consortium.

Soerjoesing, S P. (1999) "Software quality improvement through product-process dependency modelling", Tokheim Report, Bladel. An electronic version of this report can be received on request to the authors.

Software engineering Institute (1997) "C4 Software Technology Reference Guide-A Prototype", Carnegie Mellon University, Pittsburgh, CMU/SEI-97-HB-001, January.

Solingen, R van (2000) "Product focused software process improvement: SPI in the embedded software domain", BETA Research Institute, Eindhoven.

Vliet, J.C. (2000) "Software Engineering", Principles and Practice 2nd Edition, Wiley.

Wichmann, B.A. (1997) Measurement Good Practice Guide No.5, Information Systems Engineering National Physical Laboratory, National Physical Laboratory, Middlesex, November.

Appendix A: ISO 9126 quality characteristics

Functionality	The capability of the software to provide functions which meet stated and implied needs when the software is used under specified conditions
Suitability	The capability of the software to provide an appropriate set of functions for specified tasks and user objectives
Accuracy	The capability of the software to provide the right or agreed results or effects
Interoperability	The capability of the software to interact with one or more specified systems
Compliance	Attributes of software that make the software adhere to application related standards or conventions or regulations in laws and similar prescriptions.
Security	The capability of the software to prevent unintended access and resist deliberate attacks intended to gain unauthorised access to confidential information, or to make unauthorised modifications to information or to the program so as to provide the attacker with some advantage or so as to deny service to legitimate users
Reliability	The capability of the software to maintain the level of performance of the system when used under specified conditions
Maturity	The capability of the software to avoid failure as a result of faults in the software
Fault-tolerance	The capability of the software to maintain a specified level of performance in cases of software faults or of infringement of its specified interface
Recoverability	The capability of the software to re-establish its level of performance and recover the data directly affected in the case of a failure
Usability	The capability of the software to be understood, learned, used and liked by the user, when used under specified conditions
Understandability	The capability of the software product to enable the user to understand whether the software is suitable, and how it can be used for particular tasks and conditions of use
Learnability	The capability of the software product to enable the user to learn its application
Operability	The capability of the software product to enable the user to operate and control it
Attractiveness	The capability of the software product to be liked by the user
Efficiency	The capability of the software to provide the required performance, relative to the amount of resources used, under stated conditions
Time behaviour	The capability of the software to provide appropriate response and processing times and throughput rates when performing its function, under stated conditions
Resource Utilisation	The capability of the software to use appropriate resources in an appropriate time when the software performs its function under stated conditions
Maintainability	The capability of the software to be modified
Analysability	The capability of the software product to be diagnosed for deficiencies or causes of failures in the software, or for the parts to be modified to be identified
Changeability	The capability of the software product to enable a specified modification to be implemented
Stability	The capability of the software to minimise unexpected effects from modifications of the software
Testability	The capability of the software product to enable modified software to be validated
Portability	The capability of software to be transferred from one environment to another
Adaptability	The capability of the software to be modified for different specified environments without applying actions or means other than those provided for this purpose for the software considered
Installability	The capability of the software to be installed in a specified environment.
Conformance	Attributes of software that make the software adhere to standards or conventions relating to portability.
Co-existence	The capability of the software to co-exist with other independent software in a common environment sharing common resources
Replaceability	The capability of the software to be used in place of other specified software in the environment of that software

Appendix B: List of life cycle phases for process dimension

1   Product requirement specification
1.1   Product requirement definition
1.1.1   Requirements gathering
1.1.2   Requirements definition
1.1.3   Requirements review
1.2   Feasibility study
1.2.1   Requirements analysis
1.2.2   Architecture specification
1.2.3   Project plan
1.2.4   Risk analysis
1.2.5   Technologies evaluation
1.2.6   Available designs evaluation
1.2.7   Product test plan Preparation
1.3   Application requirement specification
1.3.1   Product requirement analysis
1.3.2   Feasibility analysis
1.3.3   Application requirements specification
2   Product design
2.1   Functional design
2.1.1   Detailed product function design
2.1.2   Behaviour function analysis
2.1.3   Function structuring
2.1.4   Funct. product component mapping
2.1.5   User manual (functional) prototype
2.2   Architectural design
2.2.1   Detailed product architecture design
2.2.2   Design review
2.2.3   Technical product documentation
3   System design and implementation
3.1   Mechanical design and implementation
3.1.1   Mechanical design
3.1.2   Mechanical documentation
3.1.3   Mechanical design review
3.1.4   Mechanical component implementation
3.1.5   Testing of the mechanical components
3.2   Electronics design and implementation
3.2.1   Electronics design
3.2.2   Electronics documentation
3.2.3   Electronics design review
3.2.4   Electronic component implementation
3.2.5   Testing of the electronic components
3.3   Software design and implementation
3.3.1   Software design
3.3.2   Software documentation
3.3.3   Software design review
3.3.4   Software component implementation
3.3.5   Testing of the software components
4   System integration and testing
4.1   Product construction
4.1.1   Product components integration
4.1.2   Integration testing
4.1.3   Product documentation
4.1.4   Prototype building
4.2   Product validation
4.2.1   Unit testing
4.2.2   Prototype review
5   Production and Maintenance:

5.1   Pilot series production
5.2   Pilot series audit
5.3   Product installation
5.4   Product maintenance
5.5   Customer training
5.6   Customer support
6   Product Improvement:
6.1   Maintain product design
6.2   Defect reporting/tracking
6.3   Collecting Feedback
6.4   Monitor product quality
6.5   Product improvement area identification
6.6   Product follow up planning
6.7   Product improvement increment

Appendix C: Product and process dependencies matrix [7]

	Suitability	Accuracy	Interoperability	Compliance	Security	Maturity	Fault-tolerance	Recoverability	Understandability	Learnability	Operability	Attractiveness	Time-behaviour	Resource-Utilisation	Analysability	Changeability	Stability	Testability	Adaptability	Installability	Conformance	Co-existence	Replaceability
	Functionality					Reliability			Usability				Efficiency		Maintainability				Portability				
Product Requirements Specification																							
Argument-Based Design for Requirements	+++								+++						+++								
Feature-Based Design for Requirements Tracing									+++						+++		+++						
Feature-Oriented Domain Analysis	++								+++							+++							
Quality Function Deployment	+++														++								
Requirements Inspections	+++								+		+	+											
Requirements Metrication Report	+++								+		+				++								
Requirements Reviews	+++								++		++				++								
Requirements Tracing and Parsing	+++	+++							+++		+++				+++								
Software Requirements Review	+++								+		+				++								
Software Requirements Specification	+++														++								
Stress testing						++							+++	++									
Systems Requirements Analysis	+++										+				++								
Systems Requirements and Design Review	+++								+		+				++								
Product Architecture																							
Architectural Description Languages		+++				+++																	
Control Flow Analysis/Diagrams	+++														+++								
Data Flow Analysis/Diagrams	++														+++		++						
Design Reviews	+++	+				++																	
Design Verification Reporting	++	++				+									++								
ERD Diagrams	++														+++								
Formal Design Specification		+++				+++									+++								
Formal Design Verification		+++				+++			+++						+++			+++					
Function Point Analysis	+++	+++				+++																	
Hardware Prototyping (Design Validation)	+++								+++		+++	++											
Hybrid State Machines						++									+								
Object-Oriented Design	++	+				++									+++								
Simulation And Animation	+++								++		++	++	++	++	++								
Systems Specification and Design	++														++		++						
Systems Requirements and Design Review	+++								+		+				++								

Design & Implementation

	Functionality					Reliability			Usability				Efficiency		Maintainability				Portability				
	Suitability	Accuracy	Interoperability	Compliance	Security	Maturity	Fault-tolerance	Recoverability	Understandability	Learnability	Operability	Attractiveness	Time-behaviour	Resource-Utilisation	Analysability	Changeability	Stability	Testability	Adaptability	Installability	Conformance	Co-existence	Replaceability
FourGL-Programming						++							--	---		++							
Abstraction			++										-	--	+++	+++			+++	++	+++	+++	+++
Algorithm Analysis		+++				++	+++						++	-								+++	
Algorithm Formalization														++									
Algorithm Optimization																							
Application Programming Interface			+++	++												++	++						
Backward Recovery (Runtime Error Correction)		+++					+++	+++					-	-	+++								
Certified Components	++	+++		+++	+++	+++			+		++	+		-	--	-	++	0	0		+	0	
Checkpoint (Runtime Error Detection)							+++	+++															
Cluster Implementation							+++	+++						-									
Code Reuse	++	---				+++									++	++	+++						
Coding Standards															+++	++		+					
Compensation (Runtime Error Correction)		+++					+++	+++						-	--								
Compilation						+																	
Compression (Unit/Component Operation)													+	+++	---	---			--			0	
Data Encryption		--		+++									---	--		--		--					
Database Interaction Analysis		+++		+++																			
Description of Design Methods and Tools																							
Description of Programming Languages and																							
Description of Software Specification Methods																							
Exception handling (Runtime Error Correction)							+++	+++															
Executable Code Reporting																							
Expression Adjustability Analysis		+++													++	+++							
Expression Computability Analysis		+++				+++	+++								-			-					
Expression Effectiveness Analysist	-												+++	+++									
Expression Side-Effects Analysis		+++				+									+			+++					
Forward Recovery (Runtime Error Correction)		+++					+++	+++							+++	-		+					
Graphical User Interface Builders											+++	++	-	-		+++	++						
Input Checking Mechanisms		+++	++				+++			++	+++												
Module Interconnection Languages		++	++			+									+++							++	
N version programming (Runtime Error Handling)		++					+++																
Software Source Code Inspections		+++				+++									+++			+					
Source Code																							
Source code commenting															+++	+++		++					
Source Code Metrication Reporting						+									++								
Source code reading																							
Source Code Review Report						++									+++								
Object-Oriented Programming Languages																++	++	++	+++				
Program Description						+									++								
Recovery Blocks (Runtime Error Detection)							+++	+++						-	++	-							
Replication (Unit/Component Operation)							+++						-	-			---		--				
Software Design Description	++	++													++								
Software Design Review	++	++				+									++			++					
Software Design Walkthroughs	++	+++				+++									+++			+					
Principal Component Analysis		+++				+++									+++	++							
Queueing Theory Analysis	+												+++	+++									
Resource Sharing (Unit/Component Operation)							---	---						---		+++							+++
Scheduling Theory Analysis	+												++	++									
Separation (Unit/Component Operation)		-					++									+++							+++
Rate monotonic Analysis						+++							+++	+++	++								
Software Prototyping (Requirements Validation)	+++						+++		+++	+++	++	++											
Watchdogs							+++																
Variable Assignment Convention Application		+++													+			+					
Variable Commenting															+++								
Variable Naming Conventions															+++			+					

Group	Technique	Suitability	Accuracy	Interoperability	Compliance	Security	Maturity	Fault-tolerance	Recoverability	Understandability	Learnability	Operability	Attractiveness	Time-behaviour	Resource-Utilisation	Analysability	Changeability	Stability	Testability	Adaptability	Installability	Conformance	Co-existence	Replaceability
		Functionality					Reliability			Usability				Efficiency		Maintainability				Portability				
System Integration and Testing	Back-to-back Testing						+++																	
	Bad Data Testing (Unit Testing)		+																					
	Black Box Testing (Unit Testing)	++	++				++					++												
	Boundary Value Testing (Unit Testing)		++				+++	+++																
	Code Coverage Metrication	+					+++																	
	Cyclomatic Complexity Metrication						+									+++			+++					
	Discriminant analysis (Software Quality																							
	Efficiency and Performance Analysis													+++	+++									
	Field Testing	+++	+++				+++	0	+	++		++		++	++						++			
	Full Code Coverage Testing (Unit Testing)		+++				+++									+			++					
	Good Data Testing (Unit Testing)		+++				+									+			+					
	Integration testing		++				+++	+																
	Interface Testing And Analysis		++	++			++																++	
	Halstead Complexity Metrication						++									++	++		++					
	Logistic Regression (Software Quality Predictor)		+++				+++																	
	Min-Max Testing [Boundary Value Test]		+++				+++																	
	Object-Oriented Metrics for complexity reduction	0	++			0	+++			+++				0	0	++		0	+++					0
	Penetration analysis				+++		+					+												
	Regression Testing		+++				+++										+++							
	Source Code Test Planning and Reporting						++									+			+++					
	System Test Planning and Reporting	++	+				++	+		+		++		++	+	+			+					
	Testing	+++	+++				+++	+++		+		++		++	++	+			+					
	Unit Test Planning and Reporting	++	++				++							+	+	++			+					
	White Box Testing (Unit Testing)		+++																+					
Product Maintenance	Maintainability Index Technique															++	++	++	++					
	On-line Software Uploading												+		-						++	0	0	+++
Product Improvement	Video-assisted Product Evaluation (Usability)	++	+				+			+++	+++	+++	+	+++										
	Usability inspection	+								+++	+++	+++	++											
	User Documentation									+++	++	+++				+								
	User Documentation Review	++								++		++				+								
Baseline	Cleanroom Software engineering						+++			+++						+++								
	Component-Based Software Development						+++									--	++	+	--					
	Configuration Management	++														+	++	+	++					
	Document templates						+									+++	++		++					
	Organization Domain Modeling											++				+++								
	Personal Software Process for Module-Level		+++				+++									+++	++	++	++					
	Problem Reporting	++	++				+++									++		++						
	Quality Assurance Planning and Reporting																							
	Simplex Architecture						+++	+++							-	--	-	++	+					
	Software Development Planning and Tracking															++								
	Log files		++				++	++	++					+		+			+					
	Quality Profiling (Reliability)																							
	System Manuals									+						++								

The Effect of Information Systems on Firm Performance and Profitability Using a Case-Study Approach

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Abstract: Beale and Cole is a company that was experiencing significant levels of growth in its business. However, its existing operational practices and ICT infrastructure were incapable of efficiently sustaining their level of growth. A thorough analysis of the operational systems was carried out covering both the manual systems and those supported by its computerised accounting system. A number of beneficial changes were made, including the implementation of a major new business system replacing the old accounting system. In all these developments, the work of a teaching company associate, now known as knowledge transfer partnerships associate supported the analysis, but the full participation and support of all key personnel within the company was essential. Although there were problems during the implementation, these have being resolved and Beale and Cole now has a fully supported and integrated IT system which will maintain their competitive advantage and facilitate their continued growth and profitability.

Keywords: information, communication and technology (ICT), business systems integration, SMEs.

1. Introduction

A business information system is defined by Hooper and Page (1997) as "the sum of all the tools, techniques and procedures used by the business to process data". Fisher and Kenny (2000) suggested that organisations infuse information systems into their operations so as to enhance competitiveness and facilitate business growth and success. On the other hand, Laudon and Laudon (2001) believed that information systems are embedded in organisations and are the result of standard operating procedures, work flows, politics, organisational culture and structure. Although organisations have different information systems because they have varying information needs, they all strive for competitive advantage through continuous improvement; re-evaluation of the effectiveness and efficiency of their business information system (Chaffey and Wood 2005). The purpose of this paper is to investigate the Information System of Beale and Cole, to examine the course of action taken to implement changes to the existing IS practises, and to share experiences and lessons learnt from the change process and the effect on the organisation's performance.

Beale and Cole Building Services was established in 1967. The company started out in Exeter as a small family business but today, it is one of the leading firms of building services engineers in the South West of England with branches in Exeter, Yeovil and Plymouth. The company has witnessed a significant level of growth over the years. However, the existing operational practises, processes and supporting Information, Communication and Technology (ICT) infrastructure were inadequate to efficiently sustain this level of growth.

Subsequently in the summer of 2003, Beale and Cole in partnership with the University of Plymouth embarked on a Department of Trade and Industry (DTI) funded initiative known as the Teaching Company Scheme (TCS) now called Knowledge Transfer Partnerships (KTP). The main objective of this coalition was to implement new integrated business and supporting IT systems which would streamline operations, increase internal efficiency, facilitate sustained growth and increase profitability.

In order to achieve the objective of this investigation, a Knowledge Transfer Partnerships Associate with a background in business information management systems was recruited to conduct an in-depth analysis of the business information system and to propose and implement recommendations for improvement. Therefore, this paper will reflect on the experiences of this process by all parties involved in the project including management and staff of the organisation.

2. Initial review of Beale and Cole's information systems

This stage was conducted by the associate, Matthew Simmons. The first step was to review the internal processes and existing Information systems in the organisation so as to highlight the major problem areas. The main problems were found to be; duplication of effort, inefficiency in some processes including e-commerce strategy and problems with communication.. We developed a simple model, shown below, to explain all the main problems in detail and to highlight the impact of the improved information systems on operational performance and profitability in the organisation.
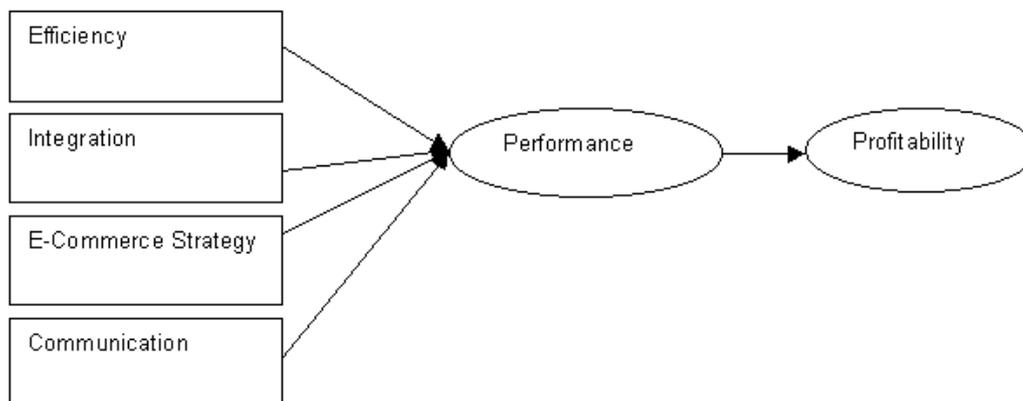
Model 1: Proposed framework for the effect of information systems on performance and profitability

2.1 Efficiency

The unprecedented expansion and consequent physical and commercial growth of the organisation opened up crevices in the organisation's business processes.

Nicholls-Nixon (2005) found in his study that rapid growth in business generates dramatic changes in the scale and scope of a firm's activities. According to her, entrepreneurs in rapidly growing business enterprises experience more difficulties in comparison to small growth companies when deciding or establishing the type of changes or evolution required to support their level of growth. This is because they face greater managerial complexity than slow growth firms. One of the solutions she recommended to solve this complex issue was that high growth organisations should develop new skills and capabilities which will allow them to cope with the complexity. This can be attained by appointing new personnel or acquiring new resources such as new information systems targeted at improving organisational efficiency and effectiveness.

The main problem area highlighted by the associate was the organisation's accounting system. The company's business system had been purchased from a software company many years ago. Initially, the software was run on a leased line which was very expensive. This was later changed to a Virtual Private Network (VPN) by the associate thereby greatly reducing the operating cost.

The software was supposed to be an extensible accounting system capable of managing all financial aspects of the organisation and though it appeared to be a tool that can be fully integrated with MS excel or access so as to facilitate data analysis and report creation; it would have required a database translation to function effectively. However, as the structure of the database was weak, translating it would have been very difficult, time consuming and cumbersome. Moreover, the system was generic, had limited documentation which was very difficult to understand and as it was outdated, the system would have failed to meet legislative regulations by 2007.

Furthermore, the software company had since changed ownership. Presently, their have been no new developments but extensions and upgrades to their existing software. Although the supplier offered these more up to date upgrades (which was not free), it still appeared to use some of the features that proved unsatisfactory in the original system. Another drawback to using this system was the maintenance agreement. Although it had been properly structured, it was however inconvenient as the software company had a third party agreement with another company which managed the maintenance of the software. Invariably, turnaround time for maintenance could sometimes be very high, prolonged and time consuming.

Another operational concern was that the company had not altered its recording procedures despite its rapid growth. The method used for monitoring labour needed to be improved as it was not centralised and was

deficient in forward planning. The job costing system that was used did not take into account the availability of labour while there was a lack of consistent structure in the recording of unstructured information about projects. Although a manual index of documents was stored online, it had become ineffective since the organisation had expanded to a second location.

A manual procedure of operation that needed much improvement was the time sheet recording. This involved engineers completing a complex time sheet which would then be faxed to the office for the contracts manager to check and calculate the necessary payment agreements. Once this stage had been completed, the time sheet would be passed on to the administration department where the time would be checked again before inputting it onto the system. Finally, the information would be printed out so that the details can be used to generate the engineers' wages. This procedure would normally take about 6 office hours and would involve about 60-70 engineers, all the contracts managers (7), 2 administrative assistants and a payroll officer.

2.2 Lack of uniformity and integration

The major concern was that there were many bespoke systems and undocumented manual system, and very little uniformity in operational procedures. This followed from the recent merging of a part of the company specialising in plumbing with the original business which specialised in electrical services. Crist (2002) observed a similar situation in his study suggesting that "traditional document control processes were usually a combination of manual and electronic systems which may result in duplication of effort and further expenditure of time". Winch and Carr (2001) recommended that an appropriate remedy was to use process mapping which focuses on actual flows of information within the organisation. They maintain that this method is less demanding with regards to resources and engenders a process whereby there are standardised protocols for business operations. Furthermore, Fisher and Kenny (2002) pointed out that there were two mandatory steps required to implement an organisation-wide information system and these are; well designed set of business processes or value chain and secondly, a cautious exercise in strategic thinking, operational planning and consultation with all end users of the system to facilitate user satisfaction and in turn better use of systems and improve performance.

Researchers like Weill and Baroudi, (1990) cited in Caldeira and Ward (2002) and Delone and Mclean (1992) established that user satisfaction was the most widely used variable for measuring IS success because there exists a strong correlation between this variable and firms' performance. However, other studies by Kim (1989) and Melone (1990) have disputed these findings as inconclusive because user satisfaction failed to consider the diverse roles, needs and interests of the users. In this study, a thorough analysis of the alternative systems was carried out by the associate and involving all the main users of the system to enhance user satisfaction. However, some users were initially opposed or averse to the change, while others had mixed feelings. The observation and interviews showed that with gradual induction of changes and good training, this might lead to improvement of performance.

2.3 e-Commerce strategy

Although Beale and Cole had a website, it did not give a clear and up to date picture of who they are and what they had achieved. The deficiencies apparent on the website meant it could not be effectively utilised as a strategic e-commerce tool for marketing the company's services. Taylor and Murphy (2004) highlighted that E-commerce strategies can be adopted by Small and Medium Enterprises (SMEs) for customer base expansion. Other researchers suggested that e-commerce strategy enhances performance in general and time-based delivery performance in particular (Jeffcoate, J., et al. 2002; Iyer, Karthik N.S., et al. 2004).

2.4 Communication

Information in the organisation was stored at a very high cost rather than being shared. The main modes of communication within branches were through phone and fax, face to face and limited use of e-mail, while for customer and suppliers, telephone and fax were used. There were also the lack of network capabilities for file sharing and organised postal system and no internal communications link for the offices. This translated to increased expenditure on telephones.

This existing communication arrangement promoted data duplication, loss of information, elongated processes and increased time frames for decision making. A lot of studies showed that clear communication channels within the organisation and between the organisation and its customers have a positive effect on firm performance, see for example (Carr, Amelia S. Kaynak, Hale, 2007).

3. Research methodology

This article describes qualitative research into the case study company through a series of in-depth interviews and observation. The evidence from the interviews and observation are compelling, and therefore the overall study is more robust. One of the limitation of case study is that it provides little basis for scientific generalization. To overcome this problem and for future research a multiple case studies approach is required. Multiple case studies are generalizable (though not necessarily to multiple populations or contexts).

4. Implementation of improved systems

To eradicate these deficiencies, a number of changes were made to the existing system. Where possible, the systems which differed on the two sites but served similar purposes were amalgamated and integrated. These changes were supported by a similarly configured file server with a permanent line between them.

The initial enhancements included

1. The introduction of electronic time sheets which has eliminated duplication reduced payment errors by 99.9% and saved 3 staff members half a day per week.

2. Improvements to the telephony system and a change of supplier saved an estimated 312 person hours per year and reduced expenditure considerably.

3. Standardisation of forms and procedures between sites, eliminating duplication of activity, reducing error and improving communication.

4. Enhanced data security through integrating the IT and communications system, improving their reliability, robustness and increasing user confidence.

5. Implementation of a suitable filing structure reduced time spent locating files and enabled improved archiving capabilities.

6. Design and development of the website by an external developer. The site now has a professional image and highlights areas of specialisation of the company and past projects executed. Further developments will be made in the future to incorporate the website onto the business system.

After the successful implementation of a number of immediate improvements, it was further decided that the old accounting business system should be replaced. Numerous studies by (Delone and McLean, 1992; Yap et al 1992; Doukidis et al, 1994) have pointed out the importance of involving all key employees at this stage of the project in order to obtain commitment to the new system. In Beale and Cole, user participation and commitment was achieved through several brainstorming sessions, meetings and thorough analysis of the alternative systems with all the main users so as to agree on the selection criteria and which package best met those criteria.

There were clear differences of opinion about which was the best package for the company's needs. This was probably due to the superiority of one package for the estimating and costing side of the business and another for the financial reporting side. However, the full participation of all key members of the company ensured that there was a high level of commitment when the final choice; Estimation software, an industry specific software package came to be implemented.

The Estimation Plus software was easier to use than its predecessor and allowed greater control. Some of the functionalities of the system were:

1. It was segregated into sections and order list, which made it possible to determine materials required for a building and individual rooms within the building.

2. Price enquiries could be sent to suppliers and purchasers.

3. It made it possible for engineers to purchase materials through the system.

4. Enquiries on job details and all contracts can be easily accessed.

5. Outstanding debtor balances are effortlessly produced.

6. The system allows users to create many of their own reports and also provides management reports which can analyse the business from 15 different perspectives.

5. Experiences gained from the implementation and impact of the systems change

The selection and implementation process took place during a period of rapid growth for the company. Consequently, all concerned were experiencing pressure on their time. The time taken to complete the selection process therefore exceeded the time planned. In an attempt to restrict the degree of consequent slippage in the implementation date, the time analysing the detailed requirements for implementation was restricted. Therefore all the areas of the business system were not completely configured before commencing the phased in implementation. They discovered after implementing some areas in the estimating and accounting software that some aspects of the system should have been done earlier. Consequently, some of the decisions taken such as cost code allocation were regretted and corrected. With hindsight, we feel that more time should have been spent getting used to the package under test conditions before its full scale implementation.

Although the new system is still in its early period of operation, there is wide agreement within the company that operational processes within the company are now running much more efficiently:

1. The communications system has been streamlined. Consequently, there is improved integration and communication, particularly between the Exeter, Yeovil and Plymouth sites.

2. Enhanced customer communications and improved opportunities for maintaining excellent customer relations.

3. Improved management information for tactical and strategic planning and control.

4. The documentation of systems and processes to ISO standards provided a framework for future developments in the organisation.

5. The company has the potential and capacity for more rapid expansion and business growth.

6. There has been increased turnover through business growth

7. Implementation of improved business system has increased profitability and improved cost control in the organisation.

8. The reports produced by the business system make information for decision making readily available to managers.

Presently, the company is considering the procurement of an electronic trade e-invoicing system which would be integrated into the business system. This e-invoicing would eliminate the need for manual input of invoices, greatly enhance cost control and reduce transaction and overhead costs.

6. Conclusion

This study describes the experiences and lessons learnt at Beale and Cole as they implemented changes to their existing IS practises in order to support the level of growth of the business. Initially, the change brought about mixed reactions, some doubt and some opposition amongst employees but these were gradually eliminated through their involvement in the search for alternatives and in the implementation stage of the change process. During the implementation stage, some teething problems were encountered. This was because the time frame allowed for implementing and studying the new system was restricted thereby leading to some errors but these were subsequently corrected.

These changes to the organisation's operational practises, business system and ICT infrastructure have improved operational processes and efficiency of the company. Consequently, this has reduced operating and transaction costs, increased turnover and enhanced profitability. The introduction of this fully supported and integrated IT system will serve as a strategic tool for Beale and Cole to sustain its continued growth and maintain its competitive advantage as one of the leading building services company in the South West region.

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References

Carr, A. and Kaynak, H. (2007) "Communication methods, information sharing, supplier development and performance: An empirical study of their relationships", *International Journal of Operations & Production Management*, Vol. 27, No. 4, pp 346 - 370

Caldeira, M. and Ward, J. (2002) "Understanding the successful adoption and use of IS/IT in SMEs: an explanation from Portuguese manufacturing industries", *Journal of Information Systems*, Vol. 12, pp 121-152.

Jeffcoate, J., Chappell, C. and Feindt, S. (2002) "Best practice in SME adoption of e-commerce, Benchmarking", *An International Journal*, Vol. 9, No. 2, pp 122-132.

Iyer, K., Germain, R. and Frankwick, G. (2004) "Supply chain B2B e-commerce and time-based delivery performance", *International Journal of Physical Distribution & Logistics Management*, Vol. 34, No. 8, pp 645-661.

Chaffey, D. and Wood, S. (2005) *Business information management: Improving performance using information systems*, Pearson Education Limited, Essex.

Delone, W. and Mclean, E. (1992) "Information systems success: the quest for the dependent variable", *Information systems Research*, Vol. 3, No. 1, pp 60-95.

Fisher, B. and Kenny, R. (2000) "Introducing a business information system into an engineering company", *Journal of Information, Knowledge and Systems Management*, Vol. 2, pp 207-221.

Doukidis, G., Smithson, S. and Lybereas,T. (1994) "Trends in information technology in small business", *Journal of End User Computing*, Vol. 6, No. 4, pp15-25.

Laudon, K. and Laudon, J. (2001) *Essentials of information systems: Organization and technology in the networked enterprise* (4th ed.), Prentice Hall, New Jersey.

Hooper, P. and Page, J. (1997) "Organising information and data flows in business systems", *National Public Accountant*, Vol. 42, Issue 9, pp 9-14.

Kim, K. (1989) "User satisfaction: a synthesis of three different perspectives", *Journal of Information Systems*, Vol. 4, pp. 1-13.

Melone, N. (1990) "A theoretical assessment of the user satisfaction construct in information systems research", *Journal of Management Science*, Vol.36, Issue. 1, pp 76-91.

Nicholls-Nixon, C. (2005) "Rapid growth and high performance: The entrepreneur's impossible dream", *Academy of Management Executive*, Vol.19, No. 1, pp77-89.

Taylor, M. and Murphy, A. (2004), "SMEs and e-business, Journal of Small Business and Enterprise Development", Vol.11, No. 3, pp 280-289.

Weill, P. and Baroudi, J. (1990) *An empirical investigation of the relationship between firm performance and systems success*, Working paper No.15, University of Melbourne, The Graduate School of Management.

Winch, G. and Carr, B. (2001) "Process, maps and protocols: Understanding the shape of the construction process", Journal *of Construction Management and Economics*, Vol.19, pp 519-531.

Yap, C., Soh, C. and Raman, K. (1992) "Information systems success factors in small business, Omega International", *Journal of Management Science*, Vol.20, No. 5/6, pp 597-609.

Heuristically Evaluating Greek e-Tourism and e-Museum Websites

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Abstract: The Internet and its World Wide Web service have reshaped the promotion of cultural and tourism products. Well designed and user adaptable e-commerce websites improve business promotion as they attract more e-visitors. Multilingualism, dynamic and thus frequently updated content, email communication and searching capabilities are crucial options of websites. In this paper we empirically build an evaluation methodology to assess the technologies and services of Greek e-tourism and e-cultural websites. The primary focus of our work is to evaluate the technical capability of tourism and cultural websites and to realize the available options offered to users. A number of tourism e-commerce websites and e-museums were randomly selected and their content and technologies were analyzed based on the methodology proposed. The results of this statistical examination are analyzed and discussed. The main conclusion is that although the reviewed websites are rich in multimedia content they need to support customers more efficiently by offering more services or by refining the offered e-services.

Keywords: e-museums, usability of cultural websites, e-tourism, e-commerce

1. Introduction

The advent of Internet reshaped the promotion of tourist and cultural products and their respective teaching demands (Connolly et al., 1998; Sigala & Christou, 2002). Well designed and user adaptable e-commerce websites improve business promotion as they attract more e-visitors. Actually, many factors are affecting website success. Much has been written about the design of websites regarding human engineering, user interface, business, and usability perspectives (Susser & Ariga, 2006), and numerous web design checklists have been developed for the purpose of identifying design and evaluation criteria (Zhang & Dran, 2000). It is noteworthy that Law and Bai (2006) review the published articles on website development and evaluations in ENTER Conference Proceedings from 2000 to 2005 and the Journal 'Information Technology & Tourism from 2000 to 2004. Hamil and Gregory (1997) suggested that successful website characteristics include information richness, regular updating, clear information paths, interactivity, and responsiveness to user feedback. Therefore, multilingualism, dynamic and thus frequently updated content, email communication and searching capabilities are crucial options of websites.

Internet is the easiest distribution channel and the most cost effective method to reach customers around the globe. Effective tourism websites should be dynamic, subject to constant update, innovation and management (Lazarinis et al., 2002; Albert et al., 2004). Several tourist agencies and cultural institutes have created online hypermedia presentations. The common aim of all these websites is to effectively promote the agency's products. To attract more e-visitors, the websites should be easy to use and attractive. Large tourism agencies and e-museums such as the British Museum (www.thebritishmuseum.ac.uk) maintain websites developed with dynamic Internet and multimedia technologies. Web pages are categorized according to their content to help visitors discover the information needed.

Greece is a country with many tourist and cultural heritage attractions. However, since most of the agencies are small, targeting usually in the Greek market, it may be the case that some websites are static or with a limited number of services. Deimezi and Buhalis (2003) report the findings of a series of interviews with Greek tourism agents. The majority of the responders stated that Internet bookings count for up to 5% of their reservations. Lack of knowledge on how to manage and market the website was identified as the limitation. Therefore, it is vital to examine users' perceptions about Greek cultural and tourism organization websites because these views give a clue to manage these website effectively and determine the eventual success. To the authors' knowledge, there are no research efforts to evaluate Greek cultural and tourism organization websites. A few research efforts focus on the hotel industry (Zafiropoulos & Vrana, 2006). Generally, there is no universally accepted method for a website evaluation. Nevertheless, the evaluation methods can be grouped in two broad categories: (a) automated methods which are based on automatic

tools able to capture, technical characteristics such as response times, conformance to language standards, or structural coherence; (b) heuristic usability methods: where casual or experts judge whether each element of a web interface follows pre-determined usability and aesthetic principles. The number of evaluators is an important element to derive a significant result from the website assessment, and the experience of the evaluators may reduce the number of evaluators needed. Time and cost considerations suggest to find ways to reduce the number of evaluators needed while assuring a reasonable statistical significance of the results (Corigliano & Baggio, 2006).

To estimate the dynamicity or static nature of the websites of the Greek cultural and tourism organizations (and their services) we assembled nine features, which most of the worldwide e-tourism and e-museums websites have. We concentrated on the Internet technologies utilized and on the wealthy and maintenance frequency of the supported services. Our primary focus is to realize whether the technologies utilized by Greek e-tourism and e-museum websites add value to the online visitors. Secondly, we introduce a quality vector to evaluate the quality of such type websites. The proposed quality vector has two elements: Total Quality = {Quality $_{Offered\ Services}$, Quality $_{Content}$}.

The evaluation of Greek tourism agencies and museum websites will provide managers with key information useful to maximize the returns (tangible or intangible) a realization can offer, and it can help studying the behaviour of the users and their interactions to the contents and services offered online. Web developers working for similar tourism organizations of other countries can adopt the proposed methodology.

The remainder of the paper is organized as follows. In section 2 the proposed methodology and the sample of the study are presented. Next, the criteria and the statistical analysis of the evaluation are presented. Section 3 synopsizes the conclusions and presents some future work.

2. Evaluation study

2.1 Methodology and sample

The need to evaluate the multimedia presentations of e-museums and e-tourism websites has been long identified (Dierking & Falk, 1998; Werthner & Klein, 1999; Cunnliffe et al., 2001)). Nevertheless most of the evaluation attempts focus on large-scale companies or are general discussions of the desired features of e-Commerce websites for tourism and culture (Nickerson, 2004). Small and medium sized agencies and institutions have been overlooked although they represent the majority of the existing agencies, especially in small countries like Greece. In this study, we focus on small museums and tourism agencies and we assemble a compact methodology for evaluating their technological features. Cultural and tourism agencies are evaluated together since in both cases these websites try to promote their products and to attract more e-visitors, although their purpose is somehow different. But since the evaluation is performed under the perspective of the technologies used they can be assessed together.

The study reviews 10 websites of tourism agencies and 10 e-museums. These websites are representative sites and were gathered from advertisements in local newspapers or by searching the Internet. In particular, the majority of the domains of the online museums were referenced and linked in the web pages of the Hellenic Ministry of Culture. All tourism agencies reviewed possess a .gr domain and offer various services, such as national or international tours, hotel bookings and airline or boat tickets. The selection of websites was random among a more extended list of e-museums and tourism agencies possessing a ".gr" domain. Table 1 shows the URL addresses of the evaluated websites.

Table 1: Tourism and cultural heritage websites

Tourism agencies	Cultural heritage websites
http://www.24hours.gr	http://www.benaki.gr
http://www.acadimostravel.gr	http://www.emst.gr
http://www.aristotle.gr	http://www.gnhm.gr
http://www.ginis.gr	http://www.karagiozismuseum.gr
http://www.grecian.gr	http://www.mbp.gr
http://www.gulliver.gr	http://www.nma.gr
http://www.pyramis-travel.gr	http://www.petrifiedforest.gr
http://www.signature.gr	http://www.thmphoto.gr
http://www.travelland.gr	http://www.tmth.edu.gr
http://www.travelware.gr	http://www.vrellis.org

During September 2006, the evaluation took place in the Technological Educational Institute of Patras. The human subjects (evaluators) who participated in the research were 25 students, 20-24 years old, registered in the third year of the 'Tourism Management' curriculum. All human subjects who took part in this evaluation were attending the course 'Internet and Tourism Enterprises' that forms part of the Computer Science curriculum. These students represented a wide range of achievement levels and were coming from a variety of social-economic background. Many more females (15) were enrolled in the research than males (10). Most of the students (93%) had computer skills and Internet usage experience (84%). We used the bootstrapping method (Efron & Tibshinary, 1993) for estimating the sampling distribution of an estimator by resampling with replacement from the original sample. Using the bootstrapping method, the confidence interval is approximately 5,4% with 25 evaluators. We may say that at 95% CL (confidence level), there is a 5,4% error on the final evaluation estimate, as it is conducted by 25 students (randomly chosen among the users).

The evaluation was deployed in two phases. Firstly, in the analysis of the offered services, the websites were visited by students so as to identify and record features such as multilingualism and the technologies utilized. During the content analysis phase, websites were checked twice, in a month's time, for broken links and changes in structure and content. These checks were performed using a link checker [http://home.snafu.de/tilman/xenulink.html] and a Web page content change monitor [http://aignes.com/]. The aim of these tests was to realize if there are broken links, to see if the content and/or the structure are regularly updated to reflect the dynamic character of tourism and cultural heritage promotion and to obtain statistical information about the visited websites.

Total Quality = {Quality$_{Offered Services}$, Quality$_{Content}$}.

If we have `n` offered services under consideration, the Quality$_{Offered Services}$ $= \sum_{i=1}^{n} c_i s_i$ where `s`$_i$ are the following attributes. In our case `n=9,` and if all coefficients `ci` are equals, then `c`$_i$`=1/n`)

During the first phase, the websites were visited by 25 students so as to identify specific attributes. These attributes are:

- Multilingualism
- Web technologies
  - Static (Text, HTML)
  - Dynamic (JSP, ASP, PHP, CGI, other)
  - Flash
  - XML
- Online booking/Event booking
- E-mail support
- Online payment

- ▪ Searching facilities

- ▪ Offers/Announcements

- ▪ Forum/Guest book

- ▪ Adaptivity/adaptability

These attributes were empirically selected and they form a minimum number of services, which should be offered to e-customers. Offers and online payment relate to tourism websites and announcements and event booking relates to cultural heritage sites. Clearly, when we visit a cultural or tourist promotion website, we would like to be able to view the information in our language, to be able to search for specific information and also to be able to communicate by email with the agency. Also, visitors are always interested in offers and special events.

2.2 Analysis of services

The URL locations mentioned in Table 1 were browsed with Internet Explorer and Mozilla Firefox so as to ensure that no compatibility problems exist. Indeed no incompatibilities and errors occurred based on the browser used.

2.2.1 Multilingualism

The first attribute concerns the natural languages supported in the websites reviewed. 9/10 tourism websites support Greek and a few present the information in English as well. All cultural heritage websites are bilingual. A small number of the other main European languages are sporadically supported. Additionally, few Balkan languages such as Bulgarian or Yugoslavian were also recorded during our assessment.

Table 2: Multilingualism of tourism and cultural websites

	Greek		English		More languages	
Tourism agencies	9	(50%)	10	(100%)	3	(30%)
Cultural heritage sites	10	(100%)	10	(100%)	1	(10%)

This finding shows that the Greek agencies realize that in the era of internationalization, presenting the information in English (in addition to Greek) it is a quite important requirement, as it allows people from other countries or people from Greece whose mother tongue is not the Greek to view the content of the websites. However, we should underline the fact that the English versions of the web pages are more limited in their content. In other words, not all the Greek web pages have been translated to English.

2.2.2 Web technologies

The enabling technologies for building tourism websites are numerous (Kappel, 1998; Kanellopoulos et al, 2004). These vary from simple text presentations to dynamic tools such as JSP (Java Server Pages) to interactive hypermedia tools such as Flash and VRML (Virtual Reality Modeling Language). Cultural and e-commerce websites need to be well designed and appealing so as to attract more e-visitors.

The majority, 70%, of the Greek tourism e-commerce websites reviewed are developed using dynamic technologies such as ASP and PHP. The remaining 30% of the tourism websites uses standard HTML, a static technology. The situation is quite opposite in the Greek e-museums. 90% of them are based on HTML and only 10% is based on dynamic technologies.

Flash presentations offer rich interactive multimedia and appealing experiences to e-visitors. This added value to customers enables them to assimilate easier the presented information and to form a clearer and desirable idea of the product. 20% of the tourism e-commerce websites and 20% of the cultural heritage www locations utilize Flash as well. Flash and VRML would significantly enhance e-museums as it would allow visitors to view animations and 3D designs of the exhibits and possibly to interact with them. These virtual tours are a common practice in some major websites of museums, e.g. British Museum (www.thebritishmuseum.ac.uk), Museum of Louvre (www.louvre.fr).

XML is a markup language for documents containing structured information. It deals only with the structure of the document and not with the display format. Web documents could subsequently be formatted and dynamically displayed in various ways. RSS (http://www.xml.com) is a format, based on XML, for syndicating news and the content of news-like websites. These technologies could enable the straightforward creation of newsletters or the automatic creation of summaries of altered documents found in a site, which could then be

forwarded to registered clients. In general XML allows for unlimited customization of the web content based on user preferences or other factors. None of the visited sites utilizes XML, a fact that prevents customers from taking advantage of these features. Sharing of digital content is a desirable feature among cultural heritage websites (Gill & Miller, 2002). This feature is only possible when the content is coded in XML.

2.2.3 Online booking/Event booking

The primary and ultimate reason for the existence of an e-commerce website is to allow customers to purchase the offered products online. E-tourism websites should therefore support online buying of tours. E-museum websites should offer their customers their ability to book places for special events.

Online purchasing is supported by 70% of the tourism websites under inspection. The few websites, which do not support this option, encourage their clients to contact them by email or phone so as to make the reservation. Event booking is not possible to any of the cultural online presentations.

2.2.4 E-mail support

E-mail is globally used for communication between clients and companies and several problems can be promptly and inexpensively solved. Promotional information can be send to clients, tailored to their preferences. All tourism and cultural websites reviewed in this study include an email address in their web pages via which clients can contact them.

However, when specific questions were addressed to them via email it was made clear that a few agencies do not utilize the email facility suitably. 40% of the travel agencies and 30% of the cultural organizations prompted us to communicate by phone so as to clarify our questions. All the other tourism and cultural agencies replied to this e-mail communication giving specific answers to the questions posed.

2.2.5 Online payment

Law and Wong (2003) identified the three most important factors in a successful website as being "secure payment methods," "different price ranges for products/services," and "user-friendly systems".

Online charging of credit cards for reservations or events is only possible to 10% of the tourism websites evaluated and to none of the e-museums. For e-museums such an option may not sound quite useful but for tourism agencies such an option is, indisputably, of crucial importance. Almost all of the main European travel agencies support online payment. The technology for integrating this option is easy and could be even achieved through initiatives such as paypal (www.paypal.com), a tactic adopted by many organizations and events.

2.2.6 Searching facilities

Discovering specific information on a website is of crucial importance, especially when websites are complex and contain several web pages. Table 3 shows that most of the tourism agencies offer limited or no searching facilities. By 'limited' we mean the ability to search information setting specific criteria, for one or more types of the available services but not for all the available services. The majority of the e-museums do not support searching of their pages according to user specified criteria. This service could be of real value to e-visitors as the majority of the e-museums are consisted of hundreds of HTML pages (Liew, 2005).

Searching capabilities could be offered through the utilization of generalized search engines, such as Google. However this tactic would not be suitable for searching tourism and cultural websites as they do not provide specialized options for date and place-name based criteria and do not truly value all the particularities of the Greek language (Lazarinis, 2005).

Table 3: Searching facilities

	Full searching		Limited searching		No searching	
Tourism agencies	1	(10%)	4	(40%)	5	(50%)
Cultural heritage sites	2	(20%)	0	(0%)	8	(80%)

2.2.7 Offers/Announcements

Several online tourism offices maintain a special offer session, which provides customers with the ability to make "last minute" purchases or to take advantage of special offers. 50% of the visited Greek tourism Internet locations contained such a session in a distinct central position.

Most of the cultural websites (60%) include online announcements in their web pages. This is a useful feature as it allows the visitors to be informed promptly about future events. However, most of the announcements are outdated, which is an indication that these websites are not properly and regularly maintained.

2.2.8 Forum/Guest book

Guest books and forums are two options that could let customers and visitors share their opinions and experiences. These two options could lead to the creation of online communities of interest, which could help customers in decision-making and companies improve their services. None of the visited tourism Internet locations offer such a possibility. On the contrary, 30% of the e-museums reviewed offer guest books, allowing their visitors to make constructive comments and share thoughts about the exhibits.

2.2.9 Adaptivity/adaptability

Adaptivity and adaptability are two relatively new research areas with applications, among other fields, to education and to tourism (Brusilovskly, 2001; Kobsa, 2001; Kanellopoulos & Panagopoulos, 2007). Adaptive systems build a model of the preferences, characteristics and navigation behavior of an individual and use this model in order to adapt to the needs of that user. Adaptivity is the ability of the system to adapt to user needs and adaptability is the ability of users to adapt the working environment to their preferences. Personalization techniques have already been applied to tourism research projects (Kobsa & Fink, 2002). Several online shops (e.g. www.amazon.com) or airline companies (e.g. www.easyjet.com) already employ similar techniques to suggest relevant products or to guide the users to the most relevant product next time they visit the site.

None of the visited websites exhibited any kind of adaptive behavior. We tried to identify even the smallest traces of personalization activities, such as color alterations, personalized offers, browser size adaptation according to the user settings, and a few extra characteristics. Unfortunately, it was not possible to recognize any kind of customization performance.

2.3 Content analysis

The content analysis results to the Quality$_{Content.}$ During the second phase, websites were checked twice within 30 days. The main aim of this step was to discover broken links and alterations in structure and content. With the aid of automated link and content checkers we were able to examine the content of the websites and obtain statistics about them.

2.3.1 Statistics and broken links

Table 4 shows the number of local files and the number of broken links of the evaluated websites. All html, asp, jsp, php, gif, jpg, css files are categorized under the "local files" header. So, by local files we mean all the files, which are linked to one of the accessible web pages and are under the agency's URL. The validity of external links was not tested as it would not be fair to charge external broken links to the website, which references them.

Table 4: Number of existing files and broken links

	Local files	Broken links	
Tourism agencies	3315	74	(2.23%)
Cultural heritage sites	14814	106	(0.72%)

In both cases the number of broken links seems as not important but even this tiny number of broken links may cause dissatisfaction to visitors. Especially, when broken links are in the first level of the navigation route then it certainly prevents users from regularly continuing their surfing.

Examining Table 4 closer one can realize that cultural heritage websites are consisted of many more files compared to the tourism e-commerce websites and the rate of broken links is smaller. This can be explained based on to two reasons. First, we must take into account that e-museums contain a large number of images

since their primary intention is to show their exhibits to the public. Indeed almost 60% of the local files of the cultural sites inspected are images. On the other hand, approximately 40% of the URLs in tourism websites point to image files. Secondly, cultural website updates are infrequent compared to the tourism websites so less problematic situations appear.

Another conclusion resulting from this distribution of results is that user specified searching facilities are very important in both cases and especially in cultural websites. Additionally, adaptive techniques, which would take into account the interests and the navigation history of the user, could enhance orientation of the user in the huge collection of available web pages.

2.3.2 *Structure and content updates*

An important factor in tourism website acceptability is maintenance frequency. E-Commerce websites should update regularly in order to be of real value to the potential e-buyers. Structure alteration means removal or addition of web pages. Content alteration refers to the modification of the information presented to existing web pages. As explained the websites were checked twice within a distance of thirty days. Table 5 presents the results of these inspections. Tourism websites, which are based mostly in dynamic technologies, tend to change their content and structure more often than cultural heritage websites. However, one would expect that in a constantly changing and demanding sector such as tourism, websites should try to keep up with this pace and so modifications of content would be more regular.

Table 5: Structure and content alterations

	Structure alterations		Content alterations	
Tourism agencies	77	(2.32%)	148	(4.65%)
Cultural heritage sites	41	(0.28%)	13	(0.09%)

Cultural organizations maintain web pages based on standard static HTML. Maintenance of static web pages is a more time consuming and demanding procedure than in dynamic Web pages connected to databases where modification of the content is automated. In standard Html format there is a higher possibility of an out-of-date content as the maintenance phase is not a straightforward procedure as in the dynamic web locations. Indeed in many cultural websites announcements concern out of date events. However it should be underlined that cultural websites inspected contain rich multimedia content (images, sounds, etc) and there is no need for very frequent updates.

Overall, in both cases the maintenance frequency is low and does not reflect the dynamic character of tourism promotion, as it would be expected.

3. Discussion & future work

In this study we evaluated the services and content changes of tourism and cultural websites. We empirically assembled a number of desirable features that e-tourism and e-culture websites should have. Then we randomly selected a number of e-tourism and e-cultural websites. The evaluation of the websites revealed a lot of their inefficiencies. Most of the websites reviewed are developed using standard HTML. This tactic increases the maintenance effort and the possibility of broken links. Static Web development technologies prevent sites from being dynamic and adaptable to the needs of their users.

Another finding is that e-mail communication is not properly utilized. Although all the websites contained an email via which customers can communicate with the agency, a significant percentage of the agencies asked the customers to contact them via the phone. This is an indication that the significance of the e-mail as a cost effective and immediate means of communication is underestimated.

Searching is one of the most common operations of the Internet users (Levene, 2006). It seems that its significance has been overlooked in the e-commerce websites reviewed. Most of the e-museums do not offer even basic searching mechanisms. Given the fact that these sites contain hundreds or thousands of pages, users can easily be disoriented during navigation. Search engines are an emerging technology for e-tourism websites (Park & Gretzel, 2006). But only a small percentage of the websites maintain a full search mechanism. This makes the discovery of information hard for users. The visitors although they may have a clear and well-defined aim they have to review the existing lengthy catalogs so as to find relevant information.

Online payment and services such as special offers and guest books are sporadically supported. This finding is surprising considering that these sites should guide and help the customers to complete their orders

quickly and easily. Especially in e-tourism websites, online payment should be a basic service. The findings of our study indicate the opposite behavior in Greek tourism e-shops.

The content analysis of the websites revealed that content changes are rare and there is a small number of broken links. This result indicates that the development of websites follows an ad-hoc path. Disciplined methods for the designed and development of complex sites are essential. Dynamic Internet technologies bound to databases would eliminate the broken links and make the enrichment of content a straightforward procedure.

In comparison to traditional media, the Internet combines and integrates all of the following functional properties:

- Information representation
- Collaboration
- Communication
- Interactivity
- Transactions

E-commerce websites should try to exploit all of these properties in order to make true contrast to the printed advertisements. Websites should be friendly and adaptive to effectively support the needs of their customers. The Greek and, more generally, the small and medium sized agencies should comprehend the needs of their customers. Their websites should be designed according to their target audiences. Data should be stored in centralized databases and be dynamically presented to users. Update of data should be performed via specialized interfaces by technical staff to ensure that their sites are free of technical problems. Managers should visit international websites to review their features and services and be inspired about their websites.

The methodology proposed in this paper for evaluating the websites is an empirical selection of the common services found in major tourism and cultural heritage websites and aimed at estimating the situation in the Greek e-commerce websites. However, the methodology should be refined to include more attributes. It also needs to be further adapted to the nature of the e-commerce sites and take into account studies focusing on the behavior of the online surfers. Also specific services should be further assessed, e.g. the searching facilities (Lazarinis, 2007), and improvements in these services should be proposed.

4. Conclusions

The present study reviews the technologies of Greek tourism agencies and cultural websites. For this purpose we propose a heuristic usability method. The evaluation took place in the Technological Educational Institute of Patras. 25 students registered in the third year of the 'Tourism Management' curriculum with good Internet usage expertise involved in the evaluation process. Actually, there is a 5,4% error on the final evaluation estimate, as it was conducted only by 25 students (randomly chosen among the users). In addition, 20 Greek websites were randomly selected so as to ensure authentic results. The evaluation results of our experiment are the following: Greek tourism websites utilize dynamic technologies such as JSP and ASP whereas cultural websites are developed using standard HTML. Searching facilities, e-mail support, forums and FAQ (frequently asked question) sections, online booking and payment are partially supported which negatively affects the options offered to e-visitors. Content and structure of the reviewed websites are not modified frequently, at least on a monthly basis. This tactic does not absolutely harmonize with the demands of the tourism industry and cultural promotion and shows that the travel agencies and cultural institutions do not utilize the full power of Internet. The current evaluation of Greek tourism agencies and museum websites will provide managers with key information useful to maximize the returns a realization can offer, and it can help studying the behaviour of the users and their interactions to the contents and services offered online. Web developers working for similar tourism organizations of other countries can adopt the proposed website evaluation methodology.

References

Albert, T. C., Goes, P. B., Gupta, A. (2004) GIST: A model for design and management of content and interactivity of customer-centric Web sites. *MIS Quarterly*, 28(2), 161-182.

Brusilovskly, P. (2001) Adaptive Hypermedia. *User Modeling and User-Adapted Interaction*, 11, 87-110.

Connolly, D., Olsen, M. D., Moore, R. G. (1998) The Internet as a Distribution Channel. *Cornell Hotel and Administration Quarterly*, 39(4), 43-54.

Corigliano, M., Baggio, R. (2006). On the Significance of Tourism Website Evaluations. In Hitz, M., Sigala, M. and Murphy, J. (Eds.), Information and Communication Technologies in Tourism 2006 - Proceedings of the International Conference in Lausanne - Switzerland (pp. 320-331).:Springer, Wien.

Cunnliffe D., Kritou, E., Tudhope, D. (2001) Usability evaluation for museum web sites. Museum Management and Curatorship, 19(3), 229-252.

Deimezi, O., Buhalis, D. (2003) Etourism and developments in Greece. In *Information & Communication technologies in Tourism* (pp. 39-48). Wien: Springer-Verlag.

Dierking, L.D., Falk, J.H. (1998) Audience and accessibility. *In the Virtual and the Real: Media in the Museum*, eds. S. Thomas and A. Mintz, pp. 57–70. American Association of Museums, Washington, DC.

Efron, B., Tibshinary, , R.J. (1993) *An introduction to the bootstrap*. New York: Chapman & Hall.

Gill, T., Miller, P. (2002) Re-inventing the wheel? Standards, interoperability and digital cultural content. *D-Lib Magazine*, 8(1), available at: www.dlib.org/dlib/january02/gill/01gill.html

Hamil, J., Gregory, K. (1997) Internet marketing in the internationalisation of UK SMEs. Journal of Marketing Management, 13, 9-28.

Kanellopoulos, D., Panagopoulos, A. (2007) Exploiting tourism destinations' knowledge in a RDF-based P2P network, Journal of Network and Computer Applications (Elsevier).

Kanellopoulos, D., Panagopoulos, A., Psillakis, Z. (2004) Multimedia applications in Tourism: the case of travel plans. *Tourism Today*, 4, 146-156.

Kappel, G., Retschitzegger, W., Schrder, B. (1998) Enabling Technologies for Electronic Commerce. *XV IFIP World Computer Congress*, http://citeseer.ist.psu.edu/kappel98enabling.html

Kobsa, A. (2001) Generic User Modeling Systems. *User Modeling and User-Adapted Interaction*, 11, 49-63.

Kobsa, A., Fink J. (2002) User Modeling for Personalized City Tours. *Artificial Intelligence Review*, 18, 33-74.

Law, R., Bai, B. (2006) Website Development and Evaluations in Tourism: A Retrospective Analysis. In M. Hitz, M. Sigala, J. Murphy (Eds). Information and Communications Technologies in Tourism 2006. Proceedings of the International Conference in Lausanne - Switzerland (pp. 1-12) Springer Vien.

Law, R., Wong, J. (2003) Successful factors for a travel website: Perceptions of online purchasers in Hong Kong. Journal of Hospitality & Tourism Research, 27(1), 118-124.

Lazarinis F., (2007) Evaluating the searching capabilities of Greek e-commerce sites. *Online Information Review Journal* (in press)

Lazarinis, F. (2005) A Rule Based Tool for Mining Textual Data from Greek Calls for Papers. 2nd *Balkan Conference in Informatics*, Skopje. pp. 126-133.

Lazarinis, F., Stefanidis, S., Kougiourouki, O. (2002) e-travelling: A Generic Paradigm for Developing Tourism Web Sites. *International Scientific Conference: Rethinking of Education and Training for Tourism*, University of Zagreb, pp. 369-379.

Levene, M. (2006) *An Introduction to Search Engines and Web Navigation*. Addison Wesley, Pearson Education. ISBN 0-321-30677-5.

Liew, C. (2005) Online cultural heritage exhibitions: a survey of information retrieval features. *Program: electronic library and information systems*, 39(1), 4-24.

Nickerson, M. (2004) Online multimedia museum exhibits: a case study in technology and collaboration. *Library Hi Tech*, 22(3), 270 – 276.

Park, Y., Gretzel U., (2006) Evaluation of Emerging Technologies in Tourism: The Case of Travel Search Engines, *ENTER 2006*.

Sigala, M., Christou, E. (2002) Using the Internet for Complementing and Enhancing the Teaching of Tourism and Hospitality Education. *International Conference Rethinking of Education and Training for Tourism*. University of Zagreb. pp. 311-324.

Susser, B., Ariga, B. (2006) Teaching e-commerce Web page evaluation and design: A pilot study using tourism destination sites. *Computers & Education*, 47(4), 399-413.

Werthner, H., Klein, S. (1999) Information Technology and Tourism - A Challenging Relationship. Wien: Springer Verlag.

Zafiropoulos, C., Vrana, V. (2006) A Framework for the Evaluation of Hotel Websites : The Case of Greece. *Information Technology & Tourism*, 8, 239-254.

Zhang, P., Dran, G. (2000) Satisfiers and dissatisfiers: A two-factor model for website design and evaluation. *Journal of the American Society for Information Science*, 51(14), 1253-1268.

26

Determinants of Information Technology Diffusion: a Study at the Firm Level for Portugal

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Abstract. Recently, many studies have shown that IT played a major role in the resurgence in the growth of US output and productivity after 1995. Some studies for European countries also confirm this idea that IT and productivity are strongly related. The contribution of IT to economic growth can only be realized when and if these technologies are widely diffused and used. Within this context, understanding the factors affecting the decision to adopt and the extent of IT use by adopters is crucial not only for applied economists, but also to creators and producers of such technologies. Using a data set for Portuguese firms, our estimation results suggest that the significant drivers of intra firm diffusion are: firm size, workers skills, technological capacities and outsourcing partner usage.

Keywords: information technologies, diffusion, adoption, cluster analysis, profit model

1. Introduction

Recent contributions to the literature have shown that IT (Information Technology) intensive firms are more productive (Black and Lynch 2001, Bresnahan *et al.* 2002, Brynjolfsson and Hitt 2000, Dedrick *et al.* 2003, Martins and Raposo 2005) and that IT adoption is important to promote economic growth (Jorgenson 2001, Litan and Rivlin 2001, Pilat and Lee, 2001). In these circumstances, a critical question arises: what are the factors that influence IT adoption and diffusion at the firm level? Some recent studies have focused on the determinants of the time period of IT adoption, also called the inter firm IT diffusion. Another approach proposed in the literature is related to the study of the factors influencing the extent of IT use/ level of IT adoption, also called the intra firm IT diffusion (Battisti et al. 2004, Hollenstein 2004, Teo and Pian 2003, Teo and Pian 2004). In the first part of our study, we analyzed this two important features of IT diffusion for one of the most used and diffused IT: the Internet. Then, we focused our attention on the determinants of the extent of IT use by firms, i.e., intra firm diffusion.

The two main purposes of this study are the following: (1) to examine Internet diffusion patterns, by exploring both inter firm and intra firm diffusion aspects, and (2) to explain, empirically, the determinants of intra firm IT diffusion by considering seven additional IT: email, extranet, intranet, EDI, WAP, LAN and WAN. To achieve this two research objectives we used a rich data set of 487 firms operating in five economic sectors in Portugal. The understanding of the determinants of the extent of IT use, at a firm level, may be a useful tool in addressing the right type of policy measures to increase the rate of productivity growth. This is a particularly needed in the case of Portugal that for several reasons is a country that has been suffering from a serious lack of competitiveness in comparison with other industrialized economies.

Our work is a contribution to the empirical literature on the determinants of IT adoption and diffusion, taking Portugal as a country of application, for which there exists no published studies on the subject. Our paper is organized as follows. The next section investigates the diffusion patterns of the Internet, in terms of the so called inter firm and intra firm diffusion. Then, we analyze the extent to which certain characteristics related to firms' internal and external behavior, influence the intra firm IT diffusion process. Finally, we presented majors findings and conclusions.

2. Diffusion patterns of the Internet

2.1 Data and measures

To accomplish the research objectives, we match data from two National surveys: the Survey on ICT usage by firms and the Annual Business Survey, both conducted by the Portuguese National Institute of Statistics (INE). The ICT usage survey records on all Portuguese business, is stratified by economic sector (NACE classification) and by firm size and is carried out annually since 2001. This survey is a part of an EU/OCDE procedure initiative to produce comparable data for ICT adoption and ICT usage in Europe. In our study, data from ICT usage survey 2002 are used because it is the only one where information on the year of IT adoption is gathered. Since 2003, we only have information on whether the firm is an adopter or not. In order to have complete information, namely on human resources qualification (a very important factor in our work),

data from ICT usage survey has been matched to the data from Annual Business Survey. The latter is also stratified by economic sectors and firm size and provides information on general characteristics of firms, including employee' level of education. The matching procedure is based on linking the ID numbers which identify firms in both surveys. Matching data for 2002 gives a cross-section of 487 observations.

In order to identify the different patterns of Internet diffusion, namely in terms of inter firm and intra firm diffusion features, we group the 487 firms using Cluster Analysis. Following the recent literature on IT diffusion models, we considered the following variables in the multivariate analysis: Inter firm diffusion: number of years since first adoption of the Internet; Intra firm diffusion: the proportion of employees working regularly with the Internet; variables related to firm's technological characteristics: IT skills (Gibbs et al. 2004, Giunta and Trivieri 2007, Zhu et al. 2003), broadband, outsourcing partner usage (Hong and Zhu 2006) and perceived obstacles (Hollenstein 2004, Hong and Zhu 2006); variables related to firm's specific characteristics: firm size (Lee and Xia 2006, Gibbs et al. 2004, Giunta and Trivieri 2007, Hollenstein 2004, Zhu et al. 2003), workers educational level (Giunta and Trivieri 2007, Hollenstein 2004), R&D (Giunta and Trivieri 2007); variables related to external pressure factors: competitive pressure (Gibbs et al. 2004).

Some variables are measured directly from the surveys: IT skills is a binary variable equal to one if firm has IT workers and zero otherwise; *firm size*, is measured by binary variables referring to 3 size classes based on the number of employees, S_1 (small firms with 10 to 49 employees), S_2 (medium-sized firms with 50 to 249 employees), S_3 (large firms with more than 250 employees); *workers education level* , EDUC, is measured by the proportion of employees with university degree; *broadband*, BB, that reflects IT technological capacities is measured by a binary variable that is equal to one if firm has broadband and zero otherwise; *outsourcing partner usage* are captured by two binary variables related to the way firms solve their IT challenges: OUT_1 is equal to one if firm solve IT problems with internal resources, and zero otherwise, and OUT_2 is equal to one if firm solve IT problems with external resources and zero otherwise; *R&D profile* is represented by two binary variables PERPROD and PERPROC, that reveal if firm is process or product innovator. Other variables were constructed with the information provided by the surveys: COMP_PRESSURE, measures the proportion of firms that uses IT more than the mean in the particular sector of activity (10 sectors are considered); *obstacles or barriers to IT adoption*, are measured by three variables resulting from a factor analysis on nine perceived barriers of IT adoption that explain 59% of the total variance: COST (implementation costs are to high), KNOW HOW (knowledge and management difficulties) and TECH (technological uncertainty).

Economic sectors were used only as descriptive variables: CAE_1 (manufacturing), CAE_2 (distribution and retail trade), CAE_3 (hotels and accommodation), CAE_4 (transport, storage and communication) and CAE_5 (business services-real state, rentals and business activities).

2.2 Diffusion patterns

Cluster analysis was conducted using SAS software to explore options for grouping the different firms. The objective of cluster analysis is to find homogeneous groups and to maximize the difference between groups. Unlike most parametric statistical techniques, cluster analysis does not explicitly provide a clearly acceptable or unacceptable solution. Sharma (1996) recommends that one should use different approaches, compare the results for consistency and use the method that results in an interpretable solution. As the variables used in our analysis were measured in different scales and some of them are qualitative, we stated cluster analysis using Gower's method to compute the initial matrix (Gower 1971). It is the most convenient matrix that should be used when there is a mixture of continuous and discrete variables.

The hierarchical cluster analysis method was chosen as a first step. The clusters were determined with complete-linkage method, Ward method and Centroid method. Based on these results, we identify the "optimal" number of clusters as being equal to five. As suggested by Sharma (1996), we used the results from hierarchical methods (Ward method) as an initial solution for the non hierarchical cluster analysis, based on K-means methodology. The solution achieved with five clusters was considered as optimal because it is interpretable and results from combining the different approaches, as suggested by Sharma (1996). Summary statistics for each of the clusters are provided in Table 1.

Table 1: Summary statistics for cluster analysis

VARIABLES		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Number of firms	487	132	63	138	61	93
		27%	13%	28%	13%	19%
Inter firm diffusion	3,52	2,94	4,24	4,13	2,75	3,45
% employees using Internet	27,0	12,27	54,63	35,84	36,84	9,67
IT skills	0,49	0,23	0,65	0,80	0,18	0,47
BB	0,48	0,14	0,90	0,90	0,43	0,12
OUT1	0,31	0,14	0,49	0,59	0,23	0,06
OUT2	0,28	0,22	0,46	0,28	0,25	0,24
COST	0,00	0,01	-0,18	0,05	-0,07	0,07
KNOW-HOW	0,00	-0,07	-0,07	0,11	-0,15	0,09
CONFIDENCE	0,00	-0,07	0,17	0,00	0,02	-0,03
S1	0,13	0,00	0,00	0,00	1,00	0,00
S2	0,40	1,00	1,00	0,00	0,00	0,00
S3	0,47	0,00	0,00	1,00	0,00	1,00
EDUC	12,93	7,70	24,24	16,50	16,26	5,23
PERCPROD	34,17	30,71	37,77	37,48	36,92	29,91
PERCPROC	36,19	35,09	37,69	37,18	34,59	36,32
COMP_PRESSURE	48,98	47,15	49,99	52,53	46,94	46,96
CAE1	0,38	0,39	0,14	0,48	0,13	0,54
CAE2	0,32	0,44	0,35	0,22	0,61	0,11
CAE3	0,02	0,00	0,02	0,03	0,02	0,05
CAE4	0,08	0,05	0,10	0,14	0,08	0,05
CAE5	0,19	0,13	0,40	0,14	0,16	0,25

The diffusion patterns of the five clusters are illustrated in Figure 1 and can be described as following:

CLUSTER 1. This group is characterized by firms that are later adopters of the Internet and that don't use it intensively. These firms have a low percentage of qualified workers, and only 23% have IT workers; most of them don't use broadband; perceived obstacles, namely those related to uncertainty are relevant barriers. This group of firms is composed by medium size firms coming from the manufacturing and distribution.
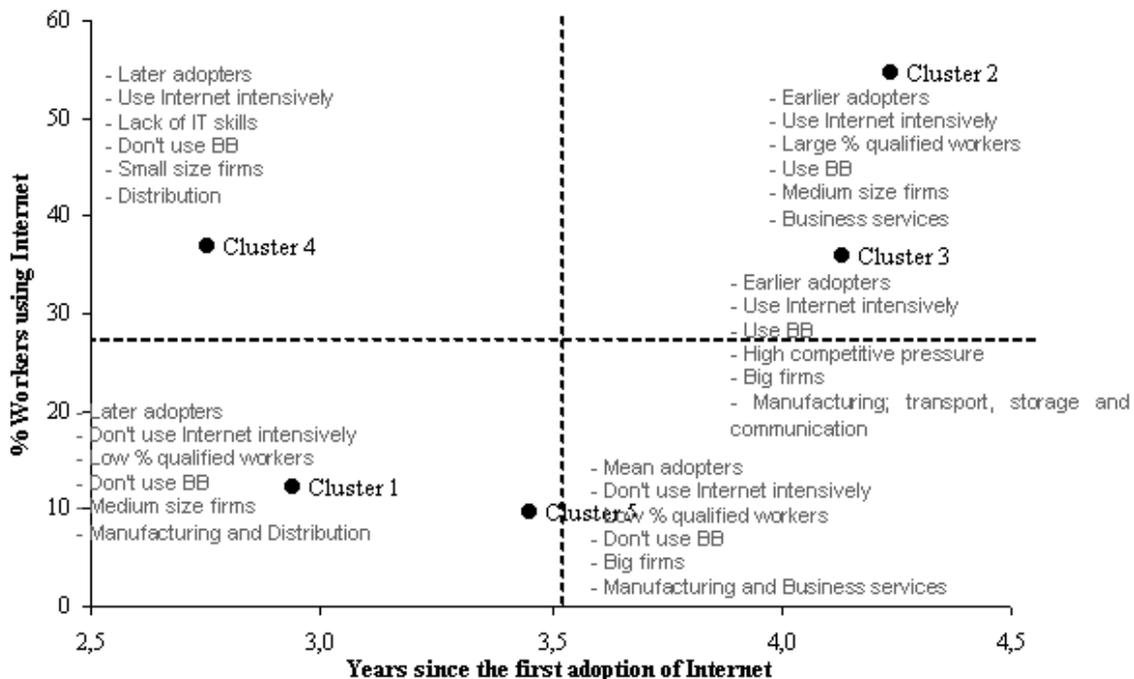
Figure 1: Patterns of Internet inter firm and intra firm diffusion

CLUSTER 2. Firms from this group are earlier adopters and use the Internet intensively. They have a large percentage of qualified workers and most of them have IT workers and use broadband; R&D activities are important and the most important perceived obstacle is the one related to implementation costs. Most of the firms come from business services and have medium size.

CLUSTER 3. This group is represented by firms that are earlier adopters and use the Internet intensively. They have qualified workers and most of them have IT workers and use broadband; R&D activities are relevant. They suffer from competitive pressure. Most of the firms from cluster 3 are big firms and come from manufacturing, transport, storage and communication sectors.

CLUSTER 4. Firms from this cluster are later adopters and use intensively the Internet. They have qualified workers but there is a lacking of IT skills. Know-how is perceived as a very important factor to Internet use. This group concerns small size firms from distribution sectors.

CLUSTER 5. This set of firms is characterized by "mean" adopters of the Internet and the intensity of its use it at very low level. The quality of the workforce is clearly below the mean: only 5% of the employees have a university degree and IT skills are deficient. Most of firms from cluster 5 are big firms from manufacturing and business services.

The major findings related to the pattern of Internet diffusion for Portuguese firms can be described as follows:

1. *Finding 1*. Firms that took up Internet earlier and made more intensive use of it, tended to be medium and big size firms, with skilled workers, that have invested in IT human capital and that have good technological capacities;

2. *Finding 2.*Earlier adopters are not necessarily those who use more intensively the Internet. There is a group of small firms that are later Internet adopters but us it intensively, probably because they have a huge percentage qualified workers;

3. *Finding 3.* The qualification of the workforce is an important facilitator of both time period of Internet adoption and intensity of its use. This finding is very important in the Portuguese context given that 80% of the workers have only 9 years of education.

Given that the Internet participation in our sample is at its saturation level - 97% of the firms are already Internet users - , in the second part of our work we assess the impact of different factors on two aspects of the intra firm diffusion process: the intensity of Internet use by workers and the extent of IT use by firms.

3. Determinants of intra-firm IT diffusion

3.1 Conceptual framework

As we have already mentioned, in last few years, research has made great progress in understanding and modeling the factors that lead to the first adoption of IT, the so called inter firm diffusion. However, if we are interested in the benefits generated by a certain technology within an economy, it is also important to understand the factors that determine the extent of IT use by adopting firms, after first adoption, i.e., the intra firm diffusion. Battisti and Stoneman (2003) have shown that the inter firm effect is more important in the early stages and that the intra firm effect is more relevant in the latter stages of the whole diffusion process.

This second part of our study explores the determinants of the intra firm diffusion process. We analyzed the impact of technological, strategic and external factors on the intensity of Internet use by workers and on the extent of IT use by firms. For the later concept, we will distinguish between a firm that is a basic IT user (uses only internet and e-mail) and a firm that is an enhanced user, which means that uses at least internet, email and two other IT. We considered the following technologies: intranet, EDI, WAP, LAN and WAN.

In our conceptual framework, we admit that the firm's extent of IT use in time t, the intra firm diffusion, is determined by firm specific profitability conditions and firm specific technological capacities (Forman 2005, Battisti et. al 2004). The idea is that firms face risks in adopting IT and that these risks affect their purchases of such technologies.

Thus, in determining the extent to which to use IT, a firm with specific technological capacities, compare benefits of further use against cost of use. Within this framework, factors influencing intra firm IT diffusion were classified into: internal factors and external pressure factors.

3.1.1 Internal factors

Broadband (technical capacity)
Firms using broadband have better technical capacities to support IT. Hence, the following is postulated:
H1. Broadband is positively associated with the intensity of Internet use by workers and positively associated to the probability of being an enhanced user.

IT skills
IT skills usually included employees' skills of using the Internet and related technologies (Zhu et al. 2003). IT skills are essential for firms to develop successfully IT applications. This complementary factor has been identified in many studies as a crucial element of IT implementation (Black and Lynch 2001; Brynjolfsson and Hitt 2000).

In our context, IT skills are defined by the number of employees that work exclusively in tasks related to IT activities. We would expect that, controlling for other factors: firms with more IT skills are more likely to be enhanced users. We also suggest that IT skills have a positive impact on the intensity of Internet use. The following is hypothesized:
H2. The level of IT skills is positively correlated with the intensity of Internet use by workers and positively associated to the probability of being an enhanced user.

Perceived obstacles
Research on IT adoption and implementation suggests that, when the technology is complex, as is the case for e-commerce technologies, perceived obstacles are particularly relevant because, in this case, the adoption process may be complicated and costly (Hong and Zhu 2006). A different behavior may occur in the case of the Internet, which is a simple technology, relatively inexpensive and easy to implement. We examined several perceived obstacles related to Internet adoption and implementation, namely: implementation costs, lack of IT skills, security, and technology excessively complex. Hence, we admit that:
H3. Perceived obstacles are probably negatively associated with the intensity of internet use and with the probability of being an enhanced user.

Outsourcing partner usage
Based on previous research (Hong and Zhu 2006), we included outsourcing partner usage as a possible predictor of IT intra firm diffusion. Firms that count on partners or contractors for IT implementation tasks, are more likely to use it intensively and more likely to be enhanced users. Hence, outsourcing may be viewed as a facilitator of features of intra firm diffusion. This leads to the following hypothesis:
H4. Greater partner usage is positively associated with both intensity of internet use and the probability of being an enhanced user.

Firm size
Firm size is one of the most commonly studied determinants of IT adoption and diffusion. In a recent study, Lee and Xia (2006) have analyzed, through a meta-analysis, the association between firm size and IT innovation adoption and concluded that although a positive relationship generally existed, the relationship was moderated by five variables: type of IT innovation, type of firm, stage of adoption, scope of size, and type of size measurement.

Three major arguments support the positive role of firm size in determining IT innovations. The first two are due to Schumpeter: firms that are large are more likely to undertake innovation both because appropriability (the benefits of the new IT) is higher for larger firms and because the availability of funds for these firms is greater. The third argument is that many IT innovations, like Internet, are scale-enhancing and therefore larger firms adopted them sooner (and more intensively) because they capture economies of scale more quickly (Zhu et. al 2003; Gibbs et al. 2004)

However, large size may also slow down the rate of IT diffusion: firstly, larger firms have multiple levels of bureaucracy and this can impede decision-making processes about new ideas and projects. Secondly, it may be relatively more expensive for larger firms to use intensively the IT innovation because they have to reconvert a large number of their employees. Finally, IT innovations often require close collaboration and

coordination that can be easily achieve in small firms. Based on these empirical results, we postulate the following:

H5. Firm size is positively or negatively associated with the intensity of Internet use and with the probability of being an enhanced user.

Quality of human resources

The presence of skilled labor in a firm increases its ability to absorb and make use of an IT innovation, and therefore is an important determinant of IT diffusion. Since usually the successful implementation of a new IT requires complex skills, we would expect that, maintaining other characteristics constant, firms with better educated workers are more likely to be enhanced users and use Internet more intensively. We hypothesized the following:

H6. Workers' educational level is positively associated with the intensity of Internet use and with the probability of being an enhanced user.

3.1.2 External pressure factors

Competitive pressure or epidemic factors

Many empirical studies show that competitive pressure is a powerful diver of IT adoption and diffusion (Gibbs et al. 2004; Hollenstein 2004; Zhu et al.2003). We would expect that, holding other factors constant, the probability of being an enhanced is positively influenced by the level of IT diffusion in the whole industry. Therefore, we assume that:

H7. Competitive pressure is positively related to the intensity of Internet use and to the probability of being an enhanced user.

We control, as usually, for economic sector specific behavior, including dummies for the five aggregate sectors of activity.

3.2 Model specification and empirical results

3.2.1 Measurements and variables

Dependent variables. For the extent of Internet use by workers we used, as in the first part of this study, a variable measuring the percentage of employees working regularly with the Internet, INTUSE. For the extent of IT use by firms we construct a variable, Y, that is equal to zero if the firm is a basic user and equal to one if the firm is an enhanced user.

Independent variables. The factors considered, broadband, IT skills, outsourcing partner usage, perceived obstacles, firm size (the reference group is small size), quality of the human resources, competitive pressure and economic sector dummies (reference sector is CAE3 and CAE5) have already been defined.

3.2.2 Model specification

For the intensity of Internet use by workers, the following linear model is specified:

$$(1)\ INTUSE=X'\alpha+u$$

where INTUSE is the dependent variable, X represents the vector of independent variables, and α is a vector of unknown parameters to be estimated. As usual, u stands for a random variable, the error term. Model (1) was estimated by Ordinary Least Squares, assuming the classical hypotheses of the multivariate regression model.

For the extent of IT use by firms, we used a binary choice model, the Probit Model, because the dependent variable is dichotomous (Y=0 if the firm is a basic user and Y=1, if the firm is an enhanced user). The specification is the following:

$$(2)\ P(Y=1/X)=\Phi(X'\beta)$$

where Y is the binary dependent variable, X is the vector of independent variables already defined, β is an unknown parameter to be estimated and Φ is the cumulative normal distribution. Model (2) was estimated, as usual by Maximum Likelihood.

Testing H1-H7 is equivalent to testing whether the coefficients α and β are significantly different from zero. Positive and significant coefficients imply that the corresponding variable is an intra firm diffusion facilitator. Negative and significant coefficients indicate that the corresponding variables are inhibitors.

3.2.3 Empirical results

Estimation results for Model (1) and Model (2) are shown in Table 2. We considered two significance levels 5% and 10% level. As can be seen, most of the independent variables are relevant to explain the intra firm diffusion pattern. The estimated coefficients have the expected signs: broadband, IT Skills and outsourcing partner usage have a positive effect on both the intensity of Internet use and the probability of being an enhanced user. Perceived barriers are important and act as an inhibitor, but only for the intensity of Internet use.

Table 2: Estimation results for the determinants of intra firm diffusion model

Variables	Linear Regression Intensity of Internet use	Probit Model Probability of enhanced user
Constant	20,743*	-1,834*
Broadband	12,313*	0,729*
IT Skills	7,945*	0,692*
Outsourcing partner usage		
OUT1	1,576	0,602*
OUT2	-7,117*	-0,205
Perceived Obstacles		
COSTS	-5,874*	-0,047
KNOW-HOW	0,648	0,067
TECH	2,170	0,131
Size		
S2	-9,671*	0,205
S3	-13,773*	0,779*
EDUCATION	0,870*	0,035*
Competitive Pressure	0,004	0,010
Economic Sectors		
CAE1	-9,690*	0,568*
CAE2	-9,685*	0,945*
CAE4	-2,656*	0,585**
R^2	0,49	
Number of firms	487	487

 * Statistically significant at the 5% level and ** at the 10% level. Robust standard errors are used.
As expected, the probability of being an enhanced user is positively influenced by workforce qualifications and by firm size. Workers educational attainment is also a facilitator of the intensity of Internet use. External competitive pressure factors or epidemic factor are not relevant in this context. The same result was obtained by Battisti *et. al* (2005). The authors also find that, for the intra firm diffusion model, the most important factors are those related to firms' internal factors.

As a whole, the pattern of the two intra firm diffusion models is quite similar. The outstanding differences refers, firstly to the impact of firm size; whereas size-effects are positive in the case of the extent of IT use by firms, for the intensity of Internet use, this impact is negative. This result means that, holding all other factors unchanged, smaller firms are more likely to be intensive Internet users. Secondly, the effects of the perceived barriers are only relevant for the intensity of the Internet use by workers, indicating that investments needs to convert the human capital to the new technology are particularly important.

4. Concluding remarks

The purpose of this paper was to offer a contribution to the empirical literature on the determinants of IT adoption and diffusion at the firm level. This topic is of particular interest because it has been recognized that a greater use of IT by firms enhances their productivity and, when amply diffused, increases the growth rate of the economic system as a whole.

Our econometric results for Portuguese firms confirm the importance of key variables tested in prior IT adoption and diffusion studies. Specifically, our findings confirm that, technological capacities, IT skills, outsourcing partner usage, perceived obstacles, size and the quality of human resources played an important role in the intra firm IT diffusion process. The results also indicate that larger firms are more likely to be enhanced users, probably due to greater resources and economies of scale. Nevertheless, small firm adopters may possess certain advantages that allow them to use the Internet more intensively. Other variables did not have a significant impact in intra firm diffusion. Perceived obstacles did not have a

significant effect on the extent of IT use by firms. One possible explanation is that perceived obstacles may impact initial adoption but not the extent of IT use. This result makes sense because firms that have adopted basic technologies (Internet and email), may have already overcome such barriers and so they become less important in distinguish between a basic and an enhanced user. Additionally, competitive pressure did not have a significant impact on both features of intra firm diffusion. Again, it is possible that competitive pressure has an effect on initial adoption but not on the extent of use after adoption.

As a whole, our results suggest that traditional policy drivers such as incentives for procurement should be complemented with incentives that give the adequate qualifications to the workforce. With the new technology costs decreasing, the major constraint for Portuguese firms does not seem to lie on lack of financial resources but rather on qualified human resources, able to absorb the new IT and make the best use of them.

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References

Battisti, G., Canepa, A., & Stoneman, P. (2004) "Profitability, Externalities and Policy in the Inter and Intra Firm Adoption of New Technology: The Example of E-Business Activities in the UK", Paper presented at the 8th Conference of the European Network on Industrial Policy, Birmingham.

Battisti, G., Hollenstein, H., Stoneman, P., & Wörter, M. (2005) "Inter and Intra firm Diffusion of ICT in the United Kingdom (UK) and Switzerland", Working Paper nº 111, Swiss Institute for Business Cycle Research.

Battisti, G., & Stoneman, P. (2003)"Inter- and intra-firm effects in the diffusion of new process technology", *Research Policy, Vol 32*, pp 1641-1655.

Black, S. and Lynch, L. (2001) "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity", *Review of Economics and Statistics*, Vol 83, pp 434-445.

Beatty, C. R., Shim, J.P. and Jones, M.C. (2001) "Factors Influencing Corporate Web Site Adoption: a time-based Assessment", *Information and Management*, Vol 38, pp 337-354.

Bresnahan, T. F., Brynjolfsson, E. and Hitt, L. M. (2002)"Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm-level Evidence", *Quarterly Journal of Economics*, Vol 117**,** pp 339-376.

Brynjolfsson E. and Hitt L. (2003) "Computing Productivity: Firm-level Evidence, *Review of Economics and Statistics*, Vol 84, No. 4, pp 793-808.

Dedrick, J., Gurbaxani, V. and Kenneth L. Kraemer (2003)"Information Technology and Economic Performance: A Critical Review of the Empirical Evidence", *ACM Computers Surveys*, Vol 35, No.1, pp 1-28.

Forman, C. (2005) "The Corporate Digital Divide: Determinants of Internet Adoption", *Management Science*, Vol. 51, No. 4, pp. 641-654.

Martins, M.R.F. and Raposo, P. (2005) "Measuring the Productivity of Computers: A Firm Level Analysis for Portugal", *Electronic Journal of Information Systems Evaluation,* Vol. 8 Iss.4.

Gibbs, L. J. and Kraemer, K. L. (2004) "A Cross-Country Investigation of the Determinants of Scope of E-commerce Use: An Institutional Approach", Electronic Markets, Vol 14, No.2, pp 124-137.

Giunta, A. and Trivieri, F. (2007) "Understanding the Determinants of Information Technology Adoption: Evidence from Italian Manufacturing Firms", *Applied Economics*, forthcoming.

Gower, J. C. (1971)"A general coefficient of similarity and some of its properties", *Biometrics,* Vol 27, pp 857-872.

Hollenstein, H. (2004)"Determinants of the adoption of Information and Communication Technologies (ICT): An empirical analysis based on firm-level data for the Swiss business sector", *Structural Change and Economic Dynamics,* Vol 15, pp 315-342.

Hong, W., & Zhu, K. (2006) "Migrating to internet-based e-commerce: Factors affecting e-commerce adoption and migration at the firm level", *Information & Management,* Vol 43, pp 204-221.

Jorgenson, D. W. (2001)"Information Technology and the U.S. Economy", *American Economic Review,* Vol 91, No.1, pp1-32.

Litan, R.E. and Rivlin, A.M. (2001) "Projecting the Economic Impact of the Internet", *American Economic Review, Papers and Proceedings*, Vol 91, No.2, pp 313-417.

Pilat, D., & Lee, F. C. (2001). Productivity growth in ICT-producing and ICT-using industries: a source of growth differentials in the OECD? STI, in OECD (Ed.). Paris.

Sharma, S. (1996). *Applied Multivariate Techniques*. New York: John Wiley & Sons, Inc.

Teo, S.H.T. and Tan, M.(1998) "An empirical Model of Adopters and Non-Adopters of the Internet in Singapore", *Information & Management*, Vol 34, pp 339-345.

Teo, S.H.T. and Pian, Y. (2003) "A contingency perspective on Internet adoption and competitive advantage", *European Journal of Information Systems*, Vol 12, pp 78-92.

Teo, S.H.T. and Pian, Y.(2004) "A Model of Web Adoption", *Information & Management*, Vol 41, pp 457-468.

Zhu, K., Kraemer, K., & Xu, S. (2003) "Electronic business adoption by European firms: a cross-country assessment of the facilitators and inhibitors", *European Journal of Information Systems,* Vol 12, No. 4, pp 251-268.

Using the Probabilistic Model Checker PRISM to Analyze Credit Card Use

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Abstract: Probabilistic model checking is a recent extension of traditional model-checking techniques for the integrated analysis of both *qualitative* and *quantitative* properties of systems which exhibit stochastic behaviour. In this paper we apply probabilistic model checking to study the effect of credit card companies on people's lives. We use the probabilistic model checking tool PRISM as the formal framework. This approach allows us to obtain performance measures on various policies. It allows us to obtain performance measures on various policies such as changes in the interest rate and its effect on the credit card loan entitlement of the card user, the effect of different repayment policies on the user's spending ability in the short and long run, the effect of different interest rates and different spending preferences on the loan in the short run, and the effect of different spending preferences and different repayment policies on the remaining balance in the long run.

From the study we investigate the level of loans and the amount of instalments after which the card holder goes through a cycle of interest repayment only. That is he/she can not use the card to withdraw money any more but has to make interest payments on the debt.

Keywords: credit card system, performability, probabilistic model checking, simulation.

1. Introduction

Probabilistic model checking is relatively new development which plans to bring automatic verification technology for real life systems which exhibit stochastic behaviour [1], [2]. The technique allows for analyzing of reliability, correctness and performance of such systems in an automatic way. Probabilistic Symbolic Model Checker (PRISM) is a probabilistic model checker which supports a range of probabilistic models and specification languages based on temporal logic, it allows accurate computation for a wide range of numerical properties and it performs a complete analysis which enables studies such as best and worst case scenarios. In the 21st century credit cards became one of the most popular methods of financing consumption. They are easy to use; they can be used in stores or on the net, and they can be used to withdraw money from banks or automated teller machines (ATMs). People in many countries around the world prefer using credit cards for safety reasons, instead of carrying cash in their pockets, and/or to utilize credit card product offers designed to meet their financial needs, since credit cards give them the opportunity to avail of more finance than they already have and pay later with "buy now, pay later" option.

In Egypt more than one million credit cards are in use now. The number of credit cards increased three times in Egypt since the year 2000, with spending rate more than one milliard dollar.[1] The monthly interest rate on the loans ranges from 1.4% to 2.5%. In the US paying by credit card gives more protection to the user than making payments by check or by debit card. [2] This creates incentives to use credit cards even more as a form of finance. In the first quarter of 2002 the total U.S. credit card debt was around $60 billion.[3] In 2004 an average American family had a credit card debt of about $4,000 and was paying around $800 a year on credit card interest.[4] In February 2006 in the UK total credit card debt was £56.4 billion.[5]

Credit card use has both advantages and disadvantages. As allured to above, the possibility of increased availability of financial means for spending and the security given by carrying credit cards instead of cash are the main advantages of credit card use. Main disadvantage of credit card use comes if the user increases his credit card purchases thereby approaching more and more his credit card limit. This in turn increases his

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[1]http://arabic.cnn.com/2005/business/12/25/million_visa_card_egypt/index.html
[2] For instance, section 5, "Billing errors and overcharges", of the U.S. Fair Credit Billing Act gives a lot of safeguards to credit card users which do not apply for payments by check or by debit card.
[3] American Consumer Credit Counseling www.consumercredit.com
[4] www.investopedia.com
[5]Bank of England Figures.

interest payments and reduces the quality of life of the user in the long run.[6] Consequently the borrower might suffer from bankruptcy and end up in a worsened condition than before starting to use the credit card. Credit card debt is about the most expensive way there is to finance consumer goods and services. In fact, with banks paying as low as 3.05% before tax (current base rate 4.5% less 1.45%)[7] annual interest rates on credit cards average 15.68%[8] in UK, around 11 percentage points above Bank of England's base rate, making it far too expensive for card users to carry any balance over the grace period.[9] In the US the average rate of interest on credit card debt is between 17-20%. In order to reduce debt more quickly and to pay less interest the user of a credit card should try to repay more than the minimum amount required each month. However, many instances borrowers are unable to repay their debts and credit card issuers are being forced to write off increasing levels of bad debt. According to the Bank of England unsecured consumer debt written off by banks increased from £2.9bn during the first nine months of 2004 to £3.7bn during the same period of 2005.In face of increasing debt problems credit card issuers as well as governments are looking for strategies to reduce loses incurred by banks and also, not least, to help over-indebted borrowers. Besides having to increase their bad debt provisions, banks often issue credit cards only if applicants can provide good credit ratings and history. In 2006 the UK government provided an amount of £45m to recruit 500 debt advisers to help increasing number of people with debts. This paper studies and analyses the effect of the credit card on the quality of the holder's life using the probabilistic model checker PRISM. The paper tries to analyze the effect of interest charges on the loans taken by the credit card user, the effect of different repayment policies of the user, and the possibilities of using the card without risking bankruptcy. The paper is organized as follow; next section presents a brief review of probabilistic model checking and an overview of PRISM; the tool used for analyzing the application. Section 3 describes how credit card system works, and presents relevant research in this field. Section 4 describes the model. Section 5 analyzes the results of the experiments. Conclusions are presented in Section 6.

2. Probabilistic model checking

In the last decade, computer scientists have made tremendous evolution in developing tools and techniques for verifying requirements of systems. One of the successful approaches is *model checking* [3], [4]. The essential aim of model checking is to verify finite-state systems algorithmically and formally thereby discovering whether a model of a system satisfies a given property. The specification is often written as temporal logic formulas. By checking design requirements, we search whether the system under study is realizable, whether the requirements are suitably modular and well structured. If incorrect requirements are implemented, incorrect system behavior might result requiring at least rework and maintenance which in turn would cause high expenses. In some cases implementing incorrect system behavior could cause huge catastrophe**s** such as loss of life and property.

In order to improve the quality of various aspects of requirements and design modelers apply automated tools to check the quality of the model. Figure 1 shows the model checking approach.
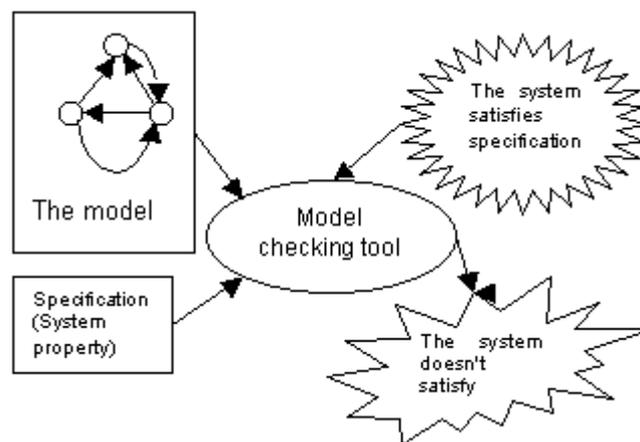
Figure 1: The model checking approach.

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[6] See Ratha 1997.

[7] As of May 2006.

[8] As of February 2006

[9] The grace period is the time after the billing date that a credit card holder has to pay off the bill without paying finance charge. Bank cards usually have 25 days but a few have 30 and many have no grace period.

A *model-checking tool* accepts a *model* and a property (called *specification*) that the system is expected to satisfy. The tool then gives either the result with output yes if the given model satisfies a given specification or shows an error message otherwise. In the case of detecting an error the tool gives example as to why the model does not satisfy the specification. From this example the modeler can identify the source of the error in the model, correct the model, and run the model checking tool again. Thus, model checking tools ensure whether a model satisfies system properties sufficiently and help to increase confidence in the correctness of the model. There are many model checking tools such as Spin [5], NuSMV2 [6] and MARIA [7].

Probabilistic model checking is a relatively recent development which aims to deliver automatic verification technology for probabilistic systems. These systems are usually represented by discrete or continuous time Markov chains [8] or Markov decision processes [9]. In discrete time Markov chains (DTMCs) time as well as probabilities of transitions occurring are considered as being discrete. They are used for studying systems with simple probabilistic. Markov decision processes (MDPs) extend DTMCs by allowing a combination of nondeterminism and probability. They are suited to model multiple probabilistic processes that execute in parallel or to model systems with unknown behaviour. Continuous time Markov chains (CTMCs) model systems with continuous time, through the use of the negative exponential distributions, allowing accurate representation of the timing characteristics of e.g. component failures and job arrivals. This technique, as in the case of traditional model checking, involves building a model to represent a system, and then performing a systematic analysis on that model to check whether it meets its specification such as "in an electrical power station, the probability of shutdown occurring is at most 0.01%", and "what is the probability that the process will successfully complete within T time and without requiring repairs".

Real life systems are complex, and therefore there is a need for high-level specification techniques to automatically generate models. Now there are several tools available for probabilistic model checking, such as E ⊦ MC^2 [10] Rapture [11] and PRISM [12], [13], [14], [15]. These tools can enhance the design process through early error detection and prediction of failure and performance.

PRISM is a probabilistic model checking tool which has already been successfully applied to verify and analyse wide range of real-life systems [14], [16], and [17]. Parker et al worked on different PRISM applications[10]. PRISM can model three types of probabilistic models: DTMCs, MDPs and CTMCs. The PRISM tool has two files as input; the first one is the model file, which can be written in either the PRISM

language or PEPA (Performance Evaluation Process Algebra) language [18]. The model file contains a description of the system. The second file is a specification file which contains a list of properties to be checked for conformity with the model.

The tool uses the Probabilistic Computation Tree Logic (PCTL) for properties of DTMCs and MDPs, and Continuous Stochastic Logic (CSL) for properties of CTMCs. After building the model PRISM performs numerical analysis to verify properties against it. The results state whether a property is in conformity with all reachable states of the model or the probability of the property conforming to the model. Rewards and costs are added to PRISM properties in order to describe how rewards should be accumulated for particular states of the model, and for particular transitions between states. PRISM structure for CTMC model looks as shown in Figure 2.
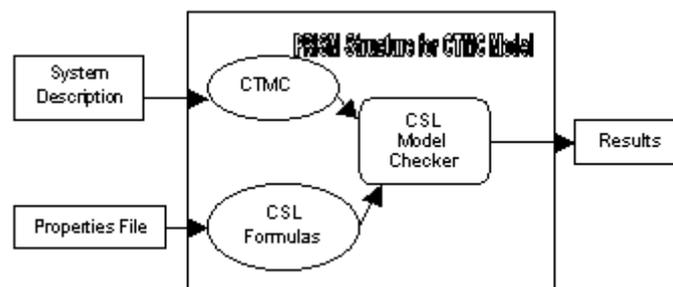
Figure 2: the structure of PRISM for CTMC model

The PRISM language consists of modules, which represent the components of the system. A module contains two parts: its variables and its guards. The variables are called local variables; they can be integers or booleans. The guard is a predicate over all the variables in the system. PRISM model can include global variables which are known to all modules. A module can transfer from its state to a new one through an

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[10] see [17] for different PRISM applications

action. A module can make this action alone, i.e. independently, which is known as *asynchronous* transition, or the action is shared by two or more modules at the same time, which is known as *synchronous* transition. In CTMCs a time delay is incurred before a transition occurs, and a delay is exponentially distributed with rate *r*. The average time of transition is $1/r$. There is more than one transition that can occur in a given state, the transition which is selected is the one that is enabled first. This is known as *the race policy*. The state of the whole model is determined by the states of all the modules together with the contents of the global variables.

Each module contains a set of commands. Each command for a particular predicate on the global state (guard) describes how the local state and global variable set can be updated, i.e. the transition that can occur if the guard is true. Property specification in PRISM for CTMCs is based on CSL probabilistic temporal logic. The principal operators calculate the probability of an event occurring, the long run probability of some condition being satisfied and the expected value of the model's costs or rewards. Experiments can run by PRISM tool. This allows having outcomes of one or more properties. It gives a way of automating multiple instances of model checking. PRISM also includes support for the specification and analysis of properties based on costs and rewards. This gives PRISM the ability to reason about expectations, such as "expected time" and "expected number of given items". A single reward item can assign different rewards to different states, depending on the values of model variables in each one. The states that do not satisfy the guard of any reward item will not have any rewards. For the states (transition) that satisfy multiple guards, the reward assigned to the state (transition) is the sum of the rewards for all the corresponding reward items. Furthermore, PRISM supports the notion of experiments, which is a way of automating multiple instances of model checking. This allows the user to easily obtain the outcome of one or more properties as functions of model and property parameters, using the same assignments of model states. The most recent addition of PRISM is provided by a simulator. It is a tool that allows further analysis of probabilistic models. It calculates and reasons about execution paths through probabilistic models using Monte-Carlo methods and discrete event simulation.

3. Credit card

Let us study the effect of the use of a credit card on the quality of the user's life in the long run.

Consider a person who has a fixed monthly income / salary equal to S. This person has a credit card which gives him the opportunity to increase his spending by H times, i.e. the person can spend amount equals HxS. The credit card issuing company pays for his spending. By the end of each month the company sends a statement with the total amount of money that the card holder spent using the card, and gives him a certain period of time for repayment. Let us assume that the period for repayment is one and half months. The card holder has the opportunity to repay all the money back or pay only part of it; in the latter case the company will charge interest rate on the rest of the money "rest balance" which has not been paid. The amount of money the card holder can spend on his card "available", is reduced each time he uses the card, and also by the amount of the interest rate added to the unpaid part, if there is any. If the card holder repays all the amount of money loaned by the card company, he will not suffer from increased debt caused by interest expenses. Also the more he repays the less the company can charge as interest. Many papers have discussed the credit card system from different research points. In [19] a credit card puzzle is presented for studying the behaviors of people using credit cards. In [20] a simple model of precautionary demand for money is presented, where a model gives an explanation for how the use of credit-cards can differ so widely across countries. In [21] a simple system dynamics model for credit card **use** is presented.

4. The model description

The PRISM model of the system consists of two modules, i.e. one module for the card holder and the other for the company. Figure 3 is the state chart diagram that describes the behaviour of the two modules.
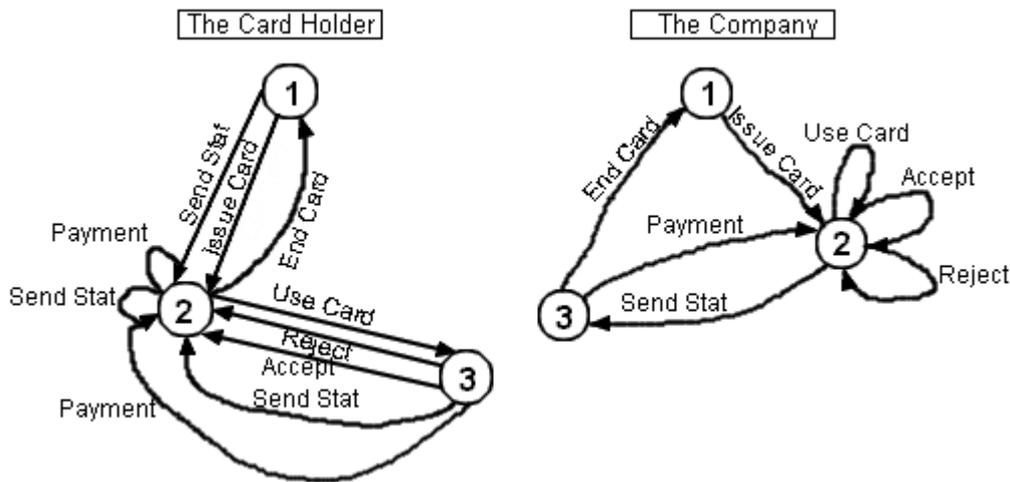
Figure 3: The state chart diagram of the behaviour of the two modules

Table 1 shows the activities shared between the two modules and their meanings.

Table 1: The activities and their meaning in the model

activity	Meaning
Issue card	The company issues a new card for the new card holder
Use card	The card holder uses the card in the machine
accept	The machine accept the order of using the card
reject	The machine rejects the order of using the card
End card	The card holder (the company) decides to end the card
Send statement	The company sends a statement with the due amount for the card holder
payment	The card holder pay back all or some of his due amount of money

There are seven variables in PRISM model; user, company, *new balance*, *pay balance*, *rest balance*, *new due* and *available*. The initial values for all of them are zero.

Let us follow the activities that the card holder involves with the card issuing company. When the person applies for a credit card his credit-worthiness is determined in order to find out whether he is eligible for a credit card. A credit card is issued (*issue card* activity), if the applicant meets the credit card eligibility criteria of the card issuing company. The card holder receives an amount, denoted as *available* value, equal to the "limit" which is H times the income (S) of the card holder. After issuing the card the card holder can use the card to purchase goods and services or use it to withdraw cash; this is done through the activity *use card*. The company, through automated teller machines can *accept* this activity or *reject* it. It accepts use of the card if the amount of money needed, X, is less than or equals to the available amount of money on the card at the time of use, otherwise the company will reject to process the activity *use card*. In case of acceptance the company evaluates the new *available* value by deducting X from the current amount of *available*. The value of *new balance* is increased by the value X. Every month the company sends a statement to the card holder with the *new due* amount of money that he owes to the credit card company. *New due* or *new balance* is calculated by adding both *rest balance* and the *interest due* on it, where *rest balance* is any amount of money owed by the card holder according to previous statements. When the card holder makes a payment (*pay balance)* the company calculates the new *rest balance* by subtracting *pay balance* from *new due* and the new value of *available* is the limit less *rest balance,* and the new values of both *new balance* and *new due* are zero. The company will accept to end the card use when the values of both *new balance* and *rest balance* are zero.

5. Analysis of the experiments and results

We use both PRISM simulator and the analytical method for running the experiments to analyze the topic under study. First we use the simulation technique to study the model for the short term by following the monthly payment statements. First we study the effect of different repayment polices and how they effect the spending ability of the card user. Consider that the card holder's salary equals 1500 units of money, and the credit card issuing company grants him a limit equaling to twice his salary. Interest rate equals to 0.01167. The card user decides to add 500 units of money each month to his salary by taking this money using the card. We study this case with different polices of repayments; repay a quarter, repay half and repay three quarters of his borrowing, respectively as shown in Table 2 and Figure 4.

Table 2: The effect of different polices of repayment on spending ability

Month	Spending ability with the salary	Spending ability with repaying a quarter	Spending ability with repaying half	Spending ability with repaying three quarter**s**
1	1500	0	0	0
2	1500	1625	1750	1875
3	1500	1340	1623	1843
4	1500	1124	1559	1835
5	1500	959	1526	1833
6	1500	834	1510	1832
7	1500	740	1502	1832
8	1500	668	1498	1832
9	1500	614	1496	1832
10	1500	572	1495	1832
11	1500	541	1494	1832
12	1500	517	1494	1832
13	1500	499	1494	1832
14	1500		1494	1832
15	1500		1494	1832
16	1500		1494	1832
17	1500		1494	1832
18	1500		1494	1832
19	1500		1494	1832
20	1500		1494	1832
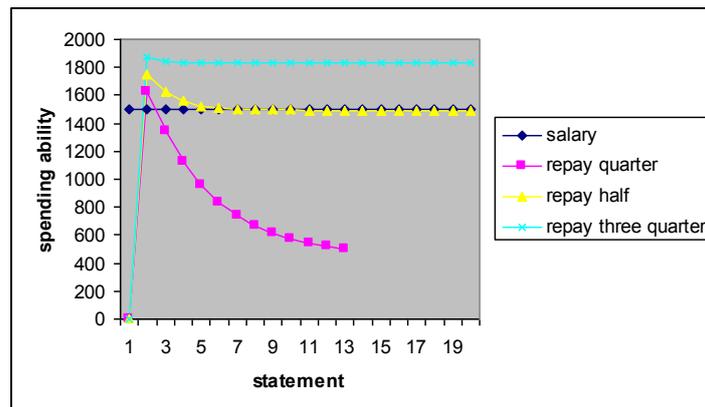
Figure 4: The effect of different polices of repayments on spending ability

Table 2 and Figure 4 show how much the card holder can spend each month according to these different repayment policies. We notice that if he decides to repay only a quarter of his loan, then the loan will accumulate and after one year (12 months) the company will block the use of the card (at least until he repays the loan). In the case when the card holder repays half of his loan we notice that after 8 months he starts to live with an amount of money less than his salary. If the card holder decides to repay three quarters of the loan he chooses the right policy, although he will spend less money than what he wishes but he will avail of more than his own salary every month (1832 units of money). Another case we study using the simulation technique is the effect of the change of the amount of money that the card holder takes every month and the interest rate that the company charges for delayed repayments by the card holder. We consider two cases; one where the card holder uses all the available amount of money and one where he uses three quarters of the available money. In both cases he repays three quarters of the loan. We study these two spending behaviors with two different interest rates, notably with 0.01167 and 0.025. Table 3 and Figure. 5 show the results.

Table 3: The effect of different spending money polices and different interest rates on the loans

Month	The loans when the user takes all the available & interest rate 0.025	The loans when the user takes all the available & interest rate 0.01167	The loans when the user takes three quarter the available &interest rate 0.025	The loans when the user takes three quarter the available & interest rate 0.01167
1	0	0	0	0
2	750	750	1500	1500
3	956	946	1538	1518
4	1013	998	1539	1518
5	1029	1011	1539	1518
6	1033	1014	1539	1518
7	1034	1015	1539	1518
8	1034	1015	1539	1518
9	1034	1015	1539	1518
10	1034	1015	1539	1518
11	1034	1015	1539	1518
12	1034	1015	1539	1518
13	1034	1015	1539	1518
14	1034	1015	1539	1518
15	1034	1015	1539	1518
16	1034	1015	1539	1518
17	1034	1015	1539	1518
18	1034	1015	1539	1518
19	1034	1015	1539	1518
20	1034	1015	1539	1518
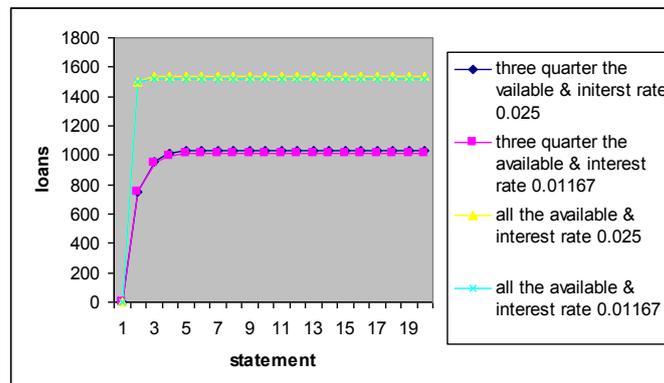
Figure 5: The effect of different spending money polices and different interest rates on the loans

As shown in Table 3 and Figure 5 for all different policies of repayment the card holder will end up in a deteriorated financial situation than if he does not use the card, due to an accumulation of the debt. Also, as the interest rate increases the debt will increase. Also we notice that after some period of time (depends on the spending behavior and the interest rate) the loan will stay at the same level due to this each month the card user goes through a cycle of repaying a fixed amount of the loan with interest charges due and as a result the amount that he can spend becomes limited.

Now we apply PRISM experiment for different values of repayment to study the system for the long run. Consider that each time the card holder uses the card he takes an amount of money equaling to M. Also consider that every time he makes the payment to the company he repays an amount equaling to (3×loan / K), where K is an integer value.

First, let us study the effect of different repayment policies on the accumulated loan. We fix both salary=100, H=2, interest rate=0.025% and let M= (3/4× available). Let K takes the values 4, 6, 8,…, and 30 (i.e. the card holder pays back three quarters of the loan, half of the loan, …, tenth of the loan). The expected rewards (loans) are calculated by running the experiment for "Steady state" properties, R=? [S], where S is used to reason about the behavior of the model in the long run. Table 4 and Figure 6 show the results approximated

to the nearest integer. From these we notice that when K=4, i.e. the card holder pays a significant proportion of this loan, his remaining debt is little. For K=6, 8 and so on it is straightforward, and the loan increases with smaller amounts of down payment and amortization. When the card holder pays back tenth of the loan (K=30) the accumulated loan for the long run becomes 18 units of money, i.e., nearly fifth of his salary.

Table 4: The long run effect of different repayment policies on the loan

K	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Accumulated loan	1.0	2.0	4.0	5.0	6.0	8.0	9.0	10.0	12.0	13.0	14.0	16.0	17.0	18.0
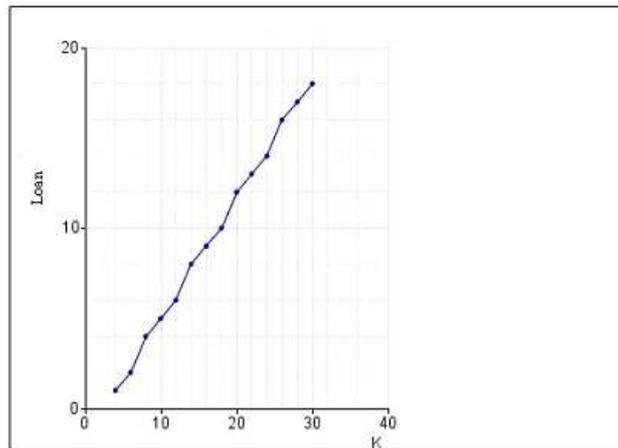
Figure 6: The long run effect of different repayment policies on the loan

Now we focus on a different spending preference and repayment policy of the card user and the impact of these on his quality of life. We fix the salary, H, and the interest rate as above. We change the values of both M and K. Let M takes the values 10, 60, 80 and 100, i.e., every time he uses the card, he spends a fixed amount of money equaling to M. Let K take the values as given in Table 5. The results are in Table 5 and Figure 7 approximated to the nearest integer.

Table 5: The long run effect of buying and payments policies on the spending ability

Spending ability according to different values of M and K	M=10	M=60	M=80	M=100
K=4	108	158	180	200
K=11	104	154	176	194
K=18	100	150	172	190
K=25	94	144	166	186
K=32	90	138	158	180
K=39	86	136	156	176
K=46	66	114	136	156
K=53	64	108	128	148
K=60	52	104	122	142
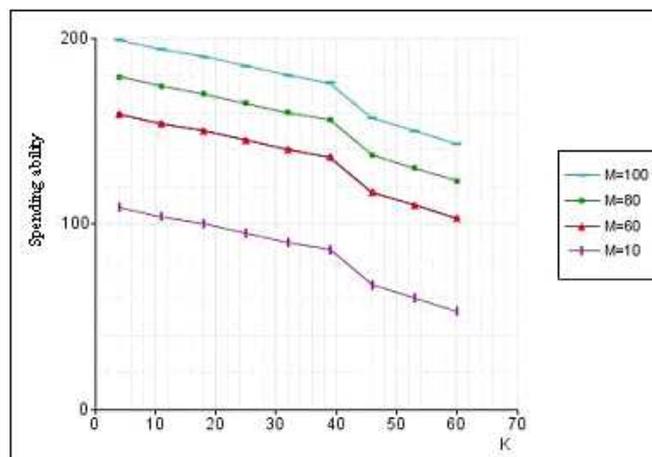
Figure 7: The long run effect of buying and payments policies on the spending ability

From Table 5 and Figure 7 we see that if the card holder borrows much and pays back much (three quarters of the loan) then his spending ability will be high. But if he pays back little (1/20 of the loan then his spending ability will be low.

6. Conclusion

In recent years, credit cards became the main source of purchasing used by consumers instead of cash payment. Credit card companies pay for the purchase, but the card user has to repay the money borrowed to the card company at a later time. In addition to the amount of the purchase, the card user also has to pay interest on the loan. Interest on a loan is calculated as a fixed fraction of the loan amount and is charged for the time period of the loan.

This paper, using the probabilistic model checker PRISM, evaluated credit card use under different conditions such as change in interest rates, different policies of borrowing/repayment and their effect on the credit card user's spending ability. It presents a model that studies the way interest payments affect the quality of the credit card user's life by reducing the amount of money he can spend on other purchases. The model can calculate the level of the money that the card holder can borrow according to his disposable income without going through a cycle of paying interest charges only.

References

A. Bianco and L. de Alfaro. (1995) "Model Checking of Probabilistic and Nondeterministic Systems", in *Proc. Foundations of Software Technology and Theoretical Computer Science*, LNCS 1026, Springer, pp. 499-513.

A. Cimatti, E. M. Clarke, E. Giunchiglia, F. Giunchiglia, M. Pistore, M. Roveri, R. Sebastiani and A. Tacchella. (2002) "NuSMV 2: An OpenSource Tool for Symbolic Model Checking", *in Proc. of International Conference on Computer-Aided Verification* (CAV 2002). Copenhagen, Denmark.

A. Hinton, M. Kwiatkowska, G. Norman, and D. Parker. (2006, March) "PRISM: A Tool for Automatic Verification of Probabilistic Systems", in H. Hermanns and J. Palsberg editors*, in Proc. 12th International Conference on Tools and Algorithms for the Construction and Analysis of Systems* (TACAS'06), Vol 3920 of LNCS, Springer. pp 441-444.

A. Hinton. (2005, April) "Software Project M60: Simulator for the Probabilistic Model Checker PRISM," MEng Final Year Project Dissertation, School of Computer Science, University of Birmingham.

A. Masters and L. Rodríguez-Reyes. (2005) "Endogenous Credit-Card Acceptance in a Model of Precautionary Demand for Money," Oxford Economic Papers, Volume 57, Number 1, pp 157-168.

B. Jeannet, P. D'Argenio, and K. Larsen. (2002) "RAPTURE: A tool for verifying Markov Decision Processes", in I. Cerna editor, in *Proc. Tools Day, affiliated to 13ʰ Int. Conf. Concurrency Theory* (CONCUR'02). Technical Report FIMU-RS-2002-05, Faculty of Informatics, Masaryk Univeristy, pp. 84-98.

C. Baier. and M. Kwiatkowska. (1996) "Model Checking for a Probabilistic Branching Time Logic with Fairness", Techn. Report CSR-96-12, University of Birmingham.

D. Parker, G. Norman, and M. Kwiatkowska. (2004, September). PRISM manual. Available: http://www.cs.bham.ac.uk/˜dxp/prism

E. M. Clarke, O. Grumberg and D. A. Peled. (2000) "*Model Checking*", The MIT press.

F. Wang. (2006) "Symbolic Implementation of Model- checking probablistic timed automata", Ph.D. thesis, School of Computer Science, University of Birmingham.

G. J. Holzmann. (2003) "The SPIN Model Checker Primer and Reference Manual", Addison-Wesley.

H. Hermanns, J.P. Katoen, J. Meyer-Kayser, and M. Siegle. (2000) "A Markov chain model checker", in S. Graf and M. Schwartzbach, editors, in *Proc. 6th International Conference on Tools and Algorithms for the Construction and Analysis of Systems* (TACAS'00), Vol 1785 of LNCS, Springer, pp. 347-362.

J. A. Filar and K. Vrieze. (2004) "*Competitive Markov Decision Processes*" Springer Press.

J. Hillston. (1996) *A Compositional Approach to Performance Modelling*. Cambridge University Press.

J. Rutten, M. Kwiatkowska, G. Norman and D. Parker. (2004) "Mathematical Techniques for Analyzing Concurrent and Probabilistic Systems". in P. Panangaden and F. van Breugel editors, Vol 23 of CRM Monograph Series, American Mathematical Society.

K. L. McMillan. (1993) "*Symbolic Model Checking*". Kluwer Academic.

M. Haliassos and M. Reiter. (2003, May) "Credit Card Debt Puzzles," University of Cyprus and Universitat Pompeu Fabra., Economics Working Papers. 901.

M. Kwiatkowska, G. Norman, and D. Parker. (2004) "PRISM 2.0: A tool for probabilistic model checking", in *Proc. 1st International Conference on Quantitative Evaluation of Systems* (QEST'04), IEEE Computer Society Press, pp. 322–323.

M. Mäkelä. (2002) " Maria: modular reachability analyser for algebraic system nets". In: J. Esparza, C. Lakos (Eds.): *Lecture Notes in Computer Science, Vol. 2360: 23rd International Conference on Applications and Theory of Petri Nets, Adelaide, Australia, June 24-30, 2002*, pages 1-434pp. Springer Verlag.

M. Ratha. (1997, June) "The Credit Card Model," prepared for the MIT System Dynamics in Education Project.

W. J. Stewart. (1994) "*Introduction to the Numerical Solution of Markov Chains*". Princeton University Press.

44

e-Commerce, Business Methods and Evaluation of Payment Methods in Nigeria

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Abstract: E-Commerce is a global trend and can be a viable source of economic reform in a nation. Nigeria, a third world country is leaving no stone unturned to make life easier and more comfortable in this electronic age. Though developed countries are on the verge of conducting e-commerce securely and comfortably, Nigeria is absorbing techniques involved either by espionage, knowledge transfer or other means. Hence, the need for ensuring effectiveness, awareness among inhabitants, and security of resources involved must be taken into account. This paper highlights different levels of e-commerce participation among banks, service providers and the public in Nigeria. A business-inclined metropolitan suburb of Lagos was used as a case study to evaluate citizenry involvement and opinions. Recommendations on the most suitable payment method (s) for citizenry was made based on their opinions.

Keywords: e-commerce, payment models.

1. Introduction

e-Commerce can be defined as the integration of communications, data management, and security capabilities that allows organizations to exchange information on sale of goods and services. It can also be defined as an act of conducting transaction via electronic medium. Such electronic media can be TV, Fax, or the internet. With the unraveling evolution of GSM in Nigeria, e-commerce brings another untapped method of commerce via mobile devices called m-commerce. Despite these technologies, there are many substandard payment methods in Nigeria with crude ways of handling security issues like authentication and non-repudiation. E-Commerce requires authentication, non-repudiation, confidentiality, and trust to mention a few (S.G.E. Garrett and P.J. Skevington 1999). Internet authentication is best implemented by a process called digital signatures and non-repudiation is a digital signature verification that a purchase is made (Tom Coffrey and Puneet Saidha 1996).

There are two major business models of e-commerce. Business to Business (B2B) model occurs between two organizations characterized by large volumes of products and small price margin. The second is Business to Consumer (B2C) model. It occurs between an organization and an individual. It is characterized by small volumes of products and large price margin. Other e-commerce models are Business to Affiliate model (B2A), Business to Portal model (B2P) and Consumer to Consumer model (C2C) to mention a few (Timothy Cumming 1991). In another sense, e-commerce has been classified into B2B, B2C and electronic markets (P. Morreale and K. Terplan 2001). Major requirements of conducting E-Commerce over the internet are servers (such as web, catalog, certificate, and mail), online merchant account, payment gateway and mail or web host account.

The kind of solution desired depends on individual or organizational financial commitment. For in-house web front or private hosting solutions, all requirements are provided or controlled by the investor while in instant web front solution, only very few requirements are provided or controlled by the investor. Other requirements need to be outsourced. Outsourced requirements include servers and payment gateways. Instant storefront which requires a shared or dedicated web hosting plan provided by a firm is cheaper and easier to maintain than in-house storefront. In developed countries, in-house solutions are mostly put in place while in developing countries like Nigeria, instant solutions are mostly used. Despite this, Nigeria has very few web merchants. Web merchants are individuals or organizations that provide e-commerce services. Alternatively, they facilitate making transactions on internet via websites, electronic mail and so on. Today in Nigeria, there is a need to know the suitable payment method(s) based on the key factors such as security and ease of use. Some of the global payment models are stated below.

1.1 Three common payment models

1.1.1 Digital cash

It entails the use of a digital wallet (a plug-in to web browsers) where invoice or receipt of payment is kept and cash is withdrawn (Timothy Cumming 1991). Advantages are that the transaction is completed

immediately, and anonymity during transaction is possible. That is, it does not require personal or contact details of the buyer.

1.1.2 Credit card

A credit card is a card whose holder has been granted a revolving credit line (Abhijit Chaudbury and Jean-Pierre Kuiler 2002 and Reserve Bank of Australia 2005). This does not include a deposit account/facility though an overdraft available. The card enables the holder to make purchases and/or cash advances up to a pre-arranged limit. The credit granted can be settled in full by the end of a specified period (usually 45days or thereabouts) or in part, with the balance taken as extended credit. Interest may be charged on the transaction amounts from the date of each transaction or only on the extended credit where the credit granted has not been settled in full.

1.1.3 Online check/electronic fund transfer

During the course of making transaction with online check, a buyer enters the digits or numbers found on the check. This is done for authorization purpose while in electronic fund transfer, there is a financial house called Automated Clearing House (ACH) responsible for transferring the money from the buyer's or originator's account to the seller's or recipient's account on completion of transaction (Patiwah Panurach 1996).

1.2 Other payment methods

1.2.1 Debit card

Debit card enables the holder to access funds in a deposit account at an authorized deposit-taking institution (Abhijit Chaudbury and Jean-Pierre Kuiler 2002). In debit card model, a buyer would have a deposit account where all purchases will be deducted from. Anytime one uses a debit card to purchase online or in a traditional store, the card goes through a debit card payment processing. The debit card payment processor gives response immediately. One of the major reasons for using debit card payment model is to ensure that a customer has enough money in his account to make the purchase or transaction.

1.2.2 Micropayment

Micropayment is a term used for amounts as low as one cent and allows vendors to sell content, information, and services over the internet at very low unit prices. Several companies offer Micropayment solutions such as IBM Micropayments and Compaq's alternative, the MilliCent (Abhijit Chaudbury and Jean-Pierre Kuiler 2002).

1.2.3 Money orders

Money orders are similar to certified checks, as a known third party such as the U.S. Postal Service, American Express, Western Union, or a bank guarantees the value. The transaction cost is small and the advantage is that it can be sent to the named receiver. The payment still carries some degree of anonymity. If the issuer preserves the privacy of both the seller and the buyer, the transaction is well protected (Abhijit Chaudbury and Jean-Pierre Kuiler 2002).

Having mentioned these payment methods, e-commerce in Nigeria has been predominated by substandard payment methods and varying business methods among her banks.

2. e-Commerce methods in Nigerian banks

Majority of the participating banks are new generation banks though the consolidation of Nigerian banks has brought about merging or acquisition between two or more banks.

2.1 Types of business methods in Nigeria

2.1.1 Electronic banking (e-banking)

E-banking can be referred to as a system whereby all the banking services are conducted via electronic medium. Such banking services include money depositing and withdrawal, checking account balance and many more. The banks are characterized by the use of virtual private network (VPN) to connect other

branches. Elaborately, the local branches of the bank are connected via Very Small Aperture Terminal (VSAT), a satellite communication system. In this case of e-banking, the network is referred to as Extranet. An extranet is the use of internet technology outside a company's premises to share commercial and operational information and tasks with customers (Okey Nwosu 2005, Marilyn Greenstein and Miklos Vasarhelyi 2002). Alternatively, it is a private network outside a business, whereas the internet is a worldwide, public network. No one outside the permitted customer group can see the extranet. It is securely protected. Customers are able to transact on the bank's website in a secured environment by using Secured Socket Layer (SSL). This makes data transmitted between the client (that is the customer's computer) and the web server to be encrypted hence it requires understanding the keys to retrieve the data. Usually, the client uses the public key while the private key remains with the server. This encryption technique is called Asymmetric Encryption (CIW Study Guide 2004). Few banks carry out e-banking in Nigeria, among them are First Atlantic Bank (now First Inland Bank PLC) and Standard Trust Bank (now United Bank for Africa PLC).

2.1.2 Internet banking

Today's Nigerian banks use VSAT for communication among their branches, what is referred to as Intranet. An intranet is the use of Internet technology inside a company. Emphatically, only staff share customer and operational information as well as tasks (Okey Nwosu 2005, Marilyn Greenstein and Miklos Vasarhelyi 2002). It has made it possible for someone to deposit or withdraw money from any of the branches of his bank. Example of the banks are United Bank for Africa PLC, Zenith Bank PLC and First Inland Bank PLC.

2.1.3 Telephone banking

Astonishingly, some banks still use what is referred to as Telephone banking. An example is Co-operative Bank PLC (now Skype Bank PLC). One branch of the bank calls another where the customer's account domiciles to confirm if the account is valid before performing the task of depositing or withdrawal.

2.1.4 Mobile banking (m-banking)

With the advent of Global System for Mobile Telecommunication (GSM), we now have very few banks using it as a medium of conducting some of their services. An example is The Sapphire FlashClub™ by First Inland Bank PLC (Okey Nwosu 2005). The Sapphire FlashClub is a bank account based on a GSM phone number. Literally, when one signs up for a Sapphire FlashClub account, his phone number becomes the bank account number. And it becomes possible to transfer cash to anyone who owns a GSM phone anywhere in Nigeria (Okey Nwosu 2005). Also with such account, the owner can perform other transactions like buying any of the bank's e-products such as recharge cards for cell phones.

2.1.5 Other transaction method(s)

Among other transaction methods, the widely used is Automated Teller Machine (ATM). ATMs are mostly situated in large stores, and hotels. Someone can cash money from this complex information processing system. It is a complete computer system in a box. It handles at least four media including currency, cards, receipts, and envelopes. It also has self-supervising operating, application, and diagnostic programs; and incorporates sophisticated physical and logical security features (Jerome Svigals 1983).

2.2 E-commerce methods by online service providers

2.2.1 Web merchants

Web merchants are those organizations that conduct transaction via their websites. They make it possible for people to buy goods or render services to people via their websites. Examples of these web merchants are Virtualkard.com and Naira.com. They offer prepaid services and charges are based on prevailing currencies exchange rate. Online buyer purchases the card (VirtualKard) based on the amount of the product(s) in dollars that he wants to buy and uses the card information to make his online purchases (VirtualKard (Nig.) PLC 2005). Another payment method is direct payment to the seller's bank. This is an offline method. Some of the companies using this method are Mcreal.net and Signonafrica.com. Both are web hosting companies. It is required that a customer pays into the bank account of the seller or service provider. A proof of payment is required, sometimes the teller is scanned and sent via email as proof of payment before the service is rendered, a process called Non-repudiation

Another trend in our e-commerce is the pre-paid method. This works best for a single operational task (Fola Odufuwa 2005). Our examination boards have proven effective in this area. Joint Matriculation Admission

Board (JAMB), West African Examination Council (WAEC), and National Examination Council (NECO) have made it possible for candidates to check their results online by buying prepaid cards. The card information is used to log on and display results. Mobile Telecommunication Operators like MTN Nigeria, Home Entertainment service providers like Multichoice and many more have provided pre-paid services to attract people and customers though such transaction might not be conducted online.

2.2.2 Payment gateway providers

Payment Gateway Providers process card information used online or at point of sale (POS) terminals. They act as interface to the banking system. Various banks have different proprietary standards hence the need for gateway or interface that can connect to any bank system regardless of her proprietary standard. At present, three payment gateways have been approved in Nigeria. Among them are Interswitch (Interswitch (Nig.) Ltd 2005) and Etranzact. Some of the prevalent payment gateways around the globe are Cybercash, Digicash, and Datacash (Kathy Yakal 1997). Though many more are emerging, each payment gateway has card types or models it supports. Typically, Interswitch supports debit card payment model in Nigeria. Banks such as United Bank for Africa offer debit cards to their customers and use Interswitch as the payment gateway.

3. Evaluation of e-Commerce participation by the public

In the course of this research, a questionnaire was used to seek public opinion and analyze their present level of participation in E-commerce. The groups of people involved were scholars, businessmen, graduate and postgraduate students. It was conducted in one of tertiary institutions in suburb of Lagos-State, Nigeria. The chosen location was meant to represent a mix of wealthy and average Nigerians. As at the moment of this evaluation process, the institution has students' capacity of six thousand, approximately four hundred and fifty non-academic staff or semi-skilled workers, and three hundred academic staff. These categories of people were dispersedly given same questionnaire. While the entire people could not be sampled, about one-fifth of them were involved in the evaluation. Learning materials like daily newspaper, articles and face-to-face conversation with staff of some banks, e-commerce service providers were also used in this research.

3.1 Research questions:

The multiple choice questions used in determining the extent of participation of Nigerians in e-commerce are these:

- Do you conduct transaction on internet?
- If **yes**, what payment method do you use?
- Your job description
- Your computer competence level
- Should you want to make purchase online, what payment method would you prefer?

While the choice answers are not included here, analyses of the aggregate responses by the public are given in section 3.2.

3.2 Presentation of results

Table 1: Current and preferred payment methods

	Current Payment methods					Preferred Payment methods				
	Direct Payment	Credit Card	Prepaid Card	Others	None	Direct Payment	Credit Card	Prepaid Card	Others	None
No. of People sampled	39	48	127	100	967	376	256	605	134	37

Table 2: Transact online, job description and computer competence level

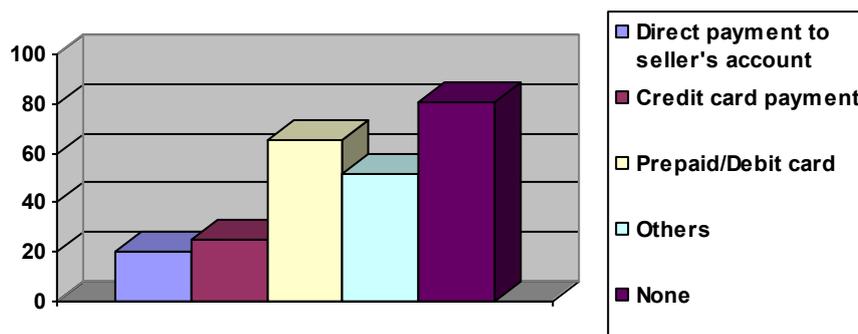|	Online Transaction		Job Description		Computer Competence Level		
	Yes	No	Student	Worker	Below Average	Average	Good
No. of People sampled	194	1006	297	903	53	272	875

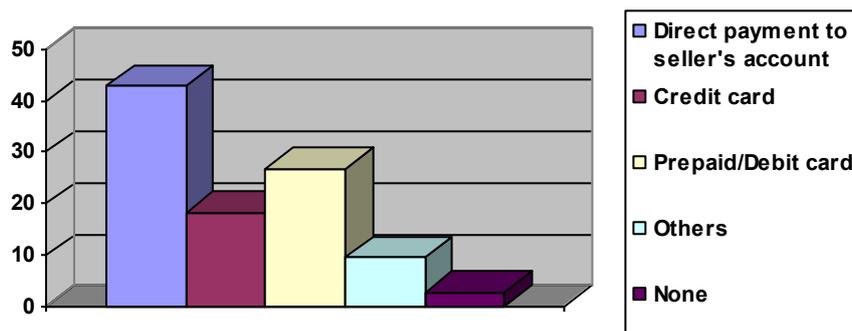**Figure 1:** Payment methods used by online buyers/sellers

Figure 2: Preferred payment methods

3.3 Analyses and discussion

Based on the results, about 84% of those sampled do not conduct transactions on internet despite being computer literate (Table 2.0), though some do so without knowing. For instance when one purchases a prepaid card in a bank to check result on the internet, he is invariably carrying out an e-commerce. For those that do e-commerce (approx. 16%), it has been by using direct payments, credit cards, prepaid cards to their settle bills.

Analyses showed that 65% of them use prepaid cards, mostly to check results online, buy airtime or renew subscription to services. About 25% conduct transaction using credit cards, the majority of those in this category make orders from foreign websites. With the current fraudulent practices, Nigeria has been rated as the highest risk country on e-commerce across the globe followed by Indonesia (Cybersource 2005). To date, many orders from Nigeria are unprocessed. Only 20% of those conducting transactions use direct payment methods. Interestingly, many people choose direct payment and prepaid/debit methods. Direct payment means going to bank to pay into the seller's account. This report can play a significant role in making e-commerce formidable in Nigeria, so as to know what measures should be in place to do e-commerce in Nigeria. Having realized this, the response of those sampled to what payment methods should be used has been impressive.

The most preferred method is the prepaid card system. This is rated highest (43%) because of its ease of acquisition and use. In terms of security or safety from online fraudulent activities, about 27% of those sampled prefers direct payment to sellers' account. The third preferred method is the credit card system with approximately 18%. Observation showed that many do not understand the credit card method but as a current trend in payment models for developed countries, many choose it alongside prepaid/debit card methods. In another case, approximately 3% of those sampled made no choice on what is their preferred payment method, an indication that they are unaware of e-commerce at this present age. A suggestion given on preferred payment method was the use of Biometric payment. This is at an experimental stage in the developed nations having been found secured and accurate. Nigeria can rise up to the task though it might take a couple of years should it become a standard in the e-commerce industry.

4. Conclusion and recommendation

Indications have shown that the appropriate payment methods for us are prepaid/debit card system and direct payment to sellers' account. Debit card payment method and prepaid payment method are

synonymous since they require that the customer has sufficient money either in his account or by buying a card respectively. For convenience reasons, a prepaid card system is better than direct payment method despite it being rated the highest. Many choose direct payment because of the reduced risk in terms of fraud. At present, confirmation in direct payment method is carried out by sending a soft copy of the teller used in paying. Improvement can be made on this by using a unique number on every teller of payment when sending or indicating the proof of payment. While this can be time-wasting, the prepaid card system has proven effective and fast by its current use to check results. To have a secured card system and ensuring privacy of cardholder, a personal identification number (PIN) is required when making purchases online. Such a card system can gain more acceptability if it is based on a smart card technology capable of being used at point of sales (POS) terminals (Abhijit Chaudbury and Jean-Pierre Kuiler 2002).

 With this, a standard debit card payment method can be used to make purchases on any Nigerian physical or online store. Banks and e-commerce service providers need to be actively involved, it is recommended that e-commerce service providers should provide reliable payment gateway to our banks, thereby handling the authorization process in any online purchase. That is, they must provide an immediate response for every card detail submitted during an online purchase. Invariably, they must ensure that the card is valid or has sufficient money to make the order or purchase. Banks will handle the settlement process by transferring the money from cardholder's account to the seller's account. The need for efficient and reliable payment gateways should not be underrated because many banks will produce their own debit or prepaid cards. The payment gateways should be able to connect to these banks regardless of their various proprietary technologies. Also, a regulatory body should be set-up involving both parties to ensure a standard e-commerce system in Nigeria.

With all these, a web merchant or someone that wants to start an e-commerce website can decide on which payment gateway to use and what kind of debit card should be allowed on his website. A one-stop solution will begin to emerge sooner has a bank and a payment gateway may decide to render dependable services. That is, a web merchant who decides to use a particular payment gateway invariably has to use a matching debit card system alongside. This has been implemented in developed countries. Public awareness on benefit of getting our local stores online should be encouraged. It should be emphasized that getting online does not stop the traditional or conventional sales but rather an alternative way of generating more income.

References

Chaudbury, A. and Kuiler, J. (2002) *e-Business and e-Commerce Infrastructure: Technologies Supporting the e-Business Initiative*, McGraw Hill, International Edition, New York, pp 174-175.

Coffey, T. and Saidha, P. (1996) "Non-repudiation with mandatory proof of receipt", *ACM SIGCOMM Computer Communication Review*, Vol. 26 Issue 1, pp 6-17.

Cumming, T. (1991) *little e BIG COMMERCE-How to make profit online*, Virgin Publishing ltd, 1st Edition, London, pp 111-113.

Cybersource Corp. (2005) *New York, Nigeria Named 'Riskiest Areas for eCommerce*, [Online], Available: http://www.cybersource.com/fraudreport/ [4 September, 2005].

First Inland Bank NIG. PLC (2005) *Banking Operations*, [Online], Available: http://www.sapphirelink.com [4 September, 2005].

Garrett, S and Skevington, P. (1999) "An introduction to e-commerce", *BT Technologies Journal*, Vol. 17 No. 3, pp 11-16.

Greenstein, M. and Vasarhelyi, M. (2002) *Electronic Commerce Security, Risk Management and Control*, McGrawHill Irwin, International Edition, New York, pp 64-65.

Interswitch (Nig.) Ltd (2005) *Payment Models*, [Online], Available: http://www.interswitchng.com [8 August, 2005].

Morreale, P. and Terplan, K. (2001) *The CRC Handbook of Modern Communications*, CRCPress LLC, 1st Edition, UK, pp. 2-49.

Nwosu, O. (2005) *Financial Standard Newspaper*, Vol. 6 No. 25, Nigeria, pp. 40.

Odufuwa, F. (2005) *learning from Nigeria's e-commerce Success Stories*, [Online], Available: http://www.edc.org/GLG/gkd/2003/Dec/0494.html [4 October, 2005].

Panurach, P. (1996) "Money in Electronic Commerce: Digital Cash, Electronic Fund Transfer and Ecash", *Communications of the ACM*, Vol. 3 No. 6, pp 45-50.

Reserve Bank of Australia (2005), *Transaction card issuing (explanatory notes)*, [Online], Available: http://www.rba.gov.au/PaymentsSystem/PaymentsStatistics/RetailPaymentsStatist icsCollection/transaction_card_issuing.html [14 September, 2005].

Simmons, G. (1979) "Symmetric and Asymmetric Encryption", *Computing Surveys*, Vol. 11 No. 4, pp 305-330.

Svigals, J. (1983) *Smart Cards The new bank cards*, Macmillian Publishing Company, Updated and Expanded Edition, USA, pp. 11-19.

VirtualKard (Nig.) PLC (2005) *Virtual Kard Rules*, [Online], Available: http://www.smscolony.com/vkusers/ [4 July, 2005].

Yakal, K. (1997) "Electronic Commerce: Not yet booming, but strong beginnings", *ACM Press (Networker)*, Vol. 1 Issue 3, pp 23-27.