LNBIP 222

Daniel Palacios-Marqués
Domingo Ribeiro Soriano
Kun-Huang Huarng (Eds.)

New Information and Communication Technologies for Knowledge Management in Organizations

5th Global Innovation and Knowledge Academy Conference, GIKA 2015
Valencia, Spain, July 14–16, 2015, Proceedings

Global Innovation & Knowledge Academy
GIKA

Springer

Lecture Notes in Business Information Processing 222

More information about this series at http://www.springer.com/series/7911

Daniel Palacios-Marqués · Domingo Ribeiro Soriano
Kun-Huang Huarng (Eds.)

New Information and Communication Technologies for Knowledge Management in Organizations

5th Global Innovation and Knowledge Academy Conference, GIKA 2015
Valencia, Spain, July 14–16, 2015
Proceedings

Springer

Editors
Daniel Palacios-Marqués
University Polytechnic of Valencia
Valencia
Spain

Kun-Huang Huarng
Feng Chia University
Taichung
Taiwan

Domingo Ribeiro Soriano
University of Valencia
Valencia
Spain

ISSN 1865-1348 ISSN 1865-1356 (electronic)
Lecture Notes in Business Information Processing
ISBN 978-3-319-22203-5 ISBN 978-3-319-22204-2 (eBook)
DOI 10.1007/978-3-319-22204-2

Library of Congress Control Number: 2015944723

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media
(www.springer.com)

Preface

The Global Innovation and Knowledge Academy (GIKA) and the University of Valencia are pleased to present the main results of the 5th annual conference, held in Valencia, July 14–16, 2015, through these proceedings published in Springer's *Lecture Notes in Business Information Processing* series.

GIKA 2015 was co-organized by the GIKA Academy and the University of Valencia, Spain. It was co-supported by the Faculty of Economics of the University of Valencia, IUDESCOOP University of Valencia, Department of Business Administration J.J. Renau Piqueras of the University of Valencia, Grupo Maicerias Españolas – Arroz Dacsa, Generalitat Valenciana, IBERIA, and Grupo Studio. The conference offers a unique opportunity for researchers, professionals, and students to present and exchange ideas concerning management, information systems, and business economics and see its implications in the real world.

The theme of this edition of GIKA was "New Knowledge Impacts on Designing Implementable Innovative Realities," being conscious of the importance that new technologies represent for dealing with innovation. The aim is to publish research that contributes to the creation of a solid evidence base concerning new information and communication technologies for knowledge management, measuring the impact and diffusion of new technologies within organizations, as well as on the role of new technologies in the relationships between knowledge management and organizational innovation. Thus, the title of this book is "New Information and Communication Technologies for Knowledge Management in Organizations."

The increasing importance of information and communication technologies in management and business economics, and more generally in all the social sciences, is providing numerous new opportunities to researchers in these areas to find better solutions that explain the complexities of our world. By using these techniques, researchers and practitioners can develop more efficient models that adapt better to the market and permit us to maximize the benefits or minimize the costs in a more appropriate way.

The GIKA 2015 proceedings comprise **X** papers selected from a total of **X** papers presented at the conference.

We would like to thank all the contributors, the reviewers, and the scientific committee for their kind co-operation with GIKA 2015. We would also like to thank Arch Woodside, GIKA Honorary Chair. Finally, we would like to express our gratitude to Springer and in particular to W. van der Aalst, J. Mylopoulos, M. Rosemann, M. J. Shaw, and C. Szyperski (series editors of *Lecture Notes in Business Information Processing*), Ralf Gerstner (Executive Editor Computer Science), and Viktoria Meyer (Editorial Assistant) for their support in the preparation of this book.

July 2015

Daniel Palacios-Marqués
Domingo Ribeiro Soriano
Kun-Huang Huarng

Contents

The STUDENTSCALE: Measuring Students' Motivation, Interest, Learning Resources and Styles

Rui Moreira(✉), Cláudia Seabra, José Luís Abrantes, and Belmiro Rego

Polytechnic Institute of Viseu, Viseu, Portugal
rjfmoreira@gmail.com, {cseabra,jlabrantes}@estv.ipv.pt,
brego@esev.ipv.pt

Abstract. It becomes important to consider the role of Information Technologies (IT) in society and at school, including its impact on the teaching-learning process transformation. The use of IT should be done in an integrated and inclusive way, it is critical to teach how to use, consume and interact with technology. This study intends to contribute to a more depth understanding of the IT impact in the teaching-learning process. Our main goal is to create a scale to measure the Subjects' Interest and Motivation, Motivation and Involvement with Learning Resources and Learning Styles. Those are important factors that impact on students' Learning Performance. Insights from an empirical study of 357middle education students indicate that this multi-dimensional scale incorporates the following constructs: a) Interest and Motivation, b) Motivation and Involvement with IT's Learning Resources, c) Motivation and Involvement with Teachers' Learning Resources, and d) Non Literary Learning Styles. Discussion centers on this scale implications for theory development and management decisions. Teachers' and schools' managers may better understand the learning resources and styles preferred by students, and thus to create more motivational learning programs. Directions for future research are also presented.

Keywords: Pedagogy · Student behavior · Learning resources · Learning styles

1 Introduction

Students are now more demanding and know what they want and what they like. Teachers must be alert and keep interaction to motivate the students daily. From a young age, they learn to live with the Information and Communication Technologies (IT). It is crucial to understand the IT role in nowadays society, including its impact on the teaching-learning process. IT can contribute to the teaching and learning current paradigm changing. The school must become an intercultural place where students abandon their passive position to be active agents in their own learning. Teachers should leave their isolated position of single agents to also turn themselves into the students' pupils and partners in the teaching process. This requires the use of IT in schools in an integrated and inclusive way, to teach how to use, consume and interact with technology in a critical way (Bridges, 1999).

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 1–9, 2015.
DOI: 10.1007/978-3-319-22204-2_1

This study aims to understand what factors contribute to a better learning environment in the students' perspective. Also, how the education, learning and motivation for students change with the use of IT and multimedia resources in the classroom. Specifically this study main goal is to build a scale to measure the antecedents of student's Learning Performance: Students' Social Context - i) Student/Teacher; ii) Student/Student, and iii) School/Family; Personal Factors and Learning Styles - i) Motivation and Student's Interest, ii) Student's Behavior, and iii) Learning Styles; Learning Resources - i) the Use of Teacher's Resources, and ii) the Use of Technology.

2 Literature Review

The growing importance of IT in schools provokes several debates and discussions on its effectiveness in the student's learning rhythms, in the role of teachers and students, and even in the role of the school as institutions. Proponents of universalized use of IT in schools proclaim that this use allows developing new capabilities in students' learning, to extend their horizons in a diverse and global scale (McGrath, 1997-1998). On the opposite side, those who criticize IT use argue that it limits and constrains students learning, transforming them in passive receivers of information, making them socially isolated people (Abrahamson, 1998).

In this study, we adopt a cautious position on the perspective in which the use of IT itself may not be sufficient to explain and characterize the new students. Other factors may be behind the students' performance, and that will influence the way they perceive the school and therefore the use of IT, such as the student's social context, personal factors, learning styles, and learning resources.

2.1 Students' Social Context

The need to engage students and make them active and interested participants in the classroom has been recognized by many researchers (Hay, Hodgkinson, Peltier, & Drago,2004; Lowman & Mathie, 1993; Webster & Hackley, 1997). In fact, that interaction has been identified as a key factor in the learning experience (Vygotsky, 1978). In the current pedagogical relationship there are components considered essential: the student, his personality, the family and social context, the teacher, his personality, the social environment, specifically the family and society as a whole (Mialaret, 1992).

The student's performance depends on many factors that are not limited to their cognitive and/or learning performance capabilities. The environment, the social and educational context in which the learning process takes place is also essential (Young, 2005). Most elements of the school community consider school as a more enjoyable and useful place when they believe that others appreciate and value them in their environment (Goodenow & Grady, 1993). This is also a motivating factor for learning (Weiner, 1990). In sum, creating a productive learning environment requires a climate in which students feel good about themselves, about their peers and teachers and the social environment as a whole.

In line with the above, we considered the relationship of the student to the school environment in the following areas: i) student/ teacher; ii) student/student, iii) school/family, supported by research on cooperative learning and reciprocal teaching (eg. Johnson & Johnson, 1991; Palincsar & Brown, 1984;Slavin, 1990), the study of social interaction as a primary source of cognitive development (Rogoff, 1990; Vygotsky, 1978), in research on the effects of friendship, school adjustment (Berndt & Keefe, 1992) and the study of the influence of social context variables in cognitive, motivational, and educational processes (Goodenow, 1992; Weiner 1990).

2.2 Personal Factors and Learning Styles

When a student is interested and motivated, his learning is more effective. Also, the teacher's role is facilitated (Abrantes, Seabra & Lages, 2007; Young, Klemz & Murphy 2003). Students reject learning environments that they don't like and, moreover, their perception of learning is worse in those environments (Hsu, 1999). In this context, student's intrinsic factors, the learning environment and styles are important issues to examine how students focus on the contents (Young *et al.*, 2003; Hamer, 2000; Clarke III, Flaherty & Mottner, 2001). The theory of learning styles points to individual preference-related factors, such as: environment, emotions, interactions and physical needs that have an impact on the learning process (Dunn & Griggs, 1995). On the other hand, students with similar preferences in terms of learning styles have similar choices in what regards to subjects and courses; also they prefer teachers with teaching methods tailored to their learning styles (Kolb, 1988). Other researchers have shown that there is a correlation between learning styles with preferences for work (Lashinger & Boss, 1984), educational involvement, motivation and learning (Honey & Mumford, 1992), and student performance (Brokaw & Mertz, 2000).

In this context, it is important to analyze the learning environments that the student values and his perspective on what facilitates his learning process. We considered in personal factors and learning styles: i) motivation and student's interest, ii) student's behavior iii) and learning styles.

2.3 Learning Resources

Teachers have several techniques to prepare their lessons, however with the technological advances the decision is increasingly complex. In addition, many teachers carefully weigh the potential effect of new teaching techniques introduction in their students' evaluation (Clarke III *et al.*, 2001).

Several educational resources and methods have been analyzed in the literature such as exercises in class, lectures, use of case studies (Davis, Misra & Van Auken, 2000), combination of written and electronic channels (McNeilly & Ranney, 1998), collection and projects research group, teamwork (Bridges, 1999), and the effect of classroom activities on student learning process (Hamer, 2000).Other studies suggest also that a student's favorable attitude concerning the teaching style leads to better outcomes, and that the relationship between the teaching methods and learning styles results in a more effective learning (Dunn *et al.*, 1990).

The use of technological resources and IT in classrooms is common and recurring today. Potentially, students may withdraw several advantages of technologies use: first for their own skills development in using IT; also IT use offers new ways of mediated learning helping students to receive information more effectively, giving them more autonomy and freedom, and increasing their performance (Aleven & Koedinger, 2002; Hunt, Eagle & Kitchen, 2004).

Regarding the use of teacher's resources there is great unanimity among researchers as to the need for replacement of passive methods for models of experiential and interactive learning (Davis *et al.*, 2000; McNeilly & Ranney, 1998; Hamer, 2000). However, the use of IT in teaching learning raised several questions about the best combination of educational resources. The perspective that the IT use in the classroom is beneficial and effective does not invalidate the importance of using other traditional teaching resources (Berry, 1993). Both teaching resources - with and without the IT use - are important to students. Both resources should not be exclusionary and can live side by side complementing themselves in the teaching/learning process (Hamer, 2000).

We considered the learning resources as including i) the use of teacher's resources and ii) the use of technology.

3 Methodology

This study was developed based on a survey to students in 7th, 8th and 9th year of school in Portuguese schools. The questionnaire was developed based on previous scales (e.g. Abrantes et al., 2007; Hunt et al., 2004). An online questionnaire was proposed to the students between February and April of 2013. 255 questionnaires were validated from 257 questionnaires received.

Regarding the socio-demographic profile, the sample consists mainly of females (53.5%). The most represented age groups is between 13 and 14 years (30% and 29.7% respectively). Most students in the sample never failed (69.7%), 21.3% failed once, twice (7.3%), and only 8% failed three or four times. When asked about the daily study time beyond school hours, half of the students said that they spent about one to two hours daily, 34% studied less than an hour per day. Regarding the household, most of the respondents' fathers where factory or agriculture workers (51.3%) or commercial/administrative (11.2%), the mothers were mainly housewives (25.2%), factory or agriculture workers (24.9%), and business administration employees (19%).

4 Results

In this study we analyzed the factors that could impact on learning process and environment valued by students, including family involvement with the school, student interest, styles and learning resources. The responses' frequency analysis allowed us to draw some results:

- There is a great involvement of the parents with the school, as well as an active participation in school and extracurricular activities.
- Parents have an absolute knowledge of children's situation in school.

- Students reported that their main motivations to school were linked with the satisfaction in improving their knowledge and personal skills, interest in learning interesting things, and self-actualization.
- However, the expectations to complete the studies are low for most students.
- Students recognize that there are different learning styles causing different stimuli for the knowledge acquisition.
- When comparing learning resources, students prefer the use of IT in relation to reading and listening contents.
- Students value the teacher's role, namely what he says, advises or encourages them to do.
- Most of the students stated that they like to work with IT, referring that they feel very comfortable in using those resources, demonstrating familiarity, proximity, and frequent use of IT.
- In what regards to learning resources, a large proportion of students reported reduced use of IT in schools, including email, chat, teacher's webpage, research in the online library, video and audio conferencing.
- The resources that students identified as the most used were textbooks, homework, tests/exams and assignments in class. Thus, it continues to dominate the use of non IT resources.

To address the main goal of this study – building a scale to measure the antecedents of student's learning performance –, the items were subjected to a confirmatory factor analysis (CFA), using full-information maximum likelihood (FIML) estimation procedures in LISREL 8.8 (Jöreskog&Sörbom, 1996). In this model, each item is restricted to load on its pre-specified factor, with the three first-order factors allowed to correlate freely. After CFA purification, a list of 18 items was found. A full listing of the 18 final items after CFA purification and their scale reliabilities is shown in Table 1.

The chi-square for this model is significant (χ^2=249,95, 129 df, p<.00). Since the chi-square statistic is sensitive to sample size, we also assessed additional fit indices: Normed Fit Index (NFI), Comparative Fit Index (CFI), the Incremental Fit Index (IFI), and the Tucker-Lewis Fit Index (TLI). The NFI, CFI, IFI and TLI of this model are .97, .99, .99, and .98, respectively.

As can be seen in Table 1, convergent validity is evidenced by the large and significant standardized loadings of each item on its intended construct (average loading size is 0.786 and 16.90). Also all constructs presented desirable levels of composite reliability (Bagozzi, 1980). Discriminant validity among the constructs was stringently assessed using the Fornell and Larcker (1981) test; all possible pairs of constructs passed this test; more specifically, the average variance extracted was above the recommended level of 0.50 for all three constructs. Evidence of discriminant validity was also revealed by the fact that all the constructs' inter-correlations were significantly different from 1 and the shared variance between any two constructs (i.e. the square of their inter-correlations) was less than the average variance extracted for each construct.

Hence, none of the correlations in the final model was sufficiently high to jeopardize the constructs' discriminant validity (Anderson &Gerbing, 1988).

Table 1. The STUDENTSCALE- Constructs, scale items, reliabilities and T-Values

Constructs, Measurement Scales and Internal Reliability	Std.Coeficientes	T-values
INTEREST AND MOTIVATION TO THE SUBJECT		
(Scale 1=Totally Disagree / 5=Totally Agree)		
IMSUBJECT - Interest and Motivation to the Subject[1] (α=.,93, $\rho_{vc(\eta)}$=.67, ρ= .93)		
V1 I am interested in learning History	0.86	20.06
V2 I am generally attentive during the History classes	0.70	14.95
V3 I am becoming more competent in this área since I have this subject	0.78	17.31
V4 I am learning a lot in this subject	0.87	20.61
V5 I have positive feelings about this subject	0.89	21.36
V6 I am interested in the History contents	0.88	20.78
V7 Is really importante to me to be a good student in History.	0.72	15.54
[1] Adapted from Hunt, Eagle & Kitchen, 2004 and Abrantes, Seabra & Lages, 2007		
MOTIVATION AND INVOLVEMENT WITH ICT LEARNING RESOURCES		
(Scale 1=Totally Disagree / 5=Totally Agree)		
ICTMI– Motivation and Involvement with ICT Learning Resources[2] (α=.90, $\rho_{vc(\eta)}$=.67, ρ=.91)		
V8 Computers and technological information help me to have a better learning experience.	0.84	19.12
V9 Computers and technological information help me to learn.	0.89	21.13
V10 The use of technological information enhances my motivation to learn.	0.84	19.21
V11 I like to work with computers.	0.80	17.84
V12 I am confident when I have to work with computers	0.69	14.53
[2] Adapted from Hunt, Eagle & Kitchen, 2004		
LEARNING RESOURCES MADE BY TEACHERS		
(Scale 1=Totally Disagree / 5=Totally Agree)		
TEACHERLR – Learning Resources made by Teachers (α=.81, $\rho_{vc(\eta)}$=.52, ρ=.81)		
V13 School books	0.72	14.54
V14 Homework	0.76	15.43
V15 Tests/exams	0.75	15.26
V16 Exercises in class	0.65	12.64
[3] Adapted from de Hunt, Eagle & Kitchen, 2004		
NONLITERATY LEARNING STYLES		
(Scale 1=Totally Disagree / 5=Totally Agree)		
NONLITERARYLR. – Nonliteraty Learning Styles[4] (α=.71, $\rho_{vc(\eta)}$=.58, ρ=.73)		
V17 I understand better graphics than written contents.	0.86	13.18
V18 I recall better what I see or graphics than what I read or hear.	0.65	10.82
[4] Adapted from Hunt, Eagle & Kitchen, 2004		
Notas: α = Internal reliability (Cronbach, 1951)		
$\rho_{vc(\eta)}$ = (Fornell & Larker, 1981)		
ρ = Composit Reliability (Bagozzi, 1980)		

5 Conclusions, Implications and Limitations

The main aim of this study was to understand the factors, in the students' perspective, that could contribute to a better learning environment. Specifically to measure and analyze the student's performance antecedents such as students' social context, namely the students' relationship with their peers and the family involvement with the school; students' personal factors and learning styles; and the learning resources used.

The main results show that families are involved with school and that is something that students value; also, in general, students are motivated with school since they understand that learning impacts their future. Also, students are aware of the different learning resources and have different learning styles, however besides their preference on IT, students give importance to the teacher's role, namely in what regards to trust, confidence in knowledge, and willingness to help. Thus, it appears that the empathy created between elements in the teaching-learning process is crucial to the educational success.

It was also possible to build a scale to measure the Student's Motivation and Interest, Resources and Learning Styles– the STUDENTSCALE that consists in four dimensions:

- Interest and Motivation to the subject,
- Motivation and engagement with IT learning resources,
- Learning Resources made by Teachers.
- Nonliterary Learning Styles.

The framework developed in this study can be used to measure the students' interest and motivation, the teaching resources and learning styles valued and preferred by students. The existence of these four dimensions allows us to conclude that students consider the importance of i) Interest and Motivation for the subject, ii) Motivation and Engagement with IT Learning Resources, iii) Resources for Learning made by Teachers, and iv) Non-Literary Learning Styles as a whole for their learning process.

The present study can help education managers and responsible to have a middle education students' profile, also the resources that are used in our schools. So, we can realize who these students are, but also which is the actual learning environment of our schools.

The scale presented helps to know and analyze the motivation, interest, learning resources and styles valued and preferred by students. We were also able to measure the use of IT and multimedia in teaching, verifying the investment made by the governments and managers in the schools regarding hardware and software, knowing if they are used frequently by students and teachers. We can conclude that managers should invest on equipment, but also in teachers' training so they can use IT properly and diversify their strategies meeting the increasingly "technological" students.

Also, the STUDENTSCALE purpose is to contribute to a better understanding of the learning resources and styles used by teachers in classes. This framework helps teachers to select the best and more effective methodologies and learning resources to match the students' learning styles, motivating them and achieving a greater educational success.

From the research point of view it is also expected to make a relevant contribution to science in the IT' impact study, namely in the school and in the teaching/learning process. The work presented contributes thus to the development of literature in education in the various social sciences through the following implications: better understanding of the students' interests, measurement of learning styles and resources, development of scales and better understanding of learning styles, resources' impact in the learning process, and the impact of all those aspects on improving students' and teachers' skills, providing more performance and success of the learning process.

There are some limitations to be considered. The first limitation is that the final instrument (i.e. the questionnaire) may have created common method variance. This could be particularly threatening if the respondents were aware of the conceptual framework. However, they were not told the specific purpose of the study, and all of the construct items were separated and mixed so that no respondent would be able to detect which items were affecting which factors. Second, while the reported research investigates the learning performance antecedents for middle education students, the study can extend beyond this specific research set, specifically to other education levels. Hence, although the fit indices suggest a good fit of the model to the data, future research is encouraged to test our instrument across different education levels. To do so, we encourage researchers to add new items and factors applicable to the research setting. Continued refinement of the STUDENTSCALE proposed and supported in this study is certainly possible based on further qualitative research.

Thirdly, the research context involved students in Portugal, which may limit the generalizability of the results to some degree. The STUDENTSCALE should also be applied in other countries. To establish its generalizability, multiple samples in other contexts are also suggested. Finally, further research is required when analyzing the antecedents and consequences of the STUDENTSCALE.

Acknowledgments. The Instituto Politécnico de Viseu, the Center for Studies in Education, Technologies and Health (CI&DETS) and the Portuguese Foundation for Science and Technology (FCT).

References

Abrahamsom, C.: Issues in interactive communication in distance education. College Student Journal **32**(1), 33–43 (1998)

Abrantes, J., Seabra, C., Lages, L.: Major determinants of students' perceived learning: Pedagogical affect, student interest and learning performance. Journal of Business Research **60**(9), 960–964 (2007)

Aleven, V., Koedinger, K.: An effective metacognitive strategy: Learning by doing and explaining with a computer-based cognitive tutor. Cognitive Science **26**, 147–179 (2002)

Anderson, J., Gerbing, D.: Structural equation modeling in practice: A review and recommended two-step approach. Psychological Bulletin **103**(3), 411–423 (1988)

Bagozzi, R.: Causal models in marketing. John Wiley, New York (1980)

Berndt, T., Keefe, K.: Friends' influence on adolescents' perceptions of themselves at school. In: Meece, D.H. (ed.) Student Perceptions in the Classroom, pp. 51–73. LEA, Hillsdale (1992)

Berry, L.: Our roles as educator: Present and future. Journal of Marketing Education **15**, 3–8 (1993)

Bridges, E.: Experiential learning and customer needs in the undergraduate marketing research course. Journal of Marketing Education **21**(1), 51–59 (1999)

Brokaw, A.: The effects of students' behaviour and preferred learning style on performance. Journal of Business Research **1**, 44–53 (2000)

Brokaw, A., Merz, T.E.: The effects of student behavior and preferred learning style performance. Journal of Business Education, 44–53 (2000)

Clarke III, I., Flaherty, T.B., Mottner, S.: Student perceptions of educational technology tools. Journal of Marketing Education **23**(3), 169–177 (2001)

Davis, R., Auken, S.M.: Relating pedagogical preference of marketing seniors and alumni to attitude toward the major. Journal of Marketing Education **22**(2), 147–154 (2000)

Davis, R., Misra, S., Van Auken, S.: Relating pedagogical preference of marketing seniors and alumni to attitude towards the major. Journal of Marketing Education **22**, 147–154 (2000)

Dunn, R., Griggs, S.: Multiculturalism and learning style: Teaching and clousing adolescents. Praeger, Westport (1995)

Dunn, R., Giannitti, M., Murray, J., Rossi, I.: Grouping students for instruction: Effects of learning style on achievement and attitudes. Journal of Social Psychology **130**, 485–494 (1990)

Fornell, C., Larcker, D.: Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research **18**, 39–50 (1981)

Goodenow, C.: Strengthening the links between educational psychology and the study of social contexts. Educational Psychologist **27**, 177–196 (1992)

Goodenow, C., Grady, K.E.: The relationship of school belonging and friends' values to academic motivation among urban adolescent students. Journal of Experimental Education **62**(1), 60–71 (1993)

Hamer, L.: The additive effects of semistructured classroom activities on student learning: An application of classroom-based experiential learning techniques. Journal of Marketing Education **22**(1), 25–34 (2000)

Hay, A., Hodgkinson, M., Peltier, J., Drago, W.: Interaction and virtual learning. Strategic Change **13**(4), 193–204 (2004)

Honey, P., Mumford, A.: The manual of learning styles. Maidenhead, Berkshire (1992)

Hsu, C.: Learning styles of hospitality students: Nature or nurture. Hospitality Management **18**(3), 17–30 (1999)

Hunt, L., Eagle, L., Kitchen, P.: Balancing marketing education and information technology: Matching needs or needing a better match? Journal of Marketing Education **26**(1), 75–88 (2004)

Johnson, D., Johnson, R.: Learning together and alone. Prentice-Hall, Englewood Cliffs (1991)

Jöreskog, K., Sorbom, D.: LISREL 8: User's reference guide. Scientific Software International, Chicago (1996)

Kolb, D.: Learning styles and disciplinary differences. California Mangement Review **18**(3), 22–31 (1988)

Lashinger, H.K., Boss, M.W.: Learning styles and nursing students and career choices. Journal of Advanced Nursing **9**, 375–380 (1984)

Leung, D.Y., Kember, D.: The relationship between approaches to learning and reflection upon practice. Educational Psychology **23**(1), 61–71 (2003)

Lowman, J., Mathie, V.: What should graduate teaching assistants know about teaching? Teaching of Psychology **29**(2), 84–88 (1993)

McGrath, C.: A new voice on interchange: Is it talking or writing? Implications for the teaching literature. Journal of Educational Techonology Systems **26**, 291–297 (1997-1998)

McNeilly, K., Ranney, F.: Combining writing and electronic media in sales management courses. Journal of Marketing Education **20**(fall), 226–235 (1998)

Mialaret, G.: Psicopedagogia. Dom Quixote, Lisboa (1992)

Palincsar, A., Brown, A.: Reciprocal teaching of comprehension-fostering and comprehension-monioring activities. Cognition and Instruction **1**, 117–175 (1984)

Peltier, J.W., Drago, W., Schibrowsky, J.A.: Virtual communities and the assessment of online marketing education. Journal of Marketing Education **25**, 260–276 (2003)

Prelow, H.M., Loukas, A.: The role of resource, protective, and risk factors on academic achievement-related outcomes of economically disadvantaged Latino Youth. Journal of Community Psychology **31**(5), 513–529 (2003)

Rogoff, B.: Apprenticeship in thinking: Cognitive development in social context. Oxford University Press, New York (1990)

Slavin, R.: Cooperative learning: Theory, research and practice. Prentice-Hall, Englewood Cliffs (1990)

Vygotsky, L.: Mind in society: The development of higher psychological processes. Cole, M., John-Steiner, V., Scribner, S., Souberman, E. (eds.) Harvard University, Cambridge (1978)

Webster, J., Hackley, P.: Teaching effectiveness in technology-mediated distance learning. Academy of Management Journal **40**(6), 128 (1997)

Weiner, J.: Asymmetric competition in plant populations. Trends in Ecology and Evolution **5**, 360–364 (1990)

Young, M.: The motivational effects of the classroom environment in facilitating self-regulated learning. Journal of Marketing Education **27**(1), 25–40 (2005)

Young, M., Klemz, B., Murphy, J.: Enhancing learning outcomes: The effects of instructional technology, learning styles, instructional methods, and student behaviour. Journal of Marketing Education **25**(2), 130–142 (2003)

Contribution of Computing Services to Benchmarking Asset Management Knowledge Management

Anna Wiewiora[1], Kerry Brown[2], and Javier Tafur[3(✉)]

[1] Queensland University of Technology, Brisbane, Australia
a.wiewiora@qut.edu.au
[2] School of Management, Curtin University, Perth, Australia
Kerry.Brown@curtin.edu.au
[3] ESCP EUROPE Business School, Madrid, Spain
jtafur@escpeurope.eu

Abstract. Asset management has broadened from a focus on maintenance management to whole of life cycle asset management requiring a suite of new competencies from asset procurement to management and disposal. Well-developed skills and competencies as well as practical experience are a prerequisite to maintain capability, to manage demand as well to plan and set priorities and ensure on-going asset sustainability. This paper has as its focus to establish critical understandings of data, information and knowledge for asset management along with the way in which benchmarking these attributes through computer-aided design may aid a strategic approach to asset management. The paper provides suggestions to improve sharing, integration and creation of asset-related knowledge through the application of codification and personalization approaches.

1 Introduction

The research question examines how benchmarking elements of knowledge management such as asset data, integrated asset information systems and relational approaches for managing, difficult to codify tacit knowledge offer a strategic approach to the asset management life-cycle. We argue a strategic standpoint for asset management establishes a framework for knowledge management that includes tactical and operational aspects that can be brought into a comprehensive integrated approach delivered through computer-aided design. Precisely, computing services and knowledge management systems enabled the required data collection along the asset management life-cycle in order to process the right information. Prior research on asset management frameworks have identified the various operational, tactical and organisational elements that need to be considered, however, these models have not addressed how to operationalise the various aspects of knowledge management. The research establishes a coherent framework for benchmarking as a possible approach to start to develop integrated asset management from a strategic standpoint.

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 10–26, 2015.
DOI: 10.1007/978-3-319-22204-2_2

Strategic asset management is achieved through the systematic management of all decision-making processes taken throughout the life of a physical asset. It is seen to support decision making related to the acquisition, maintenance, and disposal of assets, and allows the generation of comprehensive and long term asset management plans (Jolicoeur & Barrett, 2005).

Based on our strategic asset management approach, we present a way to develop a benchmarking model that incorporates computer-aided design to understand, map and manage data, information and knowledge of whole-of-life cycle asset management activities.

In this paper we present two equally important approaches to effective knowledge management for strategic asset management: codification and personalisation. Codification involves the application of data and information management systems, suited to capture, store and transfer explicit knowledge that is easily codified and categorised (Arif et al, 2009). These systems now cover a range of Asset Management areas such as asset registration; process scheduling and control; materials, maintenance, risk, reliability, and safety management; and condition monitoring (Mathew et al, 2008). Personalization approaches are typically used to integrate and share tacit knowledge, which requires multifaceted and interpersonal approaches (Goh, 2002). Some examples of personalization approaches include face-to-face interactions, team meetings and on-the-job training. Existing technological solutions are designed to promote interpersonal interaction and collaborative practices and have capability for more embedded, tacit knowledge sharing and integration (Murphy & Salomone, 2013). These applications, including Web 2.0 solutions, comprise social networking, blogs, virtual communities of practice, and wikis to form a network effect built from users' contributions, in which users are the co-developers of the content (O'Reilly, 2007). The following definitions of codification and personalisation differentiate the explicit and implicit knowledge management approaches. *Codification* — a knowledge management approach that involves the application of data and information systems to codify, categorize and transfer asset explicit knowledge, information and data (Murphy & Salomone, 2013). *Personalization* — a knowledge management approach used to share and integrate tacit knowledge, create new knowledge, and assist in asset management decision-making. It involves personal interaction or use of collaborative technological solutions.

2 Data, Information and Knowledge

Knowledge is a multifaceted concept with multilayered meanings (Nonaka, 1994) and it represents a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information (Davenport & Prusak, 1998). Knowledge originates in the minds of knowledge holders and can be transferred into documents, organisational routines, processes, practices, and norms. It is necessary to distinguish knowledge from data and information. In asset management these terms are sometimes used interchangeably; however, their scope differ significantly.

Data are a set of discrete, objective facts about events. There is no meaning in data. Data provides no judgement or interpretation or basis of action. Information is a message, usually in the form of a document or an audible or visible communication. It has a sender and a receiver, and moves around organisations through hard and soft networks. Unlike data, information has a meaning. Data becomes information when its creator adds meaning, for example by contextualising, condensing, or categorising it. Once the information is used and becomes actionable, it is transformed into knowledge (Davenport & Prusak, 1998).

In asset management, we suggest all three — data, information and knowledge — are necessary. At several stages of the asset life-cycle, information is required on the condition of the assets. Knowing what to measure, how to measure it, and what to do with the information becomes highly important. Often information must be maintained for many years in order to identify long-term trends. There is a range of asset information systems available that allow the capture of and access to data related to asset performance, asset location, monitoring of asset condition, as well as to record work activities related to an asset, and forecast asset demand.

These systems provide access to different types of information captured in documents, drawings, photographs of the asset, asset attributes (e.g. make, model, serial number, age, capacity) subjective information about the asset (e.g. asset performance, condition, serviceability assessments) and so on (The Institute of Asset Management, 2011). The ultimate purpose for collecting data and information is to make decisions. Making meaning out of data and information and translating it into knowledge that combines experience, values, information in context, and insight, forms a basis for decision-making (The Institute of Asset Management, 2011).

3 Asset Data Management

Asset Data Management concerns the capture, management and utilisation (data acquisition, data analysis and information use) of asset data. The resulting translated data is essential to improve asset reliability, safety, availability, utilisation and an increased return on investment.

Asset data is underpinned by the two aspects of its type and of its desired outcome. There are four key types of data that organisations often acquire (Table 1).

Table 1. Asset Management Data Types

<table>
<tr><td>CONFIGURATION DATA</td><td>Typically originates from Original Equipment Manufacturer (OEM)-related asset data
Informed by periodic enhancements and upgrades
Hazard assessments requiring configuration changes
Used to provide benchmark comparisons with condition data</td><td rowspan="4">Each data type can potentially relate to a number of generic outcomes including:

Regulatory compliance: In many instances the consequences of physical asset failure dictate a level of regulatory compliance for most engineering assets.

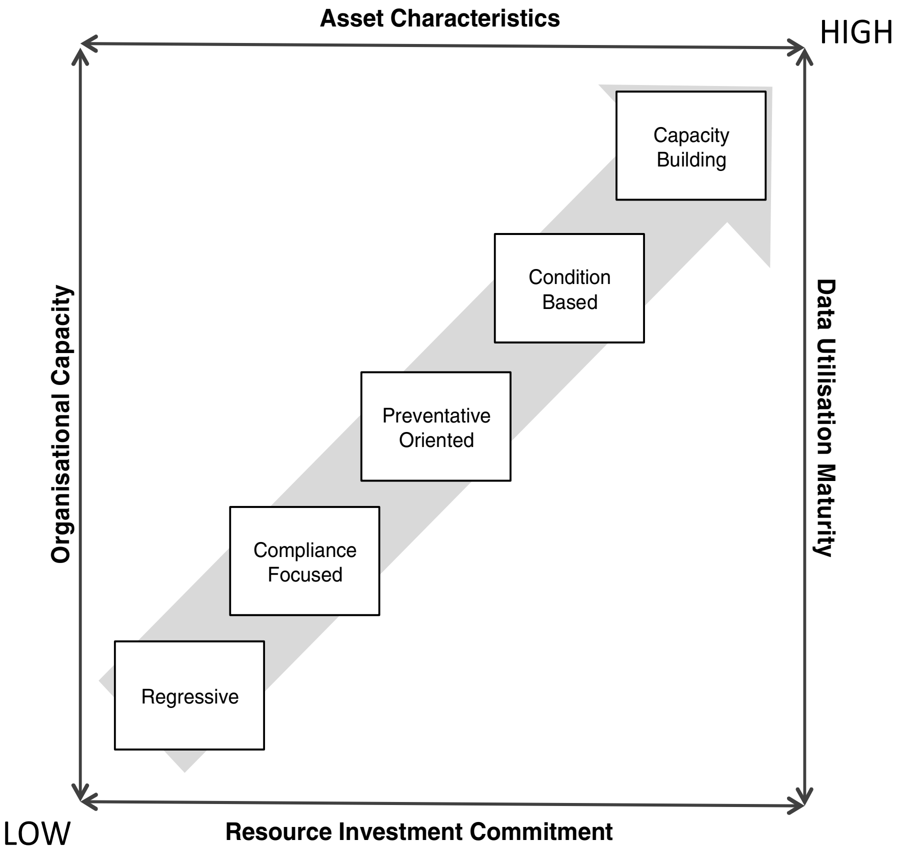
Time-based Asset Management: Refers to institutionalised, reactive or planned maintenance where data collected is only used to maintain the current condition of the asset.

Condition-based Asset Management: This Asset Management outcome largely relates to maintenance regimes such as Condition Based Maintenance (CBM) that rely on sophisticated predictive modelling to determine maintenance schedules.

Capability development: Refers to the use of data to improve the design, development and manufacture of future physical assets or ancillary processes (maintenance routines, safety procedures).</td></tr>
<tr><td>CONDITION DATA</td><td>Used to confirm compliance with regulatory requirements
Used to ascertain asset health
May identify the need for reactive (unplanned) maintenance
Can be used for the trending of asset health</td></tr>
<tr><td>EVENT AND INCIDENT DATA</td><td>Used to identify appropriate actions to reinstate the asset back to its ideal state/operational state (component focus)
Used to identify appropriate long-term strategies to prevent future asset failures of this type (system focus)
Used to inform predictive asset health systems
Used to improve future design enhancements</td></tr>
<tr><td>PROCESS DATA</td><td>Used to accurately determine Asset Management requirements
Used for scheduling, workforce planning and material management
Used to revise work instruction and safety hazard documentation
Used to drive business process improvements
Used to capture tacit knowledge</td></tr>
</table>

Source: Murphy G D, Chang A (2009): A capability maturity model for data acquisition and utilisation. In: Proceedings of the International Conference of Maintenance Societies, 1-4 June 2009, Sydney

The degree to which equilibrium can be achieved in terms of desired data management outcomes, asset performance and optimum levels of investment can be seen in the Data Management Maturity Model (Figure 1).



Source: "Murphy G D, Chang A (2009): A capability maturity model for data acquisition and utilisation. In: Proceedings of the International Conference of Maintenance Societies, 1-4 June 2009, Sydney"

Fig. 1. Data Management Maturity Model

4 Information Management

Asset Management information systems can be defined as "a combination of processes, data, software, and hardware, applied to provide the essential outputs for effective Asset Management, such as, reduced risk and optimum infrastructure investment". According to INGENIUM, an Asset Management information system may provide connectivity to other corporate information systems or databases and support a subset of engineering Asset Management processes/functions, as identified by the International Infrastructure Management Manual (INGENIUM, 2006):

- Asset Register Management
- Asset Hierarchy Management
- Asset Accounting
- Asset Life-cycle Costing
- Environmental Monitoring
- Social Monitoring
- Contract Management
- Resource Management
- Inventory Control
- Condition Monitoring
- Performance Monitoring
- Predictive Modelling
- Risk Management
- Optimised Decision-making

Different types of asset data and information can be often found in different information systems and databases, geographical data can be found in corporate repositories, whereas maintenance data and reports are often stored in separate technical databases. Some authors calls for a need to integrate IT systems and decision-making tools to execute the task of asset management (Schneider et al, 2006). It is acknowledged that isolated, independent systems when integrated into the Asset Management system are likely to provide continuous data on the physical and financial asset conditions (Amadi-Echendu et al, 2007).

Examples of such systems as identified by Cato and Mobley (2002) and Baskarada (2009) are provided in Table 2.

Table 2. Integrated Information Technology Systems System Use

SYSTEM	USE
Computer Aided Design (CAD) systems	CAD systems are mainly used in the design stage of the asset life-cycle.
Supervisory Control And Data Acquisition (SCADA) systems	SCADA systems are typically used to perform data collection and control at the supervisory level. They are placed on top of a real-time control system to control a process that is external to the SCADA system.
Geographic Information Systems (GIS)	GIS may provide for better management and visualisation of special asset information. It involves a software system, which provides a means of spatially viewing, searching, manipulating, and analysing an electronic database.
Computerised Maintenance Management Systems (CMMS)	A CMMS provides functionality that is normally grouped into subsystems or modules (along with relevant databases and/or files for the storage, manipulation, and retrieval of information), which may include asset records maintenance, asset bills of materials maintenance, inventory control, work order management, preventive maintenance plan development and scheduling, human resources management, purchasing and receiving, invoice matching and accounts payable, reporting, and so on.

- **Asset Register**

Asset Registers house information relating to various aspects of an asset portfolio, allowing it to be cross-referenced and retrieved as needed. Assets that have service potential and/or the capacity to provide economic benefits through their use in service delivery should be recorded in an Asset Register. Asset Registers come in many forms and can be electronic (e.g. computer) or paper-based (e.g. card file). Data can relate to one or more categories including:

- service delivery functions
- physical properties
- technical data

- financial information (e.g. asset valuation and expenditure)
- property title details
- key operational data
- maintenance data
- performance records.

It is contended that Asset Registers should be integrated into the organisation's management information system.

While organisations have different needs a consistent approach can be adopted. A four-staged process for the development of Asset Registers identified by the NSW Treasury (2004) is outlined in Table 3.

Table 3. Steps for the Development of Asset Register

STEP	ACTIVITIES
Conduct a needs analysis	• Identify information needs • Identify system needs • Prioritise needs
Plan the system	• Review the system development options • Review data collection requirements • Choose options
Plan the asset register	• Choose the register model • Establish assets hierarchy • Establish information hierarchy
Implement the register	• Prepare action plan • Establish data management procedures • Prepare business case • Implement plan

Source: New South Wales Treasury (2004): Asset Information Guideline

a. Asset Register Maintenance

Asset Registers should be updated on an ongoing basis. Asset changes are generally either caused or identified by operational activities. The point of time of change or discovery is the best time to identify this information and update the Asset Register. Based on the Asset Register and on the results of the Demand Management process, a Gap Analysis can show discrepancies between the agency's existing and required asset availability and reliability (capacity and performance), utilisation and functionality, safety and sustainability, and value for money.

b. Thesaurus

A records classification tool (thesaurus) can assist asset managers to maintain the integrity of information on assets. The thesaurus links an agency's business activities to the records it creates. According to the National Archives of Australia, classifying business activities can allow agencies to:

- link records relating to the same activity or purpose
- be consistent in titling records
- develop a systematic framework for the creation, management (including storage and security protection) and disposal of records
- enhance records retrieval
- describe Australian Government online resources and services.

The Australian Government's Interactive Functions Thesaurus (AGIFT) is an example of a records classification tool, describing the business functions carried out across Australian federal, state and local governments. AGIFT contains 25 high-level functions and each function has second- and third-level terms, non-preferred terms and related terms. The range of activities covered by each preferred term and any relevant cross-references are provided by way of a scope note.

A well designed and detailed agency-based functional thesaurus, congruent with the AGIFT, ensures information is available across space and time. For further information see http://www.naa.gov.au.

• Relational Knowledge Management

Existing solutions to managing knowledge for asset management focus primarily on codification approaches that apply databases and information systems to capture asset information. We suggest that these systems provide quality and timely data for decision-makers, contributing primarily to management of explicit knowledge, but overlook the importance of tacit knowledge.

The lack of personalisation approaches for managing tacit knowledge means that knowledge management for asset management is only fragmentary. Although technology-driven asset information repositories play a central role in the capture of asset data and information such as incident data and data on asset condition and monitoring, it is the relational capital promoted by personalisation approaches that have a strong potential to share and integrate tacit knowledge, underpinning the capacity to develop new ways of thinking and creative responses necessary to improve asset management decision-making.

Personalisation approaches involve the use of collaborative technological solutions or providing environment for personal interaction to facilitate sharing, integration and creation of knowledge.

Accordingly, personalisation can now be achieved through the use of sophisticated technological solutions like Web 2.0 that provide alternatives to more static knowledge repositories. These technologies can be used for collaboration (Alavi et al, 2006) and solving cognitive problems (Kimmerle et al, 2010). They can improve visibility and quality of knowledge (Wiewiora & Murphy, 2013), and have a capacity to share and integrate knowledge across a diverse range of experts, enabling large-scale creation of distributed communities of practice, and providing a single point to raise opinions and ideas used to improve decision-making (Chui et al, 2009). Having the ability to generate concepts and thoughts these technologies are able to innovate and expand asset-related knowledge. One example of Web 2.0 applications is a wiki. Wikis enable users to edit the content of entries, allowing them to freely create and organically grow web page content around a specific knowledge domain — a process sometimes referred to as dynamic authoring. Users can track the longitudinal changes to a document creating a high degree of accountability and transparency (Murphy, 2010). With wikis, text can be revised with little effort; users are free to change, add or even delete content. Most wikis have a revision-control feature that saves a history file allowing users to track all the revisions made. Users who want to improve a wiki text have to connect new content to what already exists. This procedure helps to reorganise and reconceptualise content and may lead to improved problem solving and knowledge building in an organisation (Kimmerle et al, 2010).

Another approach to personalisation relates to creating an environment for personal interaction. Research indicates that people prefer to turn to other people rather than documents for information (Mintzberg, 1973; Newell et al, 2008). This can be achieved through building social networks and creating space and time for informal meetings, coffee breaks and workshops. Organisations can endorse the development of social networks by promoting frequent interaction, openness, informality and collaboration, this in turn improves trusting relationships and leads to a greater willingness to share knowledge. Furthermore, building a collaborative environment has a potential to increase cross-functional sharing of asset-related knowledge, including insights about asset pitfalls or failures, without a risk of knowledge hoarding. Incorporating an integrated relational approach into existing data and information management systems will facilitate access to both tacit and explicit knowledge and assist in leveraging existing social and organisational relationships, thus will fully utilise organisational capabilities including skills, expertise and knowledge leading to effective knowledge management outcomes.

c. Barriers to Knowledge Management

Effective management of asset knowledge can benefit all asset management stakeholders; however, there are barriers that exist in relation to knowledge management that prevent effective sharing and integration of knowledge, and in result leading to knowledge loss and poor decision making outcomes. Table 4 lists a range of barriers to knowledge management (James, 2005; Wiewiora et al. 2009) and Table 5 proposes a number of counter strategies available to negate their effect (James, 2005).

Table 4. Barriers to Knowledge Management

BARRIERS TO KNOWLEDGE MANAGEMENT
• Knowledge management is not prioritised or rewarded thus there is no compelling reason why knowledge should be managed
• The existence of a culture of hoarding where sharing of "bad news" is not encouraged
• Functional and geographical separation between asset teams
• Lack of time for knowledge sharing activities (the focus is on activates directly related to the management of asset)
• Natural conservatism
• Red tape and bureaucracy
• Lack of standardised systems and taxonomies
• Uncertainty and job insecurity
• Highly competitive internal organisational climate where knowledge is considered as a source of power
• Reward systems that encourage individual performance
• Mechanisms stimulating socialization and communication between asset management teams are missing

d. Knowledge Management Action Plan

The use of both codification and personalisation approaches to knowledge management have the potential to bring desired outcomes for improved asset management decision-making. We argue that relying solely on one approach may not be sufficient. Technological, computer-based approaches may provide superior access to explicit knowledge, but overlook the importance of tacit knowledge acquisition, sharing and application.

Table 5. How to Achieve Improved Knowledge Management Practices

STRATEGIES TO IMPROVE KNOWLEDGE MANAGEMENT	PRACTICAL IMPLICATIONS
• Establishing a climate of continuous learning • An open culture and getting rid of red tape	• Building open, knowledge-oriented asset management culture that promotes continuous learning often requires a cultural change. • To do so your organisation needs to be aware of and evaluate its dominant culture characteristics. This will uncover knowledge sharing patterns specific for a given culture type. • Application of Denison and Spreitzer, Denison[1] or Cameron and Quinn[2] Frameworks may be useful in determining the dominant culture. Based on that, an action plan can be undertaken to introduce values promoting open, knowledge-oriented asset management culture.
• Communication, participation and consultation	• A supportive and participative leadership style will promote knowledge sharing and creation endeavours. • Support from leaders can endorse feelings of belongingness, enhance the collaborative climate and help staff recognise they are not competing amongst themselves, but are part of a team who, by sharing knowledge, will build its knowledge capabilities and gain a competitive position in the market. • Promoting active leadership engagement could potentially improve knowledge management endeavours by encouraging the use of collaborative tools for knowledge sharing and ensuring transparency of asset management norms and practices.

[1] Denison, D. R., & Spreitzer, G. M. (1991). Organizational culture and organizational development: A competing values approach. Research in organizational change and development, 5(1), 1-21.

[2] Cameron, K. S., & Quinn, R. E. (2005). *Diagnosing and changing organizational culture: Based on the competing values framework* (Revised ed.). San Francisco, USA: Jossey-Bass Inc Pub.

Table 5. (*Continued.*)

• Trust-building and team enabling activities	• In order to enhance conditions for trust building, managers may consider: • reviewing organisational norms and practices that encourage or discourage the high frequency of interaction and collaboration • supporting and recognising knowledge sharing and creation initiatives • endorsing and maintaining a friendly and non-competitive atmosphere at work • creating an atmosphere for learning not blaming • ensuring the visibility of other people's skills and competencies; this will bring the awareness of 'who knows what' • ensuring confidence in the measures evaluating people skills and expertise.
• High quality, capable staff • Senior management commitment • Induction programs • Education	• Whenever possible, facilitate face-to-face interactions by designing open plan offices or creating designated areas where staff can meet and exchange valuable tips and experience • Designing comprehensive induction programs and mentoring and training sessions will facilitate access to asset management-related knowledge
• Supporting technology	• Introduce an easily accessible, intelligible and user-friendly technological solution to capture asset data, information, and allow collective sharing and creation of knowledge • Whenever possible and applicable, incorporate an asset register and asset data management databases into the system to ensure greater useability, one point of reference and transparency of data

Table 5. (*Continued.*)

	• Develop a clear action plan for capturing, documenting and reusing asset data • Catalogue asset data and information according to themes • Enhance the system by supporting technologies, such as hyperlinks, tags, bookmarks and RSS to allow for improved discoverability Introduce ownership — a coordinator accountable for quality control, content maintenance, implementation, structuring links to the content and adding value • Use the system as a tool for decision-making and knowledge creation, encourage users to co-develop the content, but assign a coordinator to provide control to ensure the quality of the entry • Ensure user-friendly use and interface • Encourage use of the tool and creating understanding about its value and applicability through building appropriate culture and leadership support

Whereas relying only on relational approaches mean that opportunities can be lost because no one is accounted to capture these elements, revisit and follow up on them (Cooper, 2003). Table 5 provides a range of practical implications for asset managers and for agencies that aim to improve knowledge management endeavours taking into account both approaches: relational and technological (Wiewiora, 2012; Wiewiora & Murphy, 2013).

Findings from recent studies reveal that knowledge stored in databases or PDF documents is hard to retrieve and employees are often reluctant to search through overloaded spreadsheets that contain a large amount of historical data which is hard to deal with (Wiewiora & Murphy, 2013). For knowledge to be utilised and shared there needs to be a platform to ensure greater quality and transparency of knowledge.

Based on the findings from recent studies, Figure 2 provides a platform for developing a dynamic computer-based knowledge management platform for improved knowledge sharing, integration and use (Wiewiora & Murphy, 2013).

UPDATED AND DYNAMIC TOOL FOR IMPROVED KNOWLEDGE SHARING AND USE

CONTENT AND MAINTENANCE OF ENTRIES		
Require ownership and quality control	Require moderate ownership, control and maintenance	Free entries
Explicit knowledge	Tacit and explicit knowledge	Tacit knowledge
▪ Static information ▪ Links to processes ▪ Templates	▪ Lessons learned ▪ Valuable links ▪ Technical information	▪ Space for collaboration and knowledge sharing

DESIGN

- User friendly (search capability with indexing for a more intuitive way of finding knowledge)
- Intelligible (clear, easy to use and understand)
- Comprehensive (includes all types of knowledge and end-to-end processes)

ENVIRONMENT

ENVIRONMENT	
ORGANISATIONAL CULTURE	Cultural norms and practices supporting the use of online knowledge storage tool
LEADERSHIP ENGAGEMENT	Active support and engagement from top management to use online knowledge storage tool
OWNERSHIP	A person responsible for updating and maintaining entries (e.g. Project Management Office personnel)

Source: Wiewiora and Murphy (2013)

Fig. 2. Steps to Achieve Updated and Dynamic Knowledge Management Platform

5 Conclusions

Asset data and information includes particular repository material about asset characteristics, categories of assets and asset valuations and evaluative data. The current organisational environment can be considered 'knowledge rich' and, in this context, the effective management of information and information systems is a critical and complex responsibility. A contribution of this research is the differentiation between codification and personalization of asset data, information and knowledge.

While ICT systems can assist in delivering highly efficient information management for firms, professional information managers also have a vital role and add enormous organizational value in carefully considering employee information and knowledge needs, employee means of accessing and utilising data and importantly considering how the integrity of the system can be preserved.

Acknowledgments. The authors would like to acknowledge Dr Martin Laue for his valuable research particularly on the topics of Data Management and Asset Register.

References

Alavi, M., Kayworth, T., Leidner, D.: An empirical examination of the influence of organizational culture on knowledge management practices. Journal of Management Information Systems **22**(3), 191–224 (2006)

Amadi-Echendu, J., Willett, R.J., Brown, K.A., Lee, J., Mathew, J., Vyas, N., Yang, B.-S.: What is engineering asset management? In: Proceedings 2nd World Congress on Engineering Asset Management and the 4th International Conference on Condition Monitoring, Harrogate, United Kingdom, pp. 116–129 (2007)

Arif, M., Egbu, C., Alom, O., Khalfan, M.M.: Measuring knowledge retention: a case study of a construction consultancy in the UAE. Engineering, Construction and Architectural Management **16**(1), 92–108 (2009)

Baskarada, S.: Information Quality Management Capability Maturity Model, Vieweg+Teubner Research (2009)

Cameron, K.S., Quinn, R.E.: Diagnosing and changing organizational culture: Based on the competing values framework (Revised ed.). Jossey-Bass Inc. Pub., San Francisco (2005)

Cato, W.W., Mobley, R.K.: Computer-Managed Maintenance Systems. Elsevier Inc. (2002)

Chui, M., Miller, A., Roberts, R.P.: Six ways to make Web 2.0 work. The McKinsey Quarterly, 1–7, February 2009

Cooper, L.P.: A research agenda to reduce risk in new product development through knowledge management: a practitioner perspective. Journal of Engineering and Technology Management **20**(1), 117–140 (2003)

Davenport, Thomas H., Prusak, Laurence: Working Knowledge. Harvard Business School Press, Harvard (1998)

Denison, D.R., Spreitzer, G.M.: Organizational culture and organizational development: A competing values approach. Research in Organizational Change and Development **5**(1), 1–21 (1991)

Dilnutt 2000; Robbins et al. 2000; Sveiby 2001 in: James P (2005): Knowledge asset management — the strategic management and knowledge management nexus, DBA thesis, Southern Cross University, Lismore, NSW

Goh, S.C.: Managing effective knowledge transfer: An integrative framework and some practice implications. Journal of Knowledge Management **6**(1), 23–30 (2002)

Hackett 2001; Leonard-Barton 1998; Robbins et al. 2000; Sveiby 2001 in: James P (2005): Knowledge asset management — the strategic management and knowledge management nexus, DBA thesis, Southern Cross University, Lismore, NSW

INGENIUM: International Infrastructure Management Manual, Association of Local Government Engineering NZ Inc., Institute of Public Works Engineering Australia, New Zealand (2006)

Jolicoeur, P.W., Barrett, J.T.: Coming of age: Strategic asset management in the municipal sector. Journal of Facilities Management **3**(1), 41–52 (2005)

Kimmerle, J., Cress, U., Held, C.: The interplay between individual and collective knowledge: technologies for organisational learning and knowledge building. Knowledge Management Research & Practice **8**(1), 33–44 (2010)

Koronios, A., Lin, S., Gao, J.: A data quality model for asset management in engineering organisations. In: Paper presented at the Conference on Information Quality, Cambridge, MA, USA (2005)

Mathew, A.D., Ma, L., Hargreaves, D.J.: Understanding data management in asset management: a survey. In: Gao, J., Lee, J., Ni, J., Ma, L., Mathew, J.: Proceedings World Congress for Engineering Asset Management, Beijing, China, pp. 1096–1107 (2008)

Mintzberg, H.: The nature of managerial work: Harper & Row (1973)

Murphy, G.D.: Using Web 2.0 tools to facilitate knowledge transfer in complex organisational environments — a primer. In: Paper presented at the ICOMS Asset Management Conference: Maintenance and Beyond, Adelaide (2010)

Murphy, G.D., Chang, A.: A capability maturity model for data acquisition and utilisation. In: Proceedings of the International Conference of Maintenance Societies, Sydney, June 1–4, 2009

Murphy, G.D., Salomone, S.: Using social media to facilitate knowledge transfer in complex engineering environments: a primer for educators. European Journal of Engineering Education **38**(1), 70–84 (2013)

Newell, S., Goussevskaia, A., Swan, J., Bresnen, M., Obembe, A.: Interdependencies in Complex Project Ecologies: The Case of Biomedical Innovation. Long Range Planning **41**(1), 33–54 (2008)

Nonaka, I.: A Dynamic Theory of Organizational Knowledge Creation. Organization Science **5**(1) (1994)

O'Reilly, T.: What is Web 2.0: Design patterns and business models for the next generation of software. Communications & strategies, 16–37, March 2007

Schneider, J., Gaul, J., Neumann, C., Hografer, J., Wellbow, W., Schwan, M., Schnettler, A.: Asset management techniques. International Journal of Electrical Power & Energy Systems **28**(9), 643 (2006)

The Institute of Asset Management: Asset Management — an anatomy. The Institute of Asset Management, Bristol (2011)

Wiewiora, A., Murphy, G.: Unpacking 'lessons learned': investigating failures and considering alternative solutions. Journal of Knowledge Management & Practice (2013)

Wiewiora, A.: The Role of Organisational Culture, Trust and Mechanisms in Inter-Project Knowledge Sharing. Ph.D thesis, Queensland University of Technology, Brisbane, QLD, Australia (2012)

Wiewiora, A., Trigunarsyah, B., Murphy, G.D., Liang, C.: Barriers to effective knowledge transfer in project-based organisations. In: Proceedings of the 2009 International Conference on Global Innovation in Construction Proceedings, September 13–16, 2009. Loughborough University, Holywell Park (2009)

Financing of Productive Investments: A Model with Coordinated Scenarios

Carlos Lassala[1(✉)], Manuel Mocholí[2], and Valentín Navarro[1]

[1] Department of Corporate Finance, Universitat de Valencia, Valencia, Spain
{carlos.lassala,valentin.navarro}@uv.es
[2] Department of Mathematics for Economics and Business, Universitat deValencia, Valencia, Spain
manuel.mocholi@uv.es

Abstract. This research raises a company that knows the cash requirements to purchase capital equipments in order to satisfy the demand for the products of each of the proposed scenarios. The company is negotiating with credit institutions a series of loans at different interest rates. Also, the company can make capital increases. A model focused on the financial needs using scenarios allows us to combine funding sources to cover the costs of the acquisition of production equipment to meet the demand for each scenario. This combination remunerates own financing, settles interest and repays the borrowed capital. The results indicate that the model is robust and minimizes the financial cost of a possible combination of external and internal sources in each possible scenario.

Keywords: Financing · Productive investment · Scenario management · Linear programming · Robust model

1 Introduction

The creation of a business and developing its activity requires adequate funding. The problem of financing is a general practice in most companies (small, medium or large). Access to appropriate financing often proves difficult, as financial agents do not want to assume the risks of these companies. Financial agents require collateral for granting the necessary funding in companies. The insufficiencies in the financing market may threaten ordinary activities and the development of enterprises.

Therefore, from a broader perspective, we intend to address the problem of financing investment projects. We try to optimize financing, that is, as such funding is adequate to lower financial cost.

When we classify financial sources available to companies we can use a traditional approach that separates them depending on who makes the contributions. In this case, we can distinguish between equity and borrowings. Within equity, we include funds contributed by shareholders and the funds generated by the company in developing its operating activities.

The borrowed funds or funds provided by third parties that are not linked directly to the company constitute a second block of funding. The initial contribution and the

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 27–38, 2015.
DOI: 10.1007/978-3-319-22204-2_3

constant supply of equity are essential for a company to exploit its growth potential. However, in many cases, companies face an equity gap that prevents the normal development of the operating business and its investment activity.

According to Cantalapiedra (2008), there are other financial sources that may not be classified as equity or as borrowed funds. They are sources that are halfway between the two types of funding and have a special importance in the environment for SMEs. Specifically, we refer to financing through venture capital, participating loans and capital grants.

Money funds are essential for the implementation or development of a company. However, many companies often do not have sufficient collateral to obtain loans. This situation is exacerbated by the increasingly hesitant attitude of financial institutions for risk. In any case, in recent years, the emergence of new financial instruments encourages financial institutions to lend to businesses. This is possible through guarantee instruments based on risk sharing. In this way, companies can have a greater volume of credit.

As regards own resources, we pay special attention to the contributions of the owners in the constitution of the company and future capital increases. As for the borrowed funds, we analyze bank financing. In this sense, we ignore funding from exploitation and focus on the financing of medium and long term in the form of loans.

The contributions of the owners to share capital of a company in its constitution are the first monetary funds received by the firm. Its aim is to finance the first investments that will enable the company to start its ordinary operating activities. These payments involve an initial entry into the cash accounts of the company.

When the company develops its activity, it can increase its share capital through capital increases, that is, it can make an issue of new shares to enable it to enter new money in the form of equity.

While the capital increases may have a non-cash nature, that is, assets or rights may be incorporated into the company as an asset, our study finds that the capital increases that can be carried out will be considered as cash contributions.

Regarding financing using borrowings, we must always make mention of financial institutions providing such funding. Following Cantalapiedra (2008), we understand as a credit institution to the firm which owes as typical and normal activity receiving funds from the public, in the form of deposits, repos or any other similar, which carry with it the obligation of restitution applying them self to lending or other similar operations.

In general, to refer to all financial institutions listed above within the concept of credit institution we use the term banks.

The relationship between a company that needs financing and a credit institution that can grant it is established as a bilateral negotiation type. In this sense, if we take into account the usual dependence of companies from bank financing, we can easily understand that this type of negotiation should be very careful. We must not forget that in this type of relationship we are not managing only financing transactions (asset transactions for the bank). There are also other types of operations as deposits which represent an investment for the company (passive operations for the bank). Consequently, the negotiation must include all of the operations of both assets and liabilities.

This paper is organized as follows. In the second section we review the limited financial literature has addressed this issue. Then, in the third paragraph we propose the model analyzed. In the next section we expose the main conclusions of the investigation model. We also note some important implications for management and propose future research lines. Finally, we detail the literature reference.

2 Literature Review

In this research, we optimize the financial costs of a company through a mathematical programming model applied to real phenomena. These problems mean that the data involved are known and constant. Thus, it is easy to approach and solve the problem. However, in practice the starting data are often incomplete or unclear. Sometimes the data are estimates based on predictions of future conditions.

2.1 Mathematical Programming and Finance

The first applications of mathematical programming in the field of finance were proposed by Dean (1951) and Lorie-Savage (1955). In them, the financial resources were limited. Subsequently, Weingartner (1966) introduced the relations of independence, complementarity and incompatibility with the problem of limited financial resources using methods of linear resolution, nonlinear and dynamic.

To avoid having to solve problems whenever a change occurs in the input data or to what extent the data obtained from the estimates are reliable, different techniques have been developed which introduce uncertainty. Dantzig (1955) proposed the formulation of the problem in two phases. In the first, positions are taken before the random events occur and in the second, restrictions fit the new situation. Here it renamed deterministic linear programming. Horner (1999) makes an analysis of optimization under uncertainty.

In linear programming with random restrictions, the original restrictions become probability restrictions and a level of compliance for the same is established. This technique called stochastic programming was studied among others Freund (1956), Charnes, Cooper and Symons (1958), and Charnes and Cooper (1959). Then, the foundations of stochastic mathematical programming were reflected in various investigations (Elmaghraby (1959); Madansky (1962); Sengupta, Tintner and Morrison (1963); Kataoka (1963); Williams (1965). The analysis of stochastic programming with penalties when a failure occurs in the restrictions was approached by Ben-Israel, Charnes and Kirby (1973), Birge and Louveaux (1988) and Dupacova (1991).

2.2 Mathematical Programming and Financial Planning

The first studies that applied mathematical programming to financial planning problems were Charnes, Cooper and Miller (1959), Robicheck, Teichroew and Jones (1965) and Chambers (1967). Later, Ijiri, Levy and Lyon (1963) applied mathematical programming in the analysis of financial statements.

The CAPRI model (Calcul of Programmesd'Investissement) was one of the first models of financial planning who tried to combine investment decisions with funding decisions (Audibert *et al*, (1968). Later, Myers and Pogue (1974) developed the LONGER model, a model of financial planning for the long term. Given its importance, it also highlights the FIRM model, a model long term optimization (Dean, Bennett and Leather, 1975).

With regard to the problems of financial planning, Prekopa (1995) incorporates the uncertainty stochastic programming. In problems of financial planning, this option allows plans to go adjusting to reality. There are also abundant research on simulation techniques applied to financial planning (Mattesich, 1961; Maroto and Mascareñas, 1986; Araujo y Rodríguez, 1989).

CAPRI, FIRM and LONGER models have served as the basis for the development of multi-period planning models and financial policy in the company (Brick, MellonandSurkis, 1983; Lewis, 1990; Mulvey and Vladimirou, 1992)and, more recently, Navarro y Ferrando (1999), Navarro, Canós y Mocholí (2003) and Navarro y Mocholí (2005).

2.3 Robust Optimization Technique for Scenarios

Finally, based on the Stochastic Programming, but eliminating the probability distribution function and incorporating scenarios, it has developed (Mulvey, Vanderbey and Zenios, 1995).

The scenarios are very important in building the model that we will develop. Through this type of technical and mathematical programming we can incorporate uncertainty and, in any case, relax it along the study and analysis of the problem.

The scenarios assume a simplified representation of a complex reality. They allow us to develop the situations we think that may arise in the future and propose strategies and plans tailored to the specific characteristics of each scenario.

According to FernándezGüell (2004), scenarios are tools for the perceptions about alternative future environments that can affect a company. That is, we must consider that the scenarios are a tool to help us look into perspective in a world of great uncertainty. In business, the scenarios are a systematic process that allows us to outline long-term future by conducting an exercise of brainstorming with a group of experts.

3 Model Approach: Financial Needs with Scenarios

In *MNFe*, Financial Needs Model with scenarios, we assume that the analyzed company takes into account the consideration of s scenarios ($s = 1,2, .., S$), each of which has a planning horizon with t periods ($t = 1 ,. .., T$).

Moreover, new productive goods to be in corporated into the company (XN^{s}_{tcn}) are known for each period t, of the type or class c($c = 1,2,.., C$) and variant n($n = 1, 2, ...,N$), to meet demand D^{s}_{tk} in each scenario$s$, for each period t for each product k ($k =1, ...,K$).

The determination of these capital goods takes into account the uncertain demand that the company faces as a result of the launch or expansion of a range of new products on the consideration that has been made in the s scenarios. The model will only attempt to cover those operational needs with own resources or external financing.

Since *MNFe* is strictly a financing model we have two large blocks of restrictions:

- **Restrictions on Self-financing**

Lassala *et al.* (2006) conduct a general analysis of the capital increases and return on equity. Concerning the capital increases carried out in companies, we found that most companies end up being financed by equity capital and outside capital. So, from a quantitative point of view, the continuous capital increases without limit or amount are not feasible due to the loss in value of shares included in equity. Furthermore, only value is created through investment decisions.

The only proper funding we have in mind refers to the capital increases. In this sense, we consider that each capital increase may not exceed a certain percentage (*CMAX*) of the current equity capital in each period *t*. Thus, the share capital that a company can make in order to attend, along with borrowings, the payment obligations for the acquisition of new production equipment (XN_{tcn}^{s}) is given by:

$$Cap_t^s \leq CMAX \left[CP_0 + \sum_{j=1}^{t-1} Cap_j^s \right] \qquad \forall t \qquad (1)$$

where:

Cap_t^s : Amount of the capital increase carried out in period *t* under scenario *s*.

CMAX: Maximum percentage that can raise capital on each capital increase.

CP_0 : Equity at the beginning of the planning period.

- **Restrictions on External Financing**

It is unlikely that a company is only funded by equity. Consideration of external financing means taking into account the financial risk arising from debt. The combination of equity and borrowed funds can reduce financial risk and adjust the risk to the financial structure of each company. Moreover, it is clear that high indebtedness may affect the solvency of a company.

This section of restrictions, Pmo_{tl}^{s} represents the amount obtained in loans of the type *l* (*l = 1, ..., L*) in period *t* under scenario *s*. In this regard, we believe that two or more loans are of the same type *l*, when they have the same interest rate (int_l) and the same coefficients of periodal amortization (Kp_{jl}).

Credit institutions try not to concentrate a high risk in one company. This objective should also be considered by the company in the sense of not concentrating high risk in a single financial institution in order to diversify risk. We think that the outstanding debt of each of the types of loans must not exceed a certain percentage (*EMAX*) the equity of the company at time *t*.

$$\sum_{h=1}^{t} Pmo_{hl}^{s} \left(1 - \sum_{j=1}^{t-h} kp_{jl} \right) \leq EMAX \left(CP_0 + \sum_{j=1}^{t-1} Cap_j^s \right) \qquad \forall t, l \qquad (2)$$

That is, the maximum amount pending repayment in period t of the loan of type l must not exceed the maximum allowable debt to equity of the company.

Moreover, companies need to ensure a certain degree of financial solvency so that, in practice, a maximum ratio of debt to assets as a limit on the borrowing capacity applies. We raise this issue in the model *MNFe* considering the maximum debt in each period t is given by the outstanding balance of loans at beginning of period t. We define a ratio of debt to the net assets (*RE*) and formulate equity as equity at the beginning of the planning period (CP_0) and capital increases have been made so far. That is:

$$\sum_{l=1}^{L}\sum_{h=1}^{t} Pmo_{hl}^{s}\left(1-\sum_{j=1}^{t-h} kp_{jl}\right) \leq RE\left(CP_0+\sum_{j=1}^{t} Cap_j^{s}\right) \qquad \forall t \tag{3}$$

From the above two blocks of equations a series of cash flows will be generated that can be grouped into:

- **Flow of Receipts at the Beginning of Period *t***

From a financial perspective, companies invest their cash points until they are required to meet payment obligations incurred. We distinguish between the beginning and the end of period t. The capital increases and borrowing take place at the beginning of the period. Dividends and interest and amortization payments of the loans are settled at the end of the period. Consequently, we can conclude that, at the beginning of each period t, there is a current of payments that, for each scenario s, can be decomposed into:

- The difference between the treasury (*TE*) from the previous period (*t-1*) and the period t, must be remunerated at the rate "return on cash" (*rt*) since, from a financial point of view, no monetary balance should remain unproductive in the company.
- Attending to the above restrictions, the company can make capital increases (Cap_t^s) in period t and stage$s$, enabling it to acquire the capital goods needed(XN_{tcn}^s)to meet the demand in scenarios s (D_{tk}^s).
- Finally, taking into account the limitations imposed by the restrictions on external financing, we must consider in the current collection loans obtained by the company in order to be able to acquire the capital goods needed (XN_{tcn}^s)to meet the demand for each period t, product k and scenario$s$ (D_{tk}^s).

With all this, we can formulate the equation of receipts at the beginning of period and scenario s in model *MNFe* as:

$$COB_t^s = TE_{t-1}^s(1+rt) - TE_t^s + Cap_t^s + \sum_{l=1}^{L} Pmo_{tl}^s \qquad \forall t \tag{4}$$

that is, remuneration of the cash balance between periods, capital increases and obtaining loans of the type l, all for each period t and scenario$s$.

- **Flow of Payments at the Beginning of Period *t***

We can decompose the flow of payments at beginning of period *t* in the following items:

- The financial needs of the period *t* and scenario *s*(NF_t^s), to acquire capital goods(XN_{tcn}^s) whose initial cost is PCN_{cn} , properly corrected by the inflation process *g*.
- Interest on loans(int_l)at time *t*, the type *l* and stages*s*, to be paid for the outstanding principal of all loans(Pmo_{tl}^s)in each period *t*.
- Quotas of principal repayment of the sum of all loans (Pmo_{tl}^s) the type *l*, requested the beginning of each period *t* and scenarios*s*, according to their depreciation rate(Kp_{jl}).
- Dividends paid at the end of period *t*, according to the rate of return demanded by shareholders(*rea*) on the initial equity (CP_0) and on capital increases until the start of the period in question and scenarios*s*(Cap_t^s).

Thus, we can formulate the equation of payments at the beginning of period *t* and scenario *s* in the *MNFe* as:

$$
\begin{aligned}
PAG_t^s = {} & \sum_{c=1}^{C}\sum_{n=1}^{N} PCN_{cn}(1+g)^{(t-1)} XN_{tcn}^s + \\
& \sum_{l=1}^{L}\text{int}_l \left[\sum_{h=1}^{t-1} Pmo_{hl}^s \left(1 - \sum_{j=1}^{t-h} Kp_{jl} \right) \right] + \sum_{l=1}^{L}\sum_{h=1}^{t-1}\left(Pmo_{hl}^s Kp_{(t-h),l} \right) + \\
& rea\left(CP_0 + \sum_{j=1}^{t-1} Cap_j^s \right) \qquad \forall t
\end{aligned}
\tag{5}
$$

The amount of receipts needs to cover the financial resources to acquire the necessary production equipment to meet the demand of each k product for each s stage. However, as excess cash can reinvest and is paid, the appropriate management of this type of working capital requires to apply for a smaller amount of loans or make minor capital increases. Thus, companies can reduce their financing costs, while increasing its financial income.

We can reflect this general consideration that occurs in companies by saying that at the beginning of each period t for each scenario s must meet the following equation:

$$TE_{t-1}^{s}(1+rt) - TE_{t}^{s} + Cap_{t}^{s} + \sum_{l=1}^{L} Pmo_{tl}^{s} = \\ = \sum_{c=1}^{C}\sum_{n=1}^{N} PCN_{cn}(1+g)^{(t-1)} XN_{tcn}^{s} + \\ \sum_{l=1}^{L} \operatorname{int}_{l}\left[\sum_{h=1}^{t-1} Pmo_{hl}^{s}\left(1-\sum_{j=1}^{t-h} Kp_{jl}\right)\right] + \sum_{l=1}^{L}\sum_{h=1}^{t-1}\left(Pmo_{hl}^{s} Kp_{(t-h),l}\right) + \\ rea\left(CP_{0} + \sum_{j=1}^{t-1} Cap_{j}^{s}\right) \qquad \forall t \tag{6}$$

- **Collections and Payments at the End of the Planning Period *T***

At the end of the planning period (*T*), the company must make payments for dividends by capital increases and interest and capital repayment of external financing obtained. Also, at the beginning of the last planning period, the company has a cash surplus that can and should be reinvested to compensate for the payments to be made at the end of the period in respect of financial costs and dividends.

Thus, we can break down items of receipts and payments of the last planning period, such as:

- The interest earned on the cash remuneration (*rt*) of the last planning period.
- Interest on loans (int_l) for the period *T*, the type *l* and scenario *s*, to be paid for the outstanding principal of all loans (Pmo_{tl}^{s}) with outstanding balance in the last period.
- Quotas of principal repayment of the sum of all loans (Pmo_{tl}^{s}) the type *l*, to be paid at the end of the planning period *T*, according to their depreciation rate(Kp_{jl}).
- Dividends payable on the last planning period *T* at the rate of return required by shareholders(*rea*) of the initial equity capital(CP_0)and capital increases to *T* (Cap_{t}^{s}).

Therefore, at the end of period *T*, observe analytically that:

$$TE_{T}^{s}(1+rt) = \sum_{l=1}^{L} \operatorname{int}_{l}\left[\sum_{h=1}^{H} Pmo_{hl}^{s}\left(1-\sum_{j=1}^{T-h} Kp_{jl}\right)\right] + \\ \sum_{l=1}^{L}\sum_{h=1}^{H} Pmo_{hl}^{s} kp_{(T-h+1),l} + rea\left(CP_{0} + \sum_{j=1}^{T} Cap_{j}^{s}\right) \quad \forall t \tag{7}$$

At this point, we can formulate the objective function of *MNFe* model as minimizing the costs of financial sources(*CFF*),distributed as dividends on equity and interests of updated loans using the capital cost(i), as follows:

$$Min\ \ CFF^{s} = \sum_{t=1}^{T} rea\left(CP_{0} + \sum_{j=1}^{T} Cap_{j}^{s} \right)(1+i)^{-t} + + \sum_{t=1}^{T}\sum_{l=1}^{L} \mathrm{int}_{l}\left[\sum_{h=1}^{t} Pmo_{tl}^{s}\left(1 - \sum_{j=1}^{t-h} Kp_{jl} \right)\right](1+i)^{-t} \quad (8)$$

Then, the program of *MNFe* model for each scenario *s*, can be defined as:

Objective:

$$Min\ CFF^{s} \quad (9)$$

Restrictions:

$$Cap_{t}^{s} \le CMAX\ \left[CP_{0} + \sum_{j=1}^{t-1} Cap_{j}^{s} \right] \qquad \forall t \quad (10)$$

$$\sum_{h=1}^{t} Pmo_{hl}^{s}\left(1 - \sum_{j=1}^{t-h} kp_{jl} \right) \le EMAX\ \left(CP_{0} + \sum_{j=1}^{t-1} Cap_{j}^{s} \right) \qquad \forall t, l \quad (11)$$

$$\sum_{l=1}^{L}\sum_{h=1}^{t} Pmo_{hl}^{s}\left(1 - \sum_{j=1}^{t-h} kp_{jl} \right) \le RE\left(CP_{0} + \sum_{j=1}^{t} Cap_{j}^{s} \right) \qquad \forall t \quad (12)$$

$$TE_{t-1}^{s}(1+rt) - TE_{t}^{s} + Cap_{t}^{s} + \sum_{l=1}^{L} Pmo_{tl}^{s} = = \sum_{c=1}^{C}\sum_{n=1}^{N} PCN_{cn}(1+g)^{(t-1)} XN_{tcn}^{s} + \sum_{l=1}^{L} \mathrm{int}_{l}\left[\sum_{h=1}^{t-1} Pmo_{hl}^{s}\left(1 - \sum_{j=1}^{t-h} Kp_{jl} \right)\right] + \sum_{l=1}^{L}\sum_{h=1}^{t-1}\left(Pmo_{hl}^{s} Kp_{(t-h),l} \right) + rea\left(CP_{0} + \sum_{j=1}^{t-1} Cap_{j}^{s} \right) \qquad \forall t \quad (13)$$

$$TE_{T}^{s}(1+rt) = \sum_{l=1}^{L} \mathrm{int}_{l}\left[\sum_{h=1}^{H} Pmo_{hl}^{s}\left(1 - \sum_{j=1}^{T-h} Kp_{jl} \right)\right] + \sum_{l=1}^{L}\sum_{h=1}^{H} Pmo_{hl}^{s} kp_{(T-h+1),l} + rea\left(CP_{0} + \sum_{j=1}^{T} Cap_{j}^{s} \right) \qquad \forall t \quad (14)$$

$$Cap_{t}^{s}, Pmo_{tj}^{s}, TE_{t}^{s} \ge 0$$

4 Conclusions, Managerial Implications and Future Research

The solution provides the *MNFe* model indicates the combination of debt and equity for the acquisition of production equipment. At the sametime, this combination has taken into account the financial requirements of the capital increases and borrowing restrictions established on outside capital.

Since equity capital must compensate the rate of return required by shareholders (rea) and outside capital must be settled to the interest rate (int_l) for each source external of the type *l*, the above combination also takes into account dividends and interest to be paid in each period *t*, as a result of the combination of own and other resources to meet on the acquisition of new production equipment.

The funding required is achieved by a combination of own and other financial resources that involve the less financial cost to the company.

The solution obtained is a partial solution to the problem of financing, since it does not take into account revenue from the current exploitation and revenue from sales of existing old machine sat the beginning of the planning period.

The *MNFe* model is an important contribution to practical implications in the management of companies. On the one hand, it is an effective and easy application that lets us to change the input parameters to the model when external conditions change, among others, the interest rate, payment of dividends or the incorporation of a new financial institution. Moreover, the design of scenarios within the model *MNFe* enables the creation of options where the future is unclear and simplifies the future in a limited number of scenarios or situations that may arise. The use of mathematical programming stage design guarantees that the resulting solution will be optimal, that is, minimizes the financial cost.

As for future research, from the model developed in this paper, we are working with the possibility of creating a Model of Coordinated Financial Needs (*MNFc*). With this model, still under mathematical development, we hope that, regardless of the scenario to occur, the solution obtained differs as little as possible of the solution that would have taken if it had known a priori the scenario that is going to produce. This new model will incorporate revenue from the possible sale of the capital equipment removed by the company. In this way, we will have extra income that can lead to less funding for the company, both with own and other resources.

References

Araujo, A., Rodríguez, A.: Un modelo de simulación en hoja electrónica para la planificación financiera a largo plazo (1): (Fiplan 1-2-3). Cuadernos de Gestión **8**, 1–24 (1989)

Audibert, J.M., et al.: CAPRI: un modèle de calcul de programmes d'investissement. Metra, en Girault, F.; Zisswiller, R. (1972): Finances modernes: théorie y practique. Dunod. París (1968)

Ben-Israel, A., Charnes, A., Kirby, M.J.L.: On stochastic linear approximation problems. Operations Research **21**(5), 555–558 (1973)

Birge, J.R., Louveaux, F.: A multicut algorithm for two-stage stochastic linear programs. European Journal of Operational Research **34**(3), 384–392 (1988)

Brick, I.E., Mellon, W.G., Surkis, J.: Optimal capital structure. A multi-period programming model for use in financial planning. Journal of Banking and Finance **7**, 45–67 (1983)

Cantalapiedra, M.: Diseño de un modelo de planificación financiera propio. EstrategiaFinanciera **254**, 18–23 (2008)

Chambers, D.I.: Programming the allocation of funds subject to restrictions on reported results. Operating Research Quarterly **18**(4), 4 (1967)

Charnes, A., Cooper, W.W.: Chance constrained programming. Management Science **5**, 73–79 (1959)

Charnes, A., Cooper, W.W., Miller, M.H.: Application linear programming to financial budgeting and the costing of funds. The Journal of Business **32**, 20–46 (1959)

Charnes, A., Cooper, W.W., Symons, G.H.: Cost horizons and certainty equivalents: an approach to stochastic programming of heating oil. Management Science **4**, 235–263 (1958)

Dean, J.: Capital budgeting. Columbia University Press, New York (1951)

Dean, R.J., Bennett, J.W., Leather, J.: FIRM: A computer model for financial planning. The Institute of Chartered Accountants **5** (1975)

Dupacova, J.: Stochastic programming models in banking. International Institute for Applied System Analysis (AIASA) (1991)

Elmaghraby, S.E.: An approach to linear programming under uncertainty. Operations Research **7**(2), 208–216 (1959)

Fernández Güell, J.M.: El diseño de escenarios en el ámbito empresarial. Pirámide, Madrid (2004)

Freund, R.J.: The introduction of risk into a programming model. Econometrica **24**, 253–263 (1956)

Horner, O.: Planning under uncertainty. Questions & answers with George Dantzing. OR/MS Today **26**, 26–30 (1999)

Ijiri, Y., Levy, F.K., Lyon, R.C.: A linear programming model for budgeting and financial planning. Journal Accounting Research **1**(2), 198–212 (1963)

Kataoka, S.: A stochastic programming model. Econometrica **31**(1–2), 181–196 (1963)

Lassala, C., Medal, A., Navarro, V., Sanchis, V., Soler, M.A.: Dirección Financiera II. Medios de financiación empresarial. Pirámide, Madrid (2006)

Lewis, C.M.: A multiperiod theory of corporate financial plicy under taxation. Journal of Financial Applications and Analysis **25**(1), 25–43 (1990)

Lorie, J., Savage, L.J.: Three problems in rationing capital. Journal of Bussines **28**, 229–239 (1955)

Madansky, A.: Methods of solution of linear programs under uncertainty. Operations Research **10**(4), 462–471 (1962)

Maroto, J.A., Mascareñas, J.: PLAFIN-II: Un modelo de simulación para la planificación financiera empresarial. Revista Española de Financiación y Contabilidad **49**, 223–255 (1986)

Mattesich, R.: Budgetingmodels and systemsimulation. Accounting Review **56**, 364–397 (1961)

Mulvey, J.M., Vanderbei, R.J., Zenios, S.A.: Robust optimization of large-scale systems. Operations Research **43**, 262–281 (1995)

Mulvey, J.M., Vladimirou, H.: Stochastic network programming for financial planning problems. Management Science **38**, 1642–1664 (1992)

Myers, S.C., Pogue, G.A.: A programming approach to corporate financial management. Journal of Finance **29**, 283–301 (1974)

Navarro, V., Canós, M.J., Mocholí, M.: Fondos propios: una aplicación mediante la optimización robusta. Análisis Financiero **92**, 94–102 (2003)

Navarro, V., Ferrando, M.: Punto muerto multiproducto en la incertidumbre: una aplicación práctica de la teoría de los subconjuntos borrosos. ESIC **102**, 57–75 (1999)

Navarro, V., Mocholí, M.: PSI: Programa de Selección de Inversiones mediante optimización robusta. Análisis Financiero **99**, 25–34 (2005)

Robicheck, A.A., Teichroew, D., Jones, J.M.: Short term financing decision. Management Science **12**(1), 1–35 (1965)

Sengupta, J.K., Tintner, G., Morrison, B.: Stochastic linear programming with applications to economic models. Econometrica **30**, 262–275 (1963)

Weingartner, H.M.: Capital budgeting of interrelated projects: survey and synthesis. Management Science **12**, 485–516 (1966)

Williams, A.C.: Approximation formulas for stochastic linear programming. SIAM Journal of Applied Mathematics **14**, 668–677 (1965)

A Fuzzy Logic Approach to Modeling Brand Value: Evidence from Taiwan's Banking Industry

David Han-Min Wang[1] and Tiffany Hui-Kuang Yu[2(✉)]

[1] Department of Accounting, Feng Chia University, Taichung, Taiwan
hmwang@fcu.edu.tw
[2] Department of Public Finance, Feng Chia University, Taichung, Taiwan
hkyu@fcu.edu.tw

Abstract. With the growing recognition that brands are valuable assets to organizations, the measurement of brand equity has thus been of interest to the academic and practice communities. Various approaches to measuring brand value have developed but are not yet universally accepted. To capture the qualitative characteristics of brands, this paper attempts to apply fuzzy logic analysis to model the brand values of Taiwan's banking industry. And, we adopt the Hirose model to examine the effectiveness of the fuzzy logic approach in the context of brand valuation. Our findings show that the fuzzy logic and the Hirose models present similar trends in relation to brand estimation. The evidence provided by this paper would enrich our understanding of the brand valuation methodology.

Keywords: Brand value · Fuzzy logic · Hirose model

1 Introduction

Since the work of [1], many researchers have claimed that the nature of brand awareness, brand image, brand loyalty and their measurements are important determinants of firm value [2,3,23,35,40,53]. They have generally concluded that company brands represent the future economic value of assets which can create wealth for shareholders.

Although there is growing recognition that brands are important intangible assets, companies still are challenged to substantiate the brand value in clear financial terms. Srivastava et al. argued that firms have intangible assets or undertake branding strategies whose benefits are not properly identified, measured and recognized in the financial statements [48]. For example, the accounting standards IAS 38, SFAS 142 and SFAS 37 issued by the International Accounting Standards Board (IASB), the United States Financial Accounting Standards Board (FASB) and the Taiwan Financial Accounting Standards Committee state that internally generated intangible assets such as brands should not be recognized as assets in the company's balance sheet.

By comparing Market Capitalization and Inter Brand Valuations of the top 10 brands in 2001, the brand represents between 18 and 68 percent of the market value of

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 39–52, 2015.
DOI: 10.1007/978-3-319-22204-2_4

firm [7]. Traditional accounting assets for the S&P 500 companies in 2002 explain only about 25 percent of market value, compared to 80 percent in 1980 [10]. The best brands have hidden values, not priced by conventional asset pricing models [26]. These studies suggested that businesses are becoming less dependent on physical assets for value creation and look more closely at the value of intangible assets include brands.

Branding in financial services is undergoing tremendous changes, owing to the dramatic increase in competition following deregulation in the last quarter of the twentieth century [21, 32]. And, banks in Taiwan were deregulated after Taiwan's government passed the "Commercial Bank Establishment Principle" in 1991. The number of banks in Taiwan has increased from 18 to 50 over the last ten years. Under such competitive environment, banks in Taiwan have been pursuing non-pricing marketing as a fundamental strategy.

Recent studies have indicated that the role of branding in financial service marketplaces is growing in importance[8,9,11,17,19,41,43]. Although many experts have developed various approaches to measure brand value, but there is no universally accepted valuation method. A brand is defined as a name, term, design, symbol, or other feature that distinguishes products and services from competitive offerings [37]. Namely, a brand name is a collection of perceptions in the mind of the consumer and is considered to be an intangible activity of recognized value. Because of the conceptual nature of brands, this paper attempts to adopt a fuzzy logic approach to evaluate the brand value in Taiwan's banking sector. Fuzzy logic provides a method to quantify subjective variables and avoids the need for rigid mathematical modeling. The findings from the fuzzy logic approach would provide greater understanding of the techniques used to measure brand equity.

The remainder of the paper is organized as follows. Section two reviews literature on brand value. Data and research methods are then presented, followed by empirical results. The conclusions are given in the final section.

2 Literature Review

Brands are defined in many ways, but the common point is that brand names come from the root of consumers' knowledge [2,33,34]. The concept of brand equity began to be used widely in the 1980s and can be described as the value a brand name adds to a product [2,12,25,51]. Although main accounting standards setting bodies in the world do not recognize brands as accounting assets, the brand is often considered as an important factor of corporate success and a driver of competitive advantage. Therefore, the understanding and measurement of brand equity indicators are crucial for assessing the financial value of brands.

There are various types of marketing and/or financial paradigms developed to contemplate the brand value [34,49]. However, the marketing or integrated model, such as Interbrand model, has been criticized by its proprietary analytic framework and various subjective parameters employed [16]. To overcome the shortcoming of arbitrariness, the Hirose model, developed by Japan's Ministry of Economy, Trade and

Industry, provides a methodology to determine brand value on the basis of public financial data and tends to be more objective compared to other appraisal methodologies. Therefore, this study adopts the Hirose approach as the benchmark model and focuses on the brand factors related to the Hirose methodology in the following literature review.

The Hirose's methodology for assessing brand value encompasses three elements: brand prestige, brand loyalty and brand expansion. Advertisements which provide consumers with product information are argued to create prestige or image effects of products [4]. Brand-based advertising can strategically create a comparative advantage for firms through its ability to differentiate their products and/or services from those of competitors. Advertising can also be viewed as an entry barrier, which may discourage some potential competitors from entering an advertising-intensive market and maintain the established brand loyalty of the incumbent [13,31,39].

Brand Loyalty, the second driver of the Hirose valuation model, is a crucial goal and result of successful marketing programs. Studies advocated that brand loyalty can provide companies with considerable marketing benefits including lower marketing costs, better trade leverage, greater market share and higher price premium, which have been closely associated with brand equity [1, 14, 22, 44]. Many other studies have also justified the role of brand loyalty and pointed out that high brand equity is associated with brand loyalty[5,7,20,46].

While the importance of brand loyalty has been recognized by academic researchers, brand loyalty is equally espoused by marketing practitioners. Among brand consultants, brand loyalty is considered the most frequently cited consumer-based criterion for evaluating brand success [18]. Brand loyalty is considered the most important metric for assessing marketing performance and has positive association with brand equity [7]. These findings support [1] argument that the brand loyalty of the customer base represents the core of a brand's equity.

The third driver of the Hirose model is brand expansion, which is the capability of extending a brand from its traditional market to a broader target market, geographic market, or distribution channel. Brand extension has become an increasingly popular way of gaining growth [47]. Brand trust, which is fundamental to the development of loyalty, can affect brand extension, particularly where there is an increased level of risk associated with a purchase [45]. Companies therefore invest in branding can increase consumer's perceived value, which lead to brand loyalty and consequently transfer the loyalty to brand extension. By adopting a quasi-experimental field-based research method, parent brand's loyalty has a significant positive effect on brand extension [28]. The consumer preferences towards different kinds of extensions in fast fashion brands and showed that the relationship between brand loyalty and brand extension is positively correlated [15].

After examining the factors that differentiate between successful and unsuccessful brand extensions, it is found that the most favorable consumer reaction can be expected for prestige-oriented brand name when brand extension and core brand have high concept consistency [42]. However, other studies argued that brand extension may produce negative effects on brand equity if brand extension is unsuccessful [38, 50]. And, even successful repeated extensions might diminish or exhaust a core product's brand equity. Gibson (1990) therefore warned that repeated successful and unsuccessful extensions may result in the total extinction of a brand's equity [27].

Although the Hirose methodology meets the objectivity requirement, the measurement of its three drivers still needs for rigid mathematical modeling and distribution assumption. Therefore, this study applies fuzzy logic approach with these brand equity drivers to evaluate the brand values of sample firms. By comparing the results obtained from the Hirose model, we could examine the effectiveness of fuzzy logic approach in modeling brand value.

3 Data and Research Method

For the purpose of this study, our data were gathered from the Taiwan Stock Exchange for banking sector over the period 2002 to 2006. The total sample firms were identified from the Taiwan Economic Journal (TEJ) database and consist of 86 firm-year observations. And, all the data needed for the variables used in the models were collected from the TEJ database and company annual reports.

To justify the effectiveness of the fuzzy logic approach in brand valuation, we firstly apply the Hirose model to obtain estimated brand values as the benchmark for the sample firms. The Hirose model can be summarized as follows. The brand value (BV), is assumed to be function of three key factors:

$$BV = f(PD; LD; ED; r) = \frac{PD}{r} \times LD \times ED \tag{1}$$

The implied factors or drivers in the valuation model are prestige driver (PD), loyalty driver (LD) and expansion driver (ED). And, r is the risk-free interest (discount) rate.

The prestige driver (PD) is represented by the cash flows attributable to the price advantage or excess value of the brand. The proportion of advertising expense, or brand management cost, to total operation expenses is used as the brand attribution rate. Formally, PD is given by:

$$PD = \frac{1}{5} \sum_{i=-4}^{0} \left\{ \left(\frac{s_i}{c_i} - \frac{s_i^*}{c_i^*} \right) \times \frac{A_i}{OE_i} \right\} \times C_0 \tag{2}$$

Where
S = Sales or interest revenue of banks
C = Cost of sales or interest expense of banks
S^* = Sales or interest revenue of a benchmark company
C^* = Cost of sales or interest expense of a benchmark company
A = advertising expense and promotion cost
OE = operation expense.

The Hirose's second key parameter, loyalty driver (LD), is a factor related to the capability of a brand that manage to maintain stable sales over a long period based on the premise of customers loyalty and repeat business. The LD is constructed by calculating the stability of the cost of sales and can be measured from the following formula:

$$LD = \frac{\mu_c - \sigma_c}{\mu_c} \tag{3}$$

Where
μ_c = five-year average of cost of sales or interest expense of banks
σ_c= five-year standard deviation of cost of sales or interest expense of banks

The expansion driver (ED) is the third key factor of the Hirose model. The ED determines the brand's expansion capability which represents a well-recognized brand can stretch across industry sectors and geographical areas. However, there are no oversea sales are found in Taiwan's financial services sector. We therefore modify the Hirose model by focusing only on the non-core business of the ED as follows:

$$ED = \frac{1}{2}\sum_{i=-1}^{0}\left(\frac{SX_i - SX_{i-1}}{SX_{i-1}} + 1\right) \tag{4}$$

Where
SX = Sales or non-interest (other operating) revenue from non-core businesses

After measuring the brand values in the Hirose model, this study adopts the fuzzy logic approach to estimate the brand intangibles created by the sample firms. Fuzzy logic was initiated in 1965 by LotfiZadeh and has been widely used to model uncertain or vague notions. It is basically a multi-valued logic that centers on building better models of human reasoning and decision-making. Fuzzy logic, in contrast to the conventional parameter method, avoids the need for rigid mathematical modeling and the distribution assumption. The theory of fuzzy logic provides a mathematical strength to capture the uncertainties associated with human cognitive processes, such as thinking and reasoning.

Fuzzy logic translates natural language descriptions of decision policies into an algorithm using a mathematical model, which consists of a process of fuzzification, inference and defuzzication (Altrock, 1996)[6]. First, we set up the membership functions for the brand value drivers. In fuzzy logic, the drivers can be described using linguistic terms, such as Very Low (VL), Low (L), Normal (N), High (H) and Extreme High (EH). Meanwhile, the linguistic terms for brand value index are Very Small (VS), Small (S), Average (A), Big (B) and Very Big (VB). Each linguistic term is associated with membership functions. The peak of the N (degree of membership of N, where $\mu(x)$=1.0) is calculated by using the moving average of the past consecutive years. We then calculate the peaks of the remaining linguistic terms by adding or subtracting one or two standard deviations (SD) and derive the membership functions for each linguistic term, as in Table 1.

By using the associative linguistic terms of the drivers, we apply the fuzzy rules proposed by Draeseke and Giles (2002)[24] to obtain our fuzzy decision rules for the brand value index shown in Table 2 for fuzzy inference. For each rule, we use AND to connect two conditions and apply a min operator to calculate the degree of membership. For the degree of membership among more rules, we apply a max operator.

Table 1. Membership Functions for the Variable

$\mu_{VL}(x) = 1.0$,	if $x \leq Mean - 2SD$
$\mu_{VL}(x) = \frac{Mean-SD-x}{SD}$,	if $Mean - 2SD \leq x \leq Mean - SD$
$\mu_{L}(x) = \frac{x-Mean+2SD}{SD}$,	if $Mean - 2SD \leq x \leq Mean - SD$
$\mu_{L}(x) = \frac{Mean-x}{SD}$,	if $Mean - SD \leq x \leq Mean$
$\mu_{N}(x) = \frac{x-Mean+SD}{SD}$,	if $Mean - SD \leq x \leq Mean$
$\mu_{N}(x) = \frac{Mean+SD-x}{SD}$,	if $Mean \leq x \leq Mean + SD$
$\mu_{H}(x) = \frac{x-Mean}{SD}$,	if $Mean \leq x \leq Mean + SD$
$\mu_{H}(x) = \frac{Mean+2SD-x}{SD}$,	if $Mean + SD \leq x \leq Mean + 2SD$
$\mu_{EH}(x) = \frac{x-Mean-SD}{SD}$,	if $Mean + SD \leq x \leq Mean + 2SD$
$\mu_{EH}(x) = 1.0$,	if $x \geq Mean + 2SD$

Table 2. Fuzzy Decision Rules for the BV index

Rule	AD	LT	BV Index	Degree
1	extreme	extreme	very big	1
2	extreme	high	very big	0.8
3	extreme	normal	small	1
4	extreme	low	small	0.8
5	extreme	very low	average	0.8
6	high	extreme	very big	1
7	high	high	big	1
8	high	normal	big	0.8
9	high	low	average	1
10	high	very low	small	1
11	normal	extreme	small	1
12	normal	high	big	0.8
13	normal	normal	average	1
14	normal	low	small	0.8
15	normal	very low	small	1
16	low	extreme	big	1
17	low	high	average	1
18	low	normal	small	0.8
19	low	low	small	1
20	low	very low	very small	1
21	very low	extreme	average	0.8
22	very low	high	small	0.8
23	very low	normal	small	1
24	very low	low	very small	0.8
25	very low	very low	very small	1

After the fuzzy inference step, we adopt the center of area (COA) defuzzification method (Yen and Lengari, 1999)[52] to convert the fuzzy values of brand value index into numerical values. The COA is calculated as follows:

$$index of\ BV = \frac{\sum(\mu_{BV\ index} \times y_i)}{\sum \mu_{BV\ index}} \tag{5}$$

Where y_i is a weight. If BV index is zero then y_i is zero, if BV index is small then y_i is 0.25, if BV index is average then y_i is 0.5, if BV index is big then y_i is 0.75 and, finally, if BV index is very big then y_i is 1.

4 Empirical Results

Although there are three brand value drivers employed by the Hirose model, the application of fuzzy logic estimation in this paper has been simplified by using only two input variables. We choose the advertising expense and promotion cost (AD) and the value of loyalty driver (LT) as the input variables for the fuzzy logic model. Previous research in the literature review section above shows that the expansion driver (ED) may have positive or negative effects on brand equity. The ambiguous nature of the expansion driver prevents us from using this variable in the fuzzy logic estimation model.

Tables 3 and 4 show how the fuzzification process converts the advertising expense and promotion cost (AD) and the value of loyalty driver (LT) into the fuzzy sets as ‘very low’, ‘low’, ‘normal’, ‘high’ and ‘extreme high’. Each linguistic term is associated with the membership function. We then use the rules in Table 2 to apply fuzzy inference for the entire period. Table 5 reports the estimated brand value index for sample firms after defuzzification process.

Table 3. Fuzzification of the AD

obs	AD	VL	L	N	H	EH
1	11.70		0.012560	0.987440		
2	12.30			0.659156	0.340844	
3	11.83			0.9402793	0.059721	
4	7.59	1				
5	8.79	0.730239	0.269761			
6	14.89				0.132718	0.867282
7	13.02			0.236791	0.763209	
8	12.27			0.681620	0.318380	
9	11.30		0.248445	0.751555		
10	12.52			0.533060	0.466940	

Table 3. (*Continued.*)

obs	AD	VL	L	N	H	EH
11	11.61		0.066846	0.933154		
12	12.78			0.379468	0.620532	
13	10.92			1		
14	13.52				0.940682	0.059318
15	12.08			0.791723	0.208277	
16	11.89			0.902609	0.097391	
17	10.32		0.829115	0.170885		
18	12.01			0.908324	0.091676	
19	11.66		0.109545	0.890455		
20	10.89		0.554892	0.445108		
…						
72	9.21	0.719883	0.280117			
73	15.34					1
74	13.40			0.125604	0.874396	
75	12.68			0.574704	0.425296	
76	11.95		0.026064	0.973936		
77	12.14			0.905406	0.094594	
78	13.29			0.194704	0.805296	
79	12.43			0.727502	0.272498	
80	13.27			0.205365	0.794635	
81	9.91	0.287083	0.712917			
82	12.68			0.572942	0.427058	
83	12.18			0.884177	0.115823	
84	11.86		0.077860	0.922140		
85	11.97		0.009320	0.990680		
86	11.09		0.555761	0.444239		

Table 4. Fuzzification of the LT

obs	LT	VL	L	N	H	EH
1	0.75		0.239026	0.760974		
2	0.77			0.821170	0.178830	
3	0.77			0.788063	0.211937	
4	0.69	0.915644	0.084356			
5	0.73		0.714285	0.285715		
6	0.70	0.595180	0.404820			
7	0.78			0.671693	0.328307	
8	0.77			0.887418	0.112582	
9	0.77			0.905712	0.094288	
10	0.72	0.081557	0.918443			
11	0.80			0.042741	0.957259	
12	0.80			0.139883	0.860117	
13	0.78			0.457585	0.542415	
14	0.79				0.420137	0.579863
15	0.84					1
16	0.79			0.360447	0.639553	
17	0.72		0.997190	0.002810		
18	0.59		0.389486	0.610514		
19	0.61		0.046609	0.953391		
20	0.73				0.270040	0.729961
…						
72	0.68		0.4632390	0.536761		
73	0.62	0.203708	0.796292			
74	0.63	0.074994	0.925006			
75	0.70		0.211292	0.788708		
76	0.78			0.199459	0.800540	
77	0.84				0.511516	0.488484
78	0.66		0.750863	0.249137		
79	0.64	0.035107	0.964893			
80	0.52	1				
81	0.76			0.483879	0.516121	
82	0.74			0.696321	0.303679	
83	0.75			0.625846	0.374154	
84	0.72			0.958168	0.041832	
85	0.84				0.432574	0.567426
86	0.69		0.380637	0.619363		

Table 5. Estimated Index for the BV

obs	Active Value	VS	S	A	B	VB	Index
1	13,14,18,19		0.2390	0.7610			0.445
2	7,8,12,13			0.6592	0.3408		0.619
3	6,8,13,14			0.7881	0.2119		0.565
4	19,20,24,25	0.9156					0.017
5	18,19,23,24	0.7143	0.2857				0.144
6	4,5,9,10		0.4048	0.5952			0.393
7	7,8,12,13			0.2368	0.6717		0.704
8	7,8,12,13			0.6816	0.3184		0.600
9	12,13,17,18		0.2484	0.7516			0.472
10	6,7,11,12		0.5331	0.4669			0.360
11	12,13,17,18		0.0427	0.0668	0.9332		0.700
12	7,8,12,13			0.1399	0.6205		0.720
13	7,8,12,13			0.4576	0.5424		0.622
14	5,7				0.4201	0.0593	0.918
15	6,11				0.7917	0.2083	0.802
16	7,8,12,13			0.3604	0.6396		0.664
17	13,14,18,19		0.8291	0.0028			0.251
18	7,8,12,13		0.3895	0.6105	0.0917		0.524
19	13,14,18,19		0.1095	0.8905			0.460
20	11,12,16,17		0.4451	0.2700	0.5549		0.555
…							
72	18,19,23,24	0.463239	0.4632	0.5368			0.184
73	4,5			0.7963	0.2037		0.301
74	6,7,11,12			0.1256	0.8744		0.444
75	7,8,12,13			0.2113	0.5747	0.4253	0.533
76	12,13,17,18			0.0216	0.1995	0.8005	0.675
77	6,7,11,12					0.5115	0.772
78	7,8,12,13			0.1947	0.7509	0.2491	0.508
79	6,7,11,12			0.7275	0.2725		0.324
80	6,11			0.7946			0.250
81	17,18,22,23			0.4839	0.5161		0.341
82	7,8,12,13				0.5729	0.4271	0.652
83	7,8,12,13				0.6258	0.3742	0.612
84	12,13,17,18			0.0779	0.9221	0.0418	0.493
85	11,12,16,17			0.5674	0.0093	0.4326	0.443
86	13,14,18,19			0.3806	0.4442		0.321

To examine the effectiveness of the fuzzy logic approach in brand valuation, we then apply the Hirose model to calculate the brand values of the sample firms as the benchmark. The index values of the fuzzy brand value and the natural logarithm of brand values obtained from the Hirose model are plotted in Figure 1.

Although the two approaches yield some different results for the brand values of Taiwan's banks, they exhibit similar trends over the firms. The findings demonstrate that the application of fuzzy logic can capture pictures of brand values in Taiwan's financial services industry.

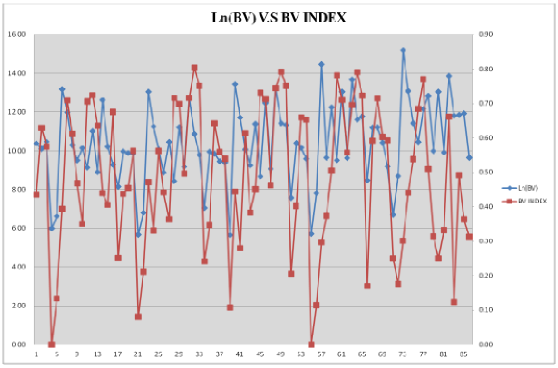


Fig. 1. Comparison of the Estimated Values

5 Conclusions

Prior research has shown that brands are intangible corporate assets that create wealth for the shareholders. The measurement of brand value has long been of interest to the academic and practice communities. However, there are no universally recognized methods used to value brands. And, most of them have been criticized by subjective parameters and rigid mathematical assumptions employed. To capture the qualitative characteristics of the brand, this paper attempts to adopt fuzzy logic to estimate the brand values of Taiwan's banking firms. Since the perceptions of brand are subjective and are based on decision maker's judgment, they are best expressed in linguistic terms. As a result fuzzy logic is used to facilitate the elicitation process.

We apply the fuzzy logic approach with two major brand drivers to model the estimated brand values of Taiwan's banks over the period of 2002 to 2006. And, the results from the fuzzy logic approach are compared with those from the Hirose model, which employs publicly available data. Our findings show that the results from the fuzzy logic approach present similar trends to those of the Hirose model. The evidence provided by this paper would enrichour understanding of the brand valuation methodology.

The major limitation of this study is that we only adopt the Hirose model to examine the effectiveness of the fuzzy logic approach in brand evaluation. Comparing the benchmarks from other models would further justify the robustness of the proposed methodology. Furthermore, future research may apply the fuzzy logic approach to complex processes with multiple brand characteristics. The findings would provide useful guidelines for the brand evaluation in the interdisciplinary programs.

References

1. Aaker, D.A.: Managing Brand Equity: Capitalizing on the Value of a Brand Name. Free Press, New York (1991)
2. Aaker, D.A.: Building Strong Brands. Free Press, New York (1996)
3. Aaker, D.A.: Dimensions of brand personality. Journal of Marketing Research **34**(3), 347–356 (1997)
4. Ackerberg, D.A.: Empirically distinguishing informative and prestige effects of advertising. RAND Journal of Economics **32**(2), 316–333 (2001)
5. Ailawadi, K.L., Lehmann, D.R., Neslin, S.A.: Revenue Premium as an Outcome Measure of Brand Equity. Journal of Marketing **67**, 1–17 (2003)
6. Altrock, C.V.: Fuzzy Logic and NeuroFuzzy Applications in Business and Finance. Prentice Hall, Upper Saddle River (1996)
7. Ambler, T.: Marketing and the Bottom Line. FT Prentice Hall, London (2003)
8. Anon: Key imperatives for value creation, Life Insurance International, August 2004 edition, 8–9 (2004a)
9. Anon: The future of financial services, US Banker, Thomas Media, Bristol, 4–6 (2004b)
10. Ballow, J.J., Burgman, R., Molnar, M.J.: Managing for shareholder value: Intangibles, future value and investment decisions. Journal of Business Strategy **25**(3), 26–34 (2004)
11. Benrud, E.: Competition between low and high quality products in the financial service market. Journal of Financial Services Research **23**(2), 133–147 (2004)
12. Chaudhuri, A.: Brand equity or double jeopardy? Journal of Product & Brand Management **4**(1), 26–32 (1995)
13. Chaudhuri, A.: How brand reputation affects the advertising-brand equity link. Journal of Advertising Research **42**, 33–43 (2002)
14. Chaudhuri, A., Holbrook, M.B.: The chain of effects from brand trust and brand effect to brand performance: The role of brand loyalty. Journal of Marketing **65**, 81–93 (2001)
15. Choi, T.M., Liu, N., Liu, S.C., Mak, J., To, Y.T.: Fast fashion brand extensions: An empirical study of consumer preferences. Journal of Brand Management **17**(7), 472–487 (2010)
16. Chu, S., Keh, H.T.: Brand value creation: Analysis of the interbrand-business week brand value rankings. Marketing Letters **17**, 323–331 (2006)
17. Dawes, J.G., Mundt, K., Sharp, B.: Consideration sets for financial services brands. Journal of Financial Services Marketing **14**(3), 190–202 (2009)
18. deChernatony, L., Dall'Olmo Riley, F., Harris, F.: Criteria to assess brand success. Journal of Marketing Management **14**(7), 765–781 (1998)
19. deChernatony, L., Cottam, S.: Internal brand factors driving successful financial services brands. European Journal of Marketing **40**(5/6), 611–633 (2006)
20. deChernatony, L., Harris, F., Christodoulides, G.: Developing a brand performance measure for financial services brands. The Service Industries Journal **24**(2), 15–33 (2004)
21. Denby-Jones, S.: Mind the gap. The Banker **145**, 66–67 (1995)
22. Dick, A.S., Basu, K.: Customer loyalty: Towards an integrated framework. Journal of The Academy of Marketing Science **22**(2), 99–113 (1994)
23. Doyle, P.: Building value-based branding strategies. Journal of Strategic Marketing **4**, 255–268 (2001)

24. Draeseke, R., Giles, D.E.A.: A fuzzy logic approach to modeling the New Zealand underground economy. Mathematics and Computers in Simulation **59**, 115–123 (2002)
25. Farquhar, P.H.: Managing brand equity. Marketing Research **1**, 24–33 (1989)
26. Fehle, S., Fournier, S.M., Madden, T.J., Shrider, D.G.: Brand value and asset pricing. Quarterly Journal of Finance and Accounting **47**(1), 3–26 (2008)
27. Gibson, R.: The end of the line? overkill on extensions, Wall Street Journal, B1, June 18, 1990
28. Hem, L.E., Iversen, N.M.: Transfer of brand equity in brand extension: The importance of brand loyalty. Advances in Consumer Research **30**, 72–79 (2003)
29. Hirose, Y.: The Report of the Committee on Brand Valuation, Ministry of Economy, Trade and Industry, The Government of Japan (2002)
30. Hirschey, M., Weygandt, J.J.: Amortization policy for advertising and research and development expenditures. Journal of Accounting Research **23**, 326–335 (1985)
31. Ho, Y.K., Keh, H.T., Ong, J.: The effects of R&D and advertising on firm value: An examination of manufacturing and non-manufacturing firms. IEEE Transactions on Engineering Management **52**(1), 3–14 (2005)
32. Jones, J.: The future of banking: Implications of branding and loyalty. Journal of Financial Services Marketing **3**, 53–66 (1999)
33. Keller, K.L.: Conceptualizing, measuring, and managing customer-based brand equity. Journal of Marketing **57**, 1–22 (1993)
34. Keller, K.L.: Strategic Brand Management. Prentice Hall, Upper Saddle River (2002)
35. Kerin, R.A., Sethuraman, R.: Exploring the brand value - shareholder value nexus for consumer goods companies. Journal of the Academy of Marketing Science **4**, 260–273 (1998)
36. Koenker, R., Basset, G.: Regression quantiles. Econometrica **46**, 33–50 (1978)
37. Kotler, P.: Marketing Management. Prentice Hall, Upper Saddle River (2000)
38. Loken, B., Roedder, J.D.: Diluting brand beliefs: when do brand extensions have a negative impact? Journal of Marketing **57**, 71–84 (1993)
39. Mizik, N., Jacobson, R.: Trading off between value creation and value appropriation: The financial implications of shifts in strategic emphasis. Journal of Marketing **67**, 63–76 (2003)
40. Mizik, N., Jacobson, R.: The Financial Value Impact of Perceptual Brand Attributes. Journal of Marketing Research **15**, 15–32 (2008)
41. O'Loughlin, D., Szmigin, I.: External and internal accountability of financial services suppliers: Current paradoxes in managing expectations and experience. Journal of Strategic Marketing **13**(2), 133–147 (2005)
42. Park, C.W., Milberg, S., Lawson, R.: Evaluation of brand extensions: The role of product feature similarity and brand concept consistency. Journal of Consumer Research **18**, 185–193 (1991)
43. Petruzzellis, L., Romanazzi, S., Tassiello, V.: Branding relationships in financial services: Paradigm shift in Mediterranean countries. Journal of Brand Management **18**(4/5), 312–328 (2011)
44. Reichheld, F.F.: Learning from customer defections. Harvard Business Review **74**, 56–69 (1996)
45. Selnes, F.: Antecedent and consequences of trust and satisfaction in buyer-seller relationships. European Journal of Marketing **32**(3/4), 305–322 (1998)
46. Slotegraaf, R.J., Pauwels, K.: The impact of brand equity and innovation on the long-term effectiveness of promotions". Journal of Marketing Research **45**, 293–306 (2008)
47. Springen, K., Miller, A.: Sequels for the shelf. Newsweek **9**, 42–43 (1990)

48. Srivastava, R.K., Shervani, T.A., Fahey, L.: Market-based assets and shareholder value: A framework for analysis. Journal of Marketing **62**, 2–18 (1998)
49. Stobart, P.: Alternative methods of brand valuation. In: Murphy, J. (ed.) Brand Valuation. Business Book, London (1991)
50. Sullivan, M.: Measuring image spillovers in umbrella branded products. Journal of Business **63**, 309–329 (1990)
51. Winters, L.C.: Brand equity measures: Some recent advances. Marketing Research **3**, 70–73 (1991)
52. Yen, J., Lengari, R.: Fuzzy Logic: Intelligence, Control and Information. Prentice Hall, New York (1999)
53. Yoo, B., Donthu, N., Lee, S.: An examination of selected marketing mix elements and brand equity. Journal of Academy of Marketing Science **28**, 195–211 (2000)

Human Resource Characteristics and E-Business: ANfsQCA Analysis

Enrique Bernal-Jurado(✉), Miguel Jesús Medina-Viruel, and Adoración Mozas-Moral

University of Jaen, Jaen, Spain
{ebernal,mjmedina,amozas}@ujaen.es

Abstract. Electronic business (e-business) is becoming a real alternative to traditional market channels, particularly for the organic product sector. Traditionally, this sector has faced a multitude of commercial obstacles that e-business can solve.

The present paper examines how the characteristics of the company's manager – following upper echelon theory – and the number of office employees available can boost or limit this sector's use of information and communication technology (ICT) and, specifically, electronic business.

This study, which used the fuzzy set Quality Comparative Analysis (fsQCA) method, confirms that for companies in this sector to make full use of e-business, the number of office employees available and the characteristics of the manager (age, educational background, knowledge of ICTs and view of the benefits of ICTs for product marketing) are important.

Keywords: Information and communication technologies (ICT) · Upper echelon electronic business · fuzzy set Quality Comparative Analysis (fsQCA)

1 Introduction

Increasing consumer awareness of environmental deterioration (European Commission, 1999) has been reflected in changing consumption habits over the past two decades and, on the supply side, in a substantial rise in organic production, making this one of the most dynamic sectors in the agri-food sphere (Willer & Yussefi, 2004).

One defining characteristic of the growth in the organic food market in Europe is its uneven distribution between regions, as demand is mainly concentrated in central and northern European countries, while southern Europe has specialized in growing and exporting these products. Spain provides one of the best examples of this imbalance. Its certified organic farming surface area is the largest in Europe and the

Funding source: This research was funded in part by the Regional Government of Andalusia (Spain) through the "Estrategias de mejora de la comercialización de losaceites de oliva" [Strategies to improve olive oil marketing] Excellence project (AGR-6132). The funding source had no involvement in the study design; in the data collection, analysis and interpretation; in the writing of the report; or in the decision to submit the article for publication.

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 53–63, 2015.
DOI: 10.1007/978-3-319-22204-2_5

fifth-largest worldwide (Willer, Lernoud & Kilcher, 2013) and shows an impressive growth rate, having multiplied by five over the 1999-2009 period. On the demand side, however, the market share of organic products in Spain is under 0.7% because of the very low proportion of these products (barely 1%) in the Spanish consumer's shopping basket (Schaack & Willer, 2010).As a result, over 80% of Spanish organic products end up in foreign markets, mainly the Netherlands, Germany, the United Kingdom and France (MAGRAMA, 2009).

In general, there is consensus on the main factors hindering the development of demand for organic foods in Spain: poor distribution – a scarcity of points of sale and little variety on offer – the price differential between organic foods and their conventional equivalents and, lastly, the consumers' confusion about the differentiating features of this type of food (Roitner-Schobesberger, Darnhofer, Somsook & Vogl, 2008).

The organic farming sector has reacted to these inhibiting factors in different ways, which include strengthening the availability of organic products through unconventional sales channels such as direct selling over the Internet (González & Cobo, 2000).Using the Internet for sales purposes provides a solution to the obstacles facing the organic product sector mentioned in the previous paragraph, as the Internet is able to concentrate the supply side in an online environment, reducing the importance of geographical distance, to cut out intermediaries by fostering direct contact with the producer, and to allow large volumes of information to be distributed attractively and cheaply. These advantages of the Internet are particularly attractive for small and medium companies – which are predominant in this sector – as they allow them to overcome their size limitations and compete more effectively with large companies in the different markets (Dholakia & Kshetri, 2004).Some authors also highlight the ability of online social media to publicize new products that have previously been ignored by conventional media (Wei, Zhang & Sutanto, 2013, Dellarocas, Gao & Narayan 2010), such as organic products. The continuous increase in the number of online companies that are including organic products in their range proves the attractiveness of these products.

Despite the potential of using the internet commercially to market organic products, few studies have attempted to investigate the factors that move a company in this sector to adopt a new technology, or ICT tools, in contrast to the abundance of such research in other sectors (Thong & Yap, 1996; Iacovou, Benbasat & Dexter, 1995; Pereda, 2000;Mehrtens, Cragg& Mills, 2001; Doherty, Ellis-Chadwick & Hart 2003; Beckinsale & Levy, 2004; Nguyen & Barret, 2006; or Kim & Jee, 2007).Studies in this field have examined how factors such as company age, external pressures, workforce characteristics, the age and educational background of the executives, company size, perceived benefits, geographical location, business sector or an innovative culture influence the possibility of a company's adopting ICTs. All these factors can be classified into two large groups: internal factors and factors that are external to the company (Lefebvre & Lefebvre, 1996).

Given the characteristics of the organic product companies (small size, low educational level of the management, scarce resources, etc.), the present study centers on internal factors that affect ICT adoption, based on upper echelon theory (Hambrick & Mason, 1984; Karake, 1995 or Pinsonneault & Rivard, 1998).According to this theory, organizations become a reflection of the personal characteristics of their executives. Along the same lines, Karake (1995) stated that company performance in relation to the use of ICTs and the effective introduction of new technologies is dependent to a decisive degree on certain characteristics of the company's management, such as age, experience within the company, education, or technological knowledge.

Based on the foregoing, the aim of this study is to examine the internal causes that lead organic product companies to decide to use e-business as a sales channel. Specifically, it attempts to analyze how the characteristics of the company's human capital can influence the decision to start selling online.

To this end, the present paper is organized as follows: after this introduction, the second section presents the hypotheses with a review of the literature on which each is based. The third section explains the research method and the variables employed, while the fourth highlights the main results. The study closes with some conclusions and the references.

2 Theoretical Arguments and Hypothesis Formulation

Some of the most important and well-studied internal factors that affect ICT introduction are the characteristics of the company's chief executive. Of these, many studies note that the qualifications of the company's general manager are fundamental for adopting new ICTs (Chan & Swatman, 2000; Mehrtens *et al.,* 2001), whether suggested by the management itself or by other members of the organization. Some studies, such as Levenburg, Magaland Kosalge(2006), show a positive association between the manager's educational level and the possibility of the company's adopting ICTs.

It should be noted that although this factor is decisive in all organizations irrespective of size, a number of authors (such as Brancheau& Buckland, 1996; Levenburg *et al.,* 2006; or Benito & Platero, 2012) emphasize the vital role of the CEO's characteristics in the process of ICT adoption bySMEs – and SMEs predominatein the organic products sector. Accordingly:

Hypothesis 1: Companies whose managers have a higher level of education are more likely to effect commercial transactions online.

More decisive for ICT adoption than the top executives' educational level, however, is their specific knowledge regarding ICTs, as this makes it easier for them to identify the implications of ICT use for the organizational and commercial functioning of the company, understand the urgent need to adopt these tools and achieve greater performance following their introduction into the company (Wang & Cheung, 2004; Matlays & Addis, 2003; Nguyen & Barret, 2006; McCole & Ramsey, 2005). In contrast, other studies such as those of Bharadwaj (2000) or Santhanam and Hartona (2003) maintain that companies which have employees with ICT skills use their technical knowledge more efficiently because they recognize the opportunities afforded by new technologies as these appear, and are more likely to adapt to them immediately.

Hypothesis 2: Companies whose managers have greater ICT knowledge are more likely to effect commercial transactions online.

The age of the top executive has been studied assiduously in relation to the company's innovative propensities and, consequently, the possibility of its adopting and adapting to the latest ICT novelties. This characteristic is even more important in micro-enterprises (Benito & Platero, 2012) and, therefore, in the subjects of the present study, of which 56.57% are micro-enterprises.

As with company age, there is no consensus on whether the manager's age and propensity to innovation are directly or inversely related. Authors such as Khan and Manopichetwattana (1989) maintain that younger managers are more prepared to introduce innovations, but more recent studies such as Lasch, Leroy and Yami (2007) maintain that there is a positive association between age and tendency to innovate and that older managers are more active in introducing ICTs into the company. The latter authors argue that age can be an indication of experience and knowledge acquired by the manager throughout his or her working life, and that this experience favors permanently updating the company.

Other studies, such as those of Verheul, Wennekers, Audretsch and Thurik (2002), Aubert, Caroli and Roger(2006) or González and Peña (2007), consider that the age of the manager does not have a linear effect on the possibility of a company's adopting new technologies. According to this group of researchers, the innovative capacity of the top manager increases with age. However, this is not a continuous curve over time, as it reaches a turning point where technological skills decline, making it difficult to adapt to changes, and the association between the manager's age and his or her adaptation to ICTs is eventually reversed. Consequently, managers in their middle years would be ideal for bringing about adoption of novel ICT tools.

Hypothesis 3: The advanced age of the manager is a negative factor for a company to effect commercial transactions online.

The perceived benefits of ICT use are another factor that has been studied as an influence on shaping an innovative attitude and, therefore, on the possibility of a company's adopting ICTs. In particular, there is a high degree of agreement in asserting that the perceived benefits have a positive influence on ICT adoption by companies (Sadowski, Maitland & Van Donden, 2002; Doherty *et al.*, 2003; Walczuch, Braven & Lundgren, 2000; Poon & Swatman, 1999).For their part, Thong and Yap (1995) and Cragg and King (1993) found a decisive association between the managers' ICT education and attitude towards these technologies, and their adoption by the company.

In the specific case of SMEs it is mainly the managers who take the decisions, so their attitude towards ICTs and perception of their benefits are fundamental for ICT adoption (Levy, Powell & Worrall, 2005 and Beckinsale & Levy, 2004).These two studies are highly relevant given the profile of the companies in the present study, where 92% are SMEs. Consequently, the next hypothesis is as follows:

Hypothesis 4: A good image of ICTs on the part of the manager is a positive factor for the company to effect commercial transactions online.

According to Cooper and Zmud (1990), Chun (2003) and Hollestein (2004), the workforce and their education and training are a decisive factor in a company's innovative attitude. Because of this, the present authors consider that for ICT to be adopted by a company it is very important to have a sufficient number of staff performing the administrative tasks and that these employees be trained in and keep up-to-date on the latest technological novelties, so that they can be a source of updating initiative and organizational and commercial renewal.

One of the main factors for achieving maximum results from the ICTs the company introduces is the effort devoted to training in the new technologies (Powell & Dent-Micalef, 1997).However, in order to deploy training courses there needs to be job continuity. In other words, it is impossible for temporary workers to undertake these training programs. It is also difficult for employees to keep up-to-date with training courses in companies where administrative tasks are carried out by only a few people, as in this case the entire working day is spent on routine office work and they do not have the necessary time for ICT training and keeping up to date. The sector examined in the present study is characterized by the high proportion of small and very small companies structured around very few employees. In Spain, Medina (2014) indicated that over 60% of these companies have two people at most working in the office.

Dholakia and Kshetri (2004) is an example of other studies that relate Internet adoption to internal factors such as size. Dholakia (1995), Ibrahim (1993) and Miller and Toulouse (1986) all agree that company size is one of the most decisive indicators for the implementation of Internet adoption strategies. Conversely, small and medium enterprises with limited resources for Internet introduction are restricting their ability to compete (Coviello & Martin 1999).For their part, Black and Lynch (2001) showed that productivity is greater in companies where the workforce has greater ICT skills.

Hypothesis 5: A high number of office workers increases the probability of effecting commercial transactions online.

3 Research Method

3.1 Population

This research focused on organic olive oil companies in Spain that have their own website. Fieldwork consisting of telephone interviews with the chief executives of the companies was conducted to obtain the necessary information. The starting point was the entire set of companies in Spain that market organic olive oil, which totaled 195 companies according to the list and directory obtained through the Ministry of Agriculture, Food and the Environment (MAGRAMA, 2007). The main search engines were used to discover which of these companies had their own website. The resulting 127 companies comprised the study population. On contacting the 127 companies that had their own website in order to conduct the telephone interview, 99 responded, as shown in Table 1.

Table 1. Technical description of the empirical study

POPULATION	
Sampling units:	Organic olive oil sector companies with a website
Total population:	127 companies
Sample elements:	CEOs
Scope:	Spain
Timescale:	1 December 2012 to 5 April 2013
SAMPLE	
Type:	Simple random
Sample size:	99 telephone interviews
Approximate sampling error:	4.74%, p=q=0.5, CI 95.5%

Lastly, companies that provided incomplete data were eliminated, giving a final sample size of 89 companies throughout Spain.

3.2 fsQCA

The Qualitative Comparative Analysis (QCA) method was used in this study. This method makes it possible to work with medium-sized samples which are neither large enough to apply traditional quantitative methods nor too small for representative conclusions to be drawn (Ragin, Shulman, Weinberg & Gran, 2003; Ragin &Rihoux, 2004).

This method was first developed by Ragin (1987), using what is known as crisp set QCA (csQCA) or conventional QCA. It employed dichotomous variables, which constitutes its main limitation. This limitation was subsequently removed by using fuzzy set theory and Boolean logic, giving rise to fuzzy set Qualitative Comparative Analysis (fsQCA) (Ragin, 2008), the method used in the present study. This modification of conventional QCA makes it possible to use continuous or interval-scale variables, which first need to be calibrated to transform them into fuzzy categories or variables. This calibration consists of assigning the variables a value between 0.0 and 1.0, depending on their grade of membership (see Woodside & Zhang, 2013).

fsQCA results in one or more antecedent combinations which are sufficient to obtain a concrete outcome, such as X_1*~X2*X3 sufficient for aout come (Y).In the notation used in this technique ($X_1*{\sim}X_2*X_3 \rightarrow Y$),$X_1$, X_2 and X_3 are the antecedents; Y is the outcome; * is union and ~ is absence or negation, in this case the opposite value to X_2 (1- X_2).

3.3 Variables

In the present study, the outcome was effecting commercial transactions online (tr_online). The antecedents examined, following the necessary prior calibration for the fsQCA method, were a series of characteristics of the company manager: age (c_age), education (c_ed), knowledge of ICTs (c_ictk) and image of the benefits of

ICTs for helping to market the company's products (c_imag).Another antecedent that was used was the total number of employees working in the office (c_empl).Table 2 shows the values and calibration of the antecedents and the outcomeprior to analysis.

Table 2. Calibration of outcome and antecedent variables

Outcome and antecedents	**Original value**	**Fuzzy-set value**
Effecting transactions online (tr_online)	0-No online transactions	0.01
	1-Online transactions	0.99
Manager's age (c_age)	Age in years	Calibrated with fsQCA 2.0
Manager's educational background (c_ed)	1-No formal education	0.01
	2-Primary education	0.25
	3-Secondary education	0.50
	4-Diplomado universitario (3-year university degree)	0.75
	5-Licenciadouniversitario (5-year university degree)	0.99
Manager's ICT skills (c_ictk)	1-None	0.01
	2-Basic	0.33
	3-Intermediate	0.67
	4-Advanced	0.99
Manager's image of the benefits of ICTsforim-provingsales* (c_imag)	1-Disagree totally	0.01
	2-Disagree	0.25
	3-Indifferent	0.50
	4-Agree	0.75
	5-Agree totally	0.99
Total number of office workers** (c_empl)	Permanent office staff + weighted seasonal employees	Calibrated with fsQCA 2.0

*The managers were asked to rate the following statement: "ICTs and e-business can help companies to improve their sales and conditions of sale"

** The total number of office workers is the sum of the permanent office staff and the weighted number of temporary staff employed during the season, calculated by multiplying the number of seasonal employees by 0.2, as the usual length of the season is approximately 2.5 months.

4 Empirical Analysis of the Results

As may be seen in Tables 3 and 4, two antecedent combinations are sufficient to lead companies to effect transactions online in the complex solution, while the number rises to three for the parsimonious solution.

Table 3. fsQCA analysis results: Complex Solution

Causal configuration	Raw coverage	Unique coverage	Consistency
c_ed*c_imag*c_empl	0.434561	0.144210	0.802917
c_ed*c_ictk*~c_age*c_imag	0.426842	0.136491	0.829526
Solution coverage: 0.571053			
Solution consistency: 0.800344			

Table 4. fsQCA analysis results: Parsimonious solution

Causal configuration	Raw coverage	Unique coverage	Consistency
c_ed*c_imag*c_empl	0.434561	0.144210	0.802917
c_ictk*~c_age*c_imag	0.438947	0.041930	0.821135
c_ed*c_ictk*~c_age*~c_empl	0.318246	0.012807	0.750517
Solution coverage: 0.595965			
Solution consistency: 0.771344			

Focusing on the complex solution results, the antecedent combination corresponding to a high educational level and positive view of ICTs on the part of the manager and a high number of office employees explains 43.46% of the decisions to use e-business to effect commercial transactions (raw coverage).Moreover, this combination has a consistency value of 0.829526 and taken alone explains 14.42% of the decisions to adopt the e-business channel (unique coverage).

The second antecedent combination in importance is that of the manager's high educational level, ICT knowledge, positive view of ICTs and not being of advancedage. This combination has a raw coverage of 0.426842 and a unique coverage of 0.136491(13.65% of decisions to use e-business are explained by this causal combination), with a consistency of 0.829526.

The solution – the set of antecedent combinations or causal configurations indicated by the fsQCA method – presents 0.571053 coverage and a consistency of 0.800344.Consequently, this solution explains 57.11% of the decisions to effect commercial transactions online. Equally, these causal combinations explain 80.03% of the sample's decisions to use e-business channels.

5 Conclusions

Based on the results shown in section 4, the five hypotheses set out in section 2 may be accepted. In other words, the Spanish organic olive oil-producing companies' decision to sell online is closely linked to characteristics of the manager (age, educational level, ICT knowledge and view of the benefits of ICTs) and to the number of employees available in the office.

This supports the findings of previous research conducted within the upper echelon theory framework, as set out in the arguments for the hypotheses in section 2.

The present study finds that it is the characteristics of Spanish organic olive oil sector companies (small number of office employees, high age of the manager, limited educational background and ICT knowledge and lack of awareness of the advantages of e-business (Medina, 2014)) that are holding back the widespread adoption of e-business in this sector.

Acknowledgements. The authors thank Mary Georgina Hardinge for translating the manuscript into English.

References

Aubert, P., Caroli, E., Roger, M.: New technologies, organization and age: firm-level evidence. The Economic Journal **116**(509), 73–93 (2006)

Beckinsale, M., Levy, M.: SMEs and Internet adoptionstrategy: Who do SMEs listen to? In: Twelfth EuropeanConference on Information Systems. Finland (2004)

Benito, S., Platero, M.: Las microempresas en tiempos decrisis: análisis de la formación, experiencia y la innovación. REVESCO Revista de Estudios Cooperativos **108**, 7–38 (2012)

Bharadwaj, A.S.: A resource-based perspective on information technology capability and firm performance: anempiricalinvestigation. MIS Quarterly **24**(1), 169–196 (2000)

Black, S.E., Lynch, L.M.: How to compete: The impact of workplace practices and information technology on productivity. The Review of Economics and Statistics **83**(3), 434–445 (2001)

Chan, C., Swatman, P.: From EDI to Internet commerce: the BHP Steel experience. Internet Research: Electronic Networking Applications and Policy **10**(1), 72–82 (2000)

Chu, H.: Information technology and the demand for educated workers: disentangling the impacts of adoption versus use. The Review of Economics and Statistics **85**(1), 1–8 (2003)

Cooper, R.B., Zmud, R.W.: Information technology implementation research: a technological diffusion approach. Management Science **36**(2), 123–139 (1990)

Coviello, N., Martin, K.: Internationalization of service SMEs: An Integrated perspective from the engineering consulting sector. Journal of International Marketing **7**(4), 42–66 (1999)

Cragg, P., King, M.: Small firm computing: motivators and inhibitors. MIS Quarterly **17**(1), 47–60 (1993)

Dellarocas, C., Gao, G., Narayan, R.: Are consumers more likely to contribute online reviews for hit or niche products? Journal of Management Information Systems **27**, 127–158 (2010)

Dholakia, R.R.: TLC Adoption Among Small Businesses in the United States, Research Report: Research Institute for Telecommunications and Information Marketing (RITIM). The University of Rhode Island, Kingston, R.I (1995)

Dholakia, R.R., Kshetri, N.: Factors impacting the adoption of the Internet among SME's. Small Business Economics **23**, 311–322 (2004)

Doherty, N., Ellis-Chadwick, F., Hart, C.: An analysis ofthe factors affecting the adoption of the Internet in the UK retailsector. Journal of Business Research **55**, 887–897 (2003)

European Commission (1999) What do Europeans think about the environment? Eurobarometer. http://ec.europa.eu/environment/archives/barometer/pdf/barometer_en.pdf, December 5, 2013

González, L., Cobo, F.B.: Agricultura ecológica en España. Las estrechas claves para el éxito. Distribución y Consumo **51**, 39–55 (2000)

González, J.L., Peña, I.: Determinantes de la capacidad deinnovación de los negocios emprendedores en España. Economía Industrial **363**, 129–147 (2007)

Hambrick, D.C., Mason, P.A.: Upper echelons: the organizationas a reflection of its managers. Academy of Management Review **9**, 193–206 (1984)

Hollenstein, H.: Determinants of the adoption of information and communication technologies (ICT). An empirical analysis based onfirm-level data for the Swiss business sector. Structural change and Economic dynamics **15**(3), 315–342 (2004)

Iacovou, C.L., Benbasat, I., Dexter, A.: Electronic datainter change and small organizations: adoption and impact oftechnology. MIS Quarterly **19**(4), 446–485 (1995)

Ibrahim, A.B.: Strategy type and small firm's performance: An empirical investigation. Journal of Small Business Strategy **4**(1), 13–22 (1993)

Karake, Z.A.: Information technology performance: Agency and upper echelon theories. Management Decision **33**(9), 30–37 (1995)

Khan, A.M., Manopichetwattana, V.: Innovative and noninnovative small firms types and characteristics. Management Science **35**, 597–606 (1989)

Kim, M., Jee, K.Y.: Factors influencing strategic use of information technology and its impact on business performance of SMEs. ETRI Journal **29**(4), 497–506 (2007)

Lasch, F., Leroy, F., Yami, S.: Critical growth factors of ICT start-ups. Management Decision **45**(1), 62–75 (2007)

Lefebvre, E., Lefebvre, L.: Factors affecting adoption, In: Information and Telecommunication Technologies: The Impact of Their Adoption on Small and Medium-sized Enterprises, IDRC (1996). http://www.idrc.ca/books/focus/807

Levenburg, N., Magal, S.R., Kosalge, P.: An exploratory investigation of organizational factors and e-Business motivations among SMFOEs in the US. Electronic Markets **16**(1), 70–84 (2006)

Levy, M., Powell, P., Worrall, L.: Strategic intent and ebusiness in SMEs: enablers and inhibitors. Information Resources Management Journal **18**(4), 1–20 (2005)

Magrama ¿Quién es quién en la agricultura ecológica?: Directorio de empresas elaboradoras y comercializadoras de productos ecológicos. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid, España (2007)

MAGRAMA.: Marketing y alimentos ecológicos. Manual de aplicación a la venta detallista. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid, España (2009)

Matlay, H., Addis, M.: Adoption of ICT and e-commerce in small businesses: an HEI-based consultancy perspective. Journal of Small Business and Enterprise Development **10**(3), 321–335 (2003)

McCole, P., Ramsey, E.: A profile of adopters and non-adoptersofe Commerce in SME professional service firms. Australian Marketing Journal **13**(1), 36–48 (2005)

Medina, M.J.: Análisis de la gestión de las tecnologías de la información y comunicación en el sector del aceite de oliva ecológico. PhD Thesis. Universidad de Jaén (2014)

Mehrtens, J., Cragg, P.B., Mills, A.M.: A model of Internet adoption by SMEs. Information & Management **39**, 165–176 (2001)

Miller, D., Toulouse, J.: Strategy structure, CEO personality and performance in small firms. American Journal of Small Business **10**(3), 47–62 (1986)

Nguyen, T.D., Barret, N.J.: The adoption of the Internet byexport firms in transitional markets. Asia Pacific Journal of Marketing and Logistic **18**(1), 29–42 (2006)

Pereda, J.M.: Factores relevantes en la adopción de lainformación por la pyme española. Economía Industrial **334**, 45–54 (2000)

Pinsonneault, A., Rivard, S.: Information technology and thenature of managerial work: from the productivity paradox to theIcarusparadox. MIS Quarterly, 287–311, Septiembre 1998

Poon, S., Swatman, P.: An exploratory study of small business Internet commerce issues. Information and Management **35**(1), 9–18 (1999)

Ragin, C.C.: The comparative method: moving beyond qualitative and quantitative strategies. University of California Press, Berkeley (1987)

Ragin, C.C.: Redesigning social inquiry: fuzzy sets and beyond. University of Chicago Press, Chicago (2008)

Ragin, C.C., Rihoux, B.: Qualitative comparative analysis (QCA): state of the art and prospects. Qualitative Methods **2**(2), 3–13 (2004)

Ragin, C.C., Shulman, D., Weinberg, A., Gran, B.: Complexity, generality and qualitative comparative analysis. Field Methods **15**(4), 323–340 (2003)

Roitner-Schobesberger, B., Darnhofer, I., Somsook, S., Vogl, C.R.: Perceptions of organic foods in Bangkok. Thailand. Food Policy **33**, 112–121 (2008)

Sadowski, B.M., Maitland, C., VanDonden, J.: Strategicuse of the Internet by small and medium sized companies: anexploratory study. Information Economics and Policy **14**, 75–93 (2002)

Santhanam, R., Hartono, E.: Issues in linking information technology capability to performance. MIS Quarterly **27**(1), 125–153 (2003)

Schaack, D., Willer, H.: Development of the organic market in europe. In: Wuiller, H., Kilcher L. (eds.) The World of Organic Agriculture, Statistics and Emerging Trends FiBL and IFOAM, Frick and Bonn, Chapter 8, pp. 141–144 (2010)

Thong, J., Yap, C.S.: CEO characteristics, organizational characteristics and information technology adoption in small business. Omega International Journal of Management Science **23**(4), 429–442 (1995)

Thong, J., Yap, C.S.: Information technology adoption by small business: an empirical study. In: Kautz, K.Y., Pries-Heje, J. (eds.) Diffusion and adoption of information technology, pp. 160–175. Chapman & Hall, London (1996)

Vadapalli, A., Ramamurthy, K.: Business use of the Internet:an analytical framework and exploratory case study. International Journal of Electronic Commerce **2**(2), 57–69 (1997)

Verheul, I., Wennekers, S., Audretsch, D., Thurik, R.: An eclectic theory of entrepreneurship: policies, institutions andculture. Entrepreneurship: Determinants and Policy in a European-US Comparison, 11–81 (2002)

Walczuch, R., Braven, G., Lundgren, H.: Internet adoption barriers for small firms in the Netherlands. European Management Journal **18**(5), 561–571 (2000)

Wang, S., Cheung, W.: E-business adoption by travel agencies: prime candidates for mobile e-business. International Journal of Electronic Commerce **8**(3), 43–63 (2004)

Wei, C., Zhang, C., Sutanto, J.: The influence of user interaction and participation in social media on the consumption intention of niche products. Information and Management **50**, 661–672 (2013)

Willer, H., Yussefi, M.: Influences of pesticide residue and environmental concerns on organic food preferences among food cooperative members and non-members. Journal of Nutrition Education **26**, 26–33 (2004)

Willer, H., Lernoud, J., Kilcher, L.: The World of Organic Agriculture, Statistics & Emerging Trends 2013. The World of Organic Agriculture, BioFach, Nuremberg (Germany), February (2013)

Woodside, A.G., Zhang, M.: Identifying x-consumers using causal recipes: “Whales” and “jumbo shrimps” casino gamblers. Journal of Gambling Studies **28**(1), 13–26 (2012)

The Complexity of Cyber Attacks in a New Layered-Security Model and the Maximum-Weight, Rooted-Subtree Problem

Geir Agnarsson[1], Raymond Greenlaw[2], and Sanpawat Kantabutra[3(✉)]

[1] Department of Mathematical Sciences, George Mason University Fairfax, Fairfax, VA 22030, USA
geir@math.gmu.edu

[2] Cyber Security Studies, United States Naval Academy Annapolis, Annapolis, MD 21402, USA
greenlaw@usna.edu

[3] The Theory of Computation Group Computer Engineering Department, Chiang Mai University, Chiang Mai 50200, Thailand
sanpawat@alumni.tufts.edu

Abstract. This paper makes three contributions to cyber-security research. First, we define a model for cyber-security systems and the concept of a *cyber-security attack* within the model's framework. The model highlights the importance of *game-over components*—critical system components which if acquired will give an adversary the ability to defeat a system completely. The model is based on systems that use defense-in-depth/layered-security approaches, as many systems do. In the model we define the concept of *penetration cost*}, which is the cost that must be paid in order to break into the next layer of security. Second, we define natural decision and optimization problems based on cyber-security attacks in terms of doubly weighted trees, and analyze their complexity. More precisely, given a tree T rooted at a vertex r, a *penetrating cost* edge function c on T, a *target-acquisition* vertex function p on T, the attacker's *budget* and the *game-over threshold* $B, G \in Q^+$ respectively, we consider the problem of determining the existence of a rooted subtree T' of T within the attacker's budget (that is, the sum of the costs of the edges in T' is less than or equal to B) with total acquisition value more than the game-over threshold (that is, the sum of the target values of the nodes in T' is greater than or equal to G). We prove that the general version of this problem is intractable. We also analyze the complexity of three restricted versions of the problems, where the penetration cost is the constant function, integer-valued, and rational-valued among a given fixed number of distinct values. Using recursion and dynamic-programming techniques, we show that for constant penetration costs an *optimal* cyber-attack strategy can be found in polynomial time, and for integer-valued and rational-valued penetration costs *optimal* cyber-attack strategies can be found in pseudo-polynomial time. Third, we provide a list of open problems relating to the architectural design of cyber-security systems and to the model.

Keywords: Cyber security · Defense-in-depth · Game over · Information security · Layered security · Weighted rooted trees · Complexity · Polynomial time · Pseudo-polynomial time

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 64–76, 2015.
DOI: 10.1007/978-3-319-22204-2_6

1 Introduction

Cyberspace has become a new frontier that comes with new opportunities, as well as new risks. According to a 2012 study of US companies, the occurrence of cyber attacks has more than doubled over a 3-year period while the adverse financial impact has increased by nearly 40 percent [6]. More specifically, US organizations experienced an average of 50, 72, and 102 successful attacks against them per week in 2010, 2011, and 2012, respectively. In [15] a wide range of cyber-crime statistics are reported, including locations of attacks, motivation behind attacks, and types of attacks. The number of cyber attacks is increasing rapidly, and for the month of June 2013, 4% of attacks were classified as cyber warfare, 8% as cyber espionage, 26% as hacktivism, and 62% as cybercrime (see [15]). Over the past couple of years these percentages have varied significantly from month-to-month. In order to respond to cyber attacks, organizations have spent increasing amounts of time, money, and energy at levels that are now becoming unsustainable. Despite the amounts of time, money, and energy pouring into cyber security, the field is still emerging and widely applicable solutions to the problems in the field have not yet been developed.

A secure system must defend against all possible cyber attacks, including zero-day attacks that have never been known to the defenders. But, due to limited resources, defenders generally develop defense systems for the attacks that they do know about. Their systems are secure to known attacks, but then become insecure as new kinds of attacks emerge, as they do frequently. To build a secure system, therefore, requires first principles of security. "In other words, we need a *science of cyber security* that puts the construction of secure systems onto a firm foundation by giving developers a body of laws for predicting the consequences of design and implementation choices" [13]. To this end Schneider called for more models and abstractions to study cyber security [13]. In his article Schneider suggested building a science of cyber security from existing areas of computer science. In particular, he mentioned formal methods, fault-tolerance, cryptography, information theory, game theory, and experimental computer science. All of these subfields of computer science are likely to be valuable sources of abstractions and laws.

Cyber security presents many new challenges. Dunlavy et al. discussed what they saw as some of the major mathematical problems in cyber security [7].One of the main challenges is modeling large-scale networks using explanatory and predictive models. Naturally, graph models were proposed. Some common measures of a graph that such a model would seek to emulate are distribution over the entire graph of vertex in-degrees and out-degrees, graph diameter, com- munity structure, and evolution of any of the mentioned measures over time [4]. Pfleeger discussed a number of useful cyber-security metrics [11]. She introduced an approach to cyber-security measurement that uses a multiple-metrics graph as an organizing structure by depicting the attributes that contribute to overall security, and uses a process query system to test hypotheses about each of the goals based on metrics and underlying models. Rue, Pfleeger, and Ortiz developed a model-evaluation framework that involves making explicit each model's assumptions, required inputs, and applicability conditions [12].

Complexity science, which draws on biological and other natural analogues, seems underutilized, but perhaps is one of the more-promising approaches to understanding problems in the cyber-security domain [3]. Armstrong, Mayo, and Siebenlist suggested that models of complex cyber systems and their emergent behavior are needed to solve the problems arising in cyber security [3]. Addition- ally, theories and algorithms that use complexity analysis to reduce an attacker's likelihood of success are also needed. Existing work in the fields of fault tolerance and high-reliability systems are applicable too. Shiva, Roy, and Dasgupta proposed a cyber-security model based on game theory [14]. They discovered that their model works well for a dynamically-changing scenario, which often occurs in cyber systems. Those authors considered the interaction between the attacks and the defense mechanisms as a game played between the attacker and the defender.

This paper is our response to the call for more cyber-security models in [13]. This work also draws attention to the importance of designing systems that do not have *game-over components*—components that are so important that once an adversary has taken them over, one's system is doomed. Since, as we will see, such systems can be theoretically hacked fairly efficiently. We model (many known) security systems mathematically and then discuss their vulnerabilities. Our model's focus is on systems having layered security; each security layer possesses valuable assets that are kept in *containers* at different levels. An attacker attempts to break into these layers to obtain assets, paying penetration costs along the way in order to break in, and wins if a given game-over threshold is surpassed before the attacker's budget runs out. A given layer of security might be, for example, a firewall or encryption. The associated cost of bypassing the firewall or encryption is the penetration cost that is used in the model. We formalize the notion of a cyber attack within the framework of the model. For a number of interesting cases we analyze the complexity of developing cyber attack strategies.

The outline of this article is as follows. In Section 2 we define the model for cyber-security systems, present an equivalent weighted-tree view of the model, and define natural problems related to the model. A general decision problem (Game-Over Attack Strategy, Decision Problem GOAS-DP) based on the model is proved NP-complete in Section 3; its corresponding optimization problem (GOAS-OP) is NP-hard. In Sections 4, 5, and 7 we provide a polynomial-time algorithm for solving GOAS-OP when penetration costs are constant, a pseudo- polynomial-time algorithm for solving GOAS-OP when penetration costs are integers, and when penetration costs are rational numbers from a prescribed finite collection of possible rational costs, respectively. In Section 6 we provide a pseudo-polynomial-time algorithm for solving an optimization problem on general weighted non-rooted trees. Conclusions and open problems are discussed in Section 8.

2 Model for Cyber-Security Systems

2.1 Basic Setup

When defining our cyber-security game-over model, we need to strike a balance between simplicity and utility. If the model is too simple, it will not be useful to provide insight into real situations; if the model is too complex, it will be cumbersome to apply, and we may get bogged down in too many details to see the forest from the trees. In consultation with numerous cyber-security experts, computer scientists, and others, we have come up with a good compromise for our model between ease-of-use and the capability of providing useful insights.

Many systems contain layered security or what is commonly referred to as *defense-in-depth*, where valuable assets are hidden behind many different layers or secured in numerous ways. For example, a *host-based defense* might layer security by using tools such as signature-based vendor anti-virus software, host-based systems security, host-based intrusion-prevention systems, *host-based firewalls*, encryption, and restriction policies, whereas a *network-based defense* might provide defense-in-depth by using items such as web proxies, intrusion-prevention systems, firewalls, router-access control lists, encryption, and filters [9]. To break into such a system and steal a valuable asset requires that several levels of security be penetrated. Our model focuses on this layered aspect of security and is intended to capture the notion that there is a cost associated with penetrating each additional level of a system and that attackers have finite resources to utilize in a cyberattack. We also build in the concept of critical game-over components.

2.2 Definition of the Cyber-Security Game-Over Model

Let $N = \{1, 2, 3, ...\}$, Q be the rational numbers, and Q^+ be the positive rational numbers. With the intuition provided in the previous section in mind, we now present the formal definition of the model.

Definition 1. A *cyber-security game-over modelM*is a six-tuple(T, C, D, L, B, G), where

1. The set $T = \{t_1, t_2, . . . , t_k\}$is a collection of targets, where $k \in N$. The value k is the number of targets. Corresponding to each targett_i, for$1 \leq i \leq k$, is an associated target acquisition value$v(t_i)$, where $v(t_i) \in Q$. We also refer to the target acquisition value as the acquisition value for short, or as the reward or prize
2. The set $C = \{c_1, c_2, . . . , c_l\}$ is a collection of containers, where $l \in N$. The value l is the number of containers. Corresponding to each container c_i, for $1 \leq i \leq l$, is an associated penetration cost $p(c_i)$, where $p(ci) \in Q$.
3. The set $D = \{C_1, C_2, . . . , C_l\}$ is the set of container nestings. The tuple C_i, for $1 \leq i \leq l$, is called the penetration list for container c_i and is a list in left-to-right order of containers that must be penetrated before c_i can be penetrated. If a container $c_i$has an empty penetration list, and its cost $p(c_i)$ has been paid, we say that the container has been penetrated. If a container ci has a non-empty penetration list and each container in its list has been penetrated in left-to-right order, and its cost $p(c_i)$ has been paid, we say that the container has been penetrated. The number of items in the tuple C_i is referred to as the depth of penetration required for C_i. The maximum required penetration depth for a model is the maximum penetration depth required for any container. If container c_j appears in c_i's tuple C_i, we say that

container c_i is dependent on container c_j. If there are no two containers c_i and c_j such that container c_i is dependent on container c_j and container c_j is dependent on container c_i, then we say the model is well-formed.

4. The set $L = \{l_1, l_2, \ldots, l_k\}$ is a list of container names. These containers specify the level-1 locations of the targets. For $1 \leq i \leq k$ if target t_i has level-1 location l_i, this means that there is no other container $\hat{c}$ such that container $\hat{c}$ is dependent on container l_i and container $\hat{c}$ contains target t_i . Target t_i is said to be located at level-1 in container l_i. The target t_i is also said to be located in container l_i or ant container on which container l_i is dependent. When a target's level-1 container has been penetrated, we say that the target has been acquired.
5. The value $B \in Q$ is the attacker's budget. The value represents the amount of resources that an attacker can spend on a cyberattack.
6. The value $G \in Q$ is the game-over threshold signifying when critical components have been acquired

The focus of this paper is on cyber-security game-over models that are well-formed, which are motivated by real-world scenarios. In the next section we introduce a graph-theoretic version of the model using weighted trees.

Remarks: (i) In part 3 of the definition we refer to the cost of a container $c_i$being paid. By this we simply mean that $p(c_i)$ has been deducted from the remaining budget, B', and we require that $B' - p(c_i) \geq 0$. (ii) In part 4 of the definition we maintain a general notion of containment for targets by specifying the inner-most container in which a target is located. Although containers can have partial overlap, we require that the inner-most container be unique. In the next definition we formalize the notion of a *cyber-security attack strategy*.

Definition 2. A cyber-security attack strategy in a cyber-security game-over model M is a list of containers $c_1, c_2, \ldots, c_r$ from M. The cost of an attack strategy is $\sum_{i=1}^{r} \boldsymbol{p(c_i)}$A valid attack strategy is one in which the penetration order is not violated. A game-over attack strategy in a cyber-security game-overmodel M is a valid attack strategy $c_1, c_2, \ldots, c_r$ whose cost is less than or equal to B and whose total target acquisition value $\sum_{i=1}^{r} v(t_i) \geq G$We call such a game-over attack strategy in a cyber-security game-over model a (successful)*cyber-security attack* or *cyberattack* for short.

Note that this notion of a cyberattack is more general than some, and, for example, espionage would qualify as a cyberattack under this definition. The definition does not require that a service or network be destroyed or disrupted. Since many researchers will think of Definition 1 from a graph-theory point of view, in the next section we offer that perspective. As we will soon see, the graph-theoretic perspective allows us to work more easily with the model mathematically and to relate to other known results.

2.3 Game-Over Model in Terms of Weighted Trees

In this section we describe the (well-formed) game-over model in terms of weighted trees. The set D of nested containers in Definition 1 has a natural rooted-tree structure, where each container corresponds to a vertex that is not the root, and we have an edge from a parent u down to a child v if and only if the corresponding container $c(u)$ includes the container $c(v)$ in it. The weight of an edge from a parent to a child represents the cost of penetrating the corresponding container. The weight of a vertex represents the acquisition value/prize/reward obtained by penetrating/breaking into that container.

Sometimes we do not distinguish a target from its acquisition value/prize/reward nor a container from its penetration cost. We can assume that the number of containers and targets is the same. Since if we have a container housing another container (and nothing else), we can just look at this “double” container as a single container of penetration cost equal to the sum of the two nested ones. Also, if a container contains many prizes, we can just lump them all into a single prize, which is the sum of them all. The following is a graph-theoretic version of Definition 1.

Definition 3. A *cyber-security (game-over) model* (CSM) M is given by an ordered five tuple $M = (T, c, p, B, G)$, where T is a tree rooted at r having $n \in N$ non-root vertices, $c : E(T) \rightarrow Q$ is a penetration-cost weight function, $p : V(T) \rightarrow Q$ is the target-acquisition-value weight function, and $B, G \in Q^+$ arethe attacker’s budget and the game-over threshold value, respectively.

Remarks: (i) Note that $V(T) = \{r, u_1, \ldots, u_n\}$, where r is the designated root that indicates the start of an attack. (ii) In most situations we have the weights c and p being non-negative rational numbers, and $p(r) = 0$.

Recall that in a rooted tree T each non-root vertex $u \in V(T)$ has exactly one parent. We let $e(u) \in E(T)$ denote the unique edge connecting u to its parent. For the root r, we let $e(r)$ be the empty set and $c(e(r))$ be 0. For a tree T with $u \in V(T)$, we let $T(u)$ denote the (largest) subtree of T rooted at u. It is easy to see the correspondence between Definitions 1 and 3. Analogously to Definition 2, we next define a *cyber-security attack strategy* in the weighted-tree model.

Definition 4. A *cyber-security attack strategy* (CSAS) in a CSM $M = (T, c, p, B, G)$ is given by a subtree T' of T that contains the root r of T.

- We define the cost of a CSAS T' to be $c(T') = \sum_{u \in V(T')} c(e(u))$.
- We define a valid CSAS (VCSAS) to be a CSAS T' with $c(T') \leq B$.
- We define the prize of a CSAS T' to be $p(T') = \sum_{u \in V(T')} p(u)$.

A game-over attack strategy (GOAS) in a CSM $M = (T, c, p, B, G)$ is a VCSAS T' with $p(T') \geq G$. We sometimes refer to such a GOAS simply as a cyber-security attack or cyberattack for short.

Note that in Definition 4 we use $c(p)$ to denote the total cost (respectively, total prize) of a cyber-security attack strategy. We also use $c(p)$ as the penetration- cost weight function (respectively, target-acquisition-value weight function). The overloading of this notation should not cause any confusion. Throughout the remainder of the paper, we will use Definitions 3 and 4.

2.4 Cyber-Attack Problems in the Game-Over Model

We now state some natural questions based on the CSM.

Problem 1. Given: A cyber-security model $M = (T, c, p, B, G)$.

- Game-Over Attack Strategy, Decision Problem (GOAS-DP): Is there a game-over attack strategy in M?
- Game-Over Attack Strategy, Optimization Problem (GOAS-OP): What is the maximum prize of a valid game-over attack strategy in M?

Needless to say, some special cases are also of interest, in particular, in Problems 1 when c is (i) a constant rational function, (ii) an integer-valued function, or (iii) takes only finitely many given rational values. We explore the general GOAS and these other questions in the following sections.

2.5 Some Limitations of the Model

Our model is a theoretical model. It is designed to give us a deeper understanding of cyber attacks and cyber-attack strategies. Of course, a real adversary is not in possession of complete knowledge about a system and its penetration costs. Nevertheless, it is interesting to suppose that an adversary is in possession of all of this information, and then to see what an adversary is capable of achieving under these circumstances. Certainly an adversary with less information could do no better than our fully informed adversary.

We are considering systems as they are. That is, we are given some system, targets, and penetration costs. If the system is a real system, we are not concerned about how to improve the security of that system per se. We assume that the system is already in a hardened state. We then examine how difficult it would be to attack such a system. We do not examine the question of implementations of a system. Our model can be used on any existing system. Some real systems will have more than one possible path to attack a target. And, in the future it may be worth generalizing the model to structures other than trees. The first step is to look at trees and derive some insight from these cases.

We have purposely chosen a target acquisition function which is simple. That is, we merely add together the total costs of the targets acquired. Studying this simple acquisition function is the first step. It may be interesting to study more- complex acquisition functions in the future. For example, one can imagine two targets that in and of themselves are of no real value, but when the information contained in the two are combined they are of great value. In some cases our additive function can capture this type of target depending on the structure of the model.

We describe the notion of a game-over component. In the model this concept is an abstract one. A set of components whose total value exceeds a given threshold comprise a "game-over component." A game-over component is not necessarily a single target although one can think of a high-cost target, which is included as a target in a set of targets that push us over the game-over threshold, as being the game-over component.

3 Complexity of Cyber-Attack Problems

In this section we show that the general game-over attack strategy problems are intractable, that is, highly unlikely to be amenable to polynomial-time solutions. Consider a cyber-security attack model M, where T is a star centered at r having n leaves $u_1, \ldots, u_n$. Since each cyber-security attack T' of M can be presented as a collection $E \subseteq E(T)$ of edges of T, and hence also as a collection of vertices $V' \subseteq V(T)$ by $T' = T[\{r\} \cup V']$, and vice versa, each collection of vertices $V' \subseteq V(T)$ can be presented as $V' = V(T')$ for some cyber-security attack T' of M, the GOAS-DP is exactly the decision problem of the 0/1- Knapsack Problem, and the GOAS-OP is the optimization problem of the Knapsack Problem. Note that the 0/1-Knapsack Problem is usually stated using natural numbers as weights, but clearly the case for weights consisting of rational numbers is no easier to solve yet still in NP. So, we have the following observation.

Observation 1. *The* GOAS-DP *is NP-complete; the* GOAS-OP *is an NP-hard optimization problem.*

Remark: Observation 1 answers an open question in the last section of [10], where it is asked whether or not the LST-Tree Problem can be solved in polynomial time (we presume) for general edge lengths. Observation 1 is similar to [5, Theorem 2], where also a star is considered to show that their SUBTREEE is as hard as KNAPSACK.

Notice that the NP-completeness of GOAS-DP is a double-edge sword. It suggests that even an attack who has detailed knowledge of the defenses of a cyber-security system would find the problem of allocating his (attack) resources difficult. On the other hand, the NP-completeness also makes it difficult for the defender to assess the security of his system.

4 Cyber Attacks: Constant Penetration Costs

Consider a CSM M, where c is a constant function taking a constant rational value $c(e) = c$ for each $e \in E(T)$. This variant is the first interesting case of the GOAS-DP and GOAS-OP, as there are related problems and solutions in the literature. One of the first papers on maximum-weight subtrees of a given tree with a specific root is [1], where it is shown that the *rooted subtree problem*, that is, to find a maximum-weight subtree with a specific root from a given set of subtrees, is in polynomial time if, and only if, the *subtree packing problem*, that is, to find maximum-weight packing of vertex-disjoint subtrees from a given set of subtrees (where the value of each subtree can depend on the root), is in polynomial time. In more-recent papers the *weight-constrained maximum-density subtree problem* (*WMSP*) is considered: given a tree T having n vertices, and two functions l, w: $E(T) \rightarrow Q$ representing the "length" and "weight" of the edges, respectively, determine the subtree T' of T such that $\sum_{e \in E(T')} w(e) / \sum_{e \in E(T')} l(e)$ is a maximum, subject to $\sum_{e \in E(T')} w(e)$ having a given upper bound. In [8] an $O(w_{max} n)$-time algorithm is given to solve the related, and more restricted, *weight-constrained maximum-density path problem* (WMPP), as well as an $O(w_{max}^2 n)$-time algorithm to solve theWMSP. In [10] an $O(nU^2)$ -time algorithm is given for the WMSP, where U is the maximum total length of the subtree, and in [16] an $O(nU\, lgn)$-time algorithm for the WMSP isgiven, which is an improvement in the case when $U = \Omega(lg\ n)$. The WMSP has a wide range of practical applications. In particular, the related WMPP has applications in computational biology [8], and the related weight-constrained least density path problem (WLPP) also has applications in computational biology, as well as in computer, traffic, and logistic network designs [10].

The WMSP is similar to our problem, and some of the same approaches used in [8], [10], and [16] can be applied in our case, namely the techniques of recursion and dynamic programming. There are not existing results that apply directly to our problems. Note that there is a subtle difference between our GOAS-OP and the WMSP, as a maximum-weight subtree (that is, with the prize $p(T')$a maximum) might have low density and vice versa; a subtree of high density might be "small" with low total weight (that is, prize).

In [5] a problem on trees related to the Traveling Salesman Problem with profits is studied, which is similar to what we do. Both here and in [5] the most general form of the problems considered, in our case GOAS-DP in Observation 1 and in their case (as mentioned above) Subtree E in [5, Theorem 2], are observed to be as hard as Knapsack and hence NP-complete. Also, the results of fixed costs, in our case Theorem 1 and in their case [5, Theorem 3], the problems are shown to be solvable in $O(n)$ time, given certain conditions. Theorem 1, however, provides a precise accounting for the time complexity and for certain values of m, defined there, our algorithm would be faster than that given in [5]. Their work is not in the context of cyber-security, and does not handle cases as general as this work. For a CSM M, where c is a constant function, we first note that T' is a VCSAS if and only if$m = |E(T')| \leq \lfloor B/c \rfloor$. Hence, in this case the GOAS-OP reduces to finding a CSAS T' with at most m edges having $p(T')$ at a maximum. Note that if $m \geq n$, then the GOAS-OP is trivial since $T' = T$is the optimal subtree. Hence, we will assume the budget B is such that $< n$.

We may assume that our rooted tree T has its vertices ordered from left-to-right in some arbitrary but fixed order, that is, $T$is a planted plane tree. Since T has $n \geq 1$ non-root vertices and $n + 1$ vertices total, we know by a classic counting exercise [2] that the number of planted plane trees on $n + 1$ vertices is given by the Catalan bers,$C_n = \frac{1}{n+1}\binom{2n}{n}$ by obtaining a defining recursion for C_n by decomposing each planted plane tree into two rooted subtrees. Using this decomposition, we introduce some notation. For a subtree τ of T rooted at $u \in V(T)$ denote by $\tau(v)$ the largest subtree of τ that is rooted at a vertex v (if $v \in T[V(\tau)]$). Denote by $u\ell$ the leftmost child of u in τ (if it exists). Let $\tau\ell = \tau(u\ell)$ denote the subtree of τ generated by $u\ell$, that is, the largest subtree of T rooted at $u\ell$. Finally, let $\tau'' = \tau - V(\tau\ell) = T[V(\tau) \backslash V(\tau\ell)]$ denote the subtree of τ generated by the vertices not in $\tau\ell$. In this way we obtain a decomposition/partition of the planted plane tree τ into two vertex-disjoint subtrees $\tau\ell$ and τ'' whose roots are connected by a single edge $e(u\ell)$. We can then establish the following lemma and theorem. All proofs in this paper are omitted due to space limitations, but can be found in our full manuscript [17].

Lemma 2. *The arbitrary subtree τ rooted at u is a maximum-prize subtree with at most k edges that contains the leftmost child uℓ of u if and only if the included subtree of τℓ is a maximum-prize subtree with at most i − 1 edges rooted at uℓ and the included subtree of τ" is a maximum-prize subtree with at most k – iedges rooted at u for some* $i \in \{1, \ldots, k\}$.

Theorem 1. If *M* = (*T*, *c*, *p*, *B*, *G*) *is a CSM, where T has n vertices, c is a constant function, and* $m = \lfloor B/c \rfloor$ *then the* GOAS-OP *can be solved in* $O(m^2n)$*-time*.

Remarks: (i) Note that Theorem 1 is similar to [5, Theorem 3]. (ii) Also note that our overhead constant is "small."

5 Cyber Attacks with Integer Penetration Costs

In this section we show that if all penetration costs are non-negative integers then the Game-Over Attack Strategy Problems can be solved in pseudo- polynomial time.

Theorem 2. *IfM* = (*T*, *c*, *p*, *B*, *G*) *is a CSM, where T has n vertices and* $c : E(T) \to N$ *takes only positive-integer values, then the* GOAS-OP *can be solved in* $O(B^2n)$*-time*

Remark: (i) Although we are not able to obtain a compact expression for the exact number of arithmetic operations that yield Theorem 2, the bound $N(n, B) = 2(n - 1)B^2$ still is an upper bound, as for Theorem 1. (ii) Note the assumption that *c* is an integer-valued cost function is crucial, since otherwise, we would not have been able to use the recursion in at most *B* steps.

6 General Weighted Trees

In our framework a CSM *M* is presented as a rooted tree provided with two weight functions: one on the vertices and one on the edges. In the model the root serves merely as a starting vertex and does not (usually) carry any weight (that is, has no prize attached to it). However, given a general non-rooted tree *T* provided with two edge-weight functions *w*, *w'* : $E(t) \to Q$, we can always add a root to some vertex and then push the weights of one of the weight functions, say w down to the unique vertex away from the root. In this way we obtain a CSM *M* to which we can apply both Theorems 1 and 2. With this slight modification, we have the following corollary for general weighted trees.

Corollary 1. *Let T be a tree on n vertices, w, w': E(T) → Q two edge-weight functions, and B, G two rational numbers. If the function w is either (i) a rational constant* $c \in Q$ *or (ii) integer-valued, then the existence of a subtree T' of T such that* $w'(T') \leq B$ *and* $w(T')$ *is a maximum can be determined in* $O(m^2n)$*- time, where* $m = \lfloor B/c \rfloor$ *in case (i), and in* $O(B^2\ n)$*-time in case (ii).*

7 Cyber Attack: Rational Penetration Costs

In this section we consider the more-general case of a CSM $M = (T, c, p, B, G)$ where the cost function $c : E(T) \to Q$ takes at most d distinct rational values, say $c_1, \ldots, c_d \in Q$. This case can model quite realistic scenarios, as there are currently only a finite number of known encryption methods and cyber-security designs, where a successful hack for each method/design has a specific penetration cost. The proof of the following theorem requires two pages and is omitted due to space limitations.

Theorem 3. *If* $M = (T, c, p, B, G)$ *is a CSM where* T *has* n *vertices,* $m = \lfloor B/c \rfloor$, *and* $c : E(T) \to Q$ *takes at most d distinct rational values, then the* GOAS-OP *can be solved in* $O(m^{2d}n)$*-time.*

Remarks: (i) Note that when $d = 1$, and hence $c_1 = c$, then m in Theorem 3 is given by$m = m_1 = \min(\lceil B'/c_1 \rceil, n) = \min(\lceil B/c \rceil + 1, n)$, whereas in Theorem 1 $m = \lceil B/c \rceil = min(\lceil B/c \rceil, n)$, by the assumption that $\lceil B/c \rceil \leq n$. Still, the complexity when $d = 1$ in Theorem 3 clearly agrees with the complexity of $O(m^2 n)$ for solving the GOAS-OP when c is a constant function in Theorem 1. (ii) If each$m_i = O(f(n))$, for some "slow-growing" function of n, then Theorem 3 yields an $O(nf(n)^{2d})$-time algorithm for solving the GOAS-OP. In particular, if each $m_i = O(1)$, then Theorem 3 yields a linear-time in n algorithm to solve the GOAS-OP.

8 Summary and Conclusions

This paper defined a new cyber-security model that models systems which are designed based on defense-in-depth. Table 1 summarizes the results.

Table 1. Summary of results about the cyber-security model contained in the paper. Note that in the table "pc" stands for "penetration cost," and "pseudo-pt" stands for pseudo-polynomial time. The values of *m*, *n*, *B*, and dare as given in the respective theorems.

ProblemName	Time	Class
GOAS-DP	–	NP-complete
GOAS-OP	–	NP-hard
GOAS-DPconstantpc	$O(m^2 n)$	P
GOAS-OPconstantpc	$O(m^2 n) O(B^2$	P
GOAS-DPinteger pc	$n) O(B^2 n)$	pseudo-pt
GOAS-OPinteger pc	$O(m^{2d} n)$	pseudo-pt
GOAS-DPrationalpc	$O(m^{2d} n)$	pseudo-pt
GOAS-OPrationalpc		pseudo-pt

These results suggest that in a real system the penetration costs should vary, that is, although each level should be difficult to attack, the cost of breaking into some levels should be even higher. The tree representation of the models suggests that systems should be designed to distribute targets in a bushy tree, rather than in a narrow tree. Most security systems are linear, and such systems could be strengthen by distributing targets more widely, providing defense-in-deception. Although in most situations a cyber attacker will not a priori known exact pen- etration costs, target locations, and prizes, the model still gives us insight into which types of security designs would be more effective.

We conclude the paper with a number of open questions.

1. Can we quantify how much targets need to be distributed in order to maximize security?
2. If targets are allowed to be repositioned periodically, what does that do to the complexity of the problems, and what is the best movement strategy for protecting targets?
3. Can the notion of time and intrusion detection be built into the model?
4. Are there online variants of the model that are interesting to study?

References

1. Aghezzaf, E.H., Magnanti, L.T., Wolsey, A.L.: Optimizing Constrained Subtrees of Trees. Mathematical Programming **71**(2), 113–126 (1995). Series A
2. Agnarsson, G., Greenlaw, R.: Graph Theory: Modeling, Applications, and Algorithms. Pearson Prentice Hall, Upper Saddle River (2007)
3. Armstrong, R.C., Mayo, J.R., Siebenlist, F.: Complexity Science Challenges in Cybersecurity. Sandia Report, March 2009
4. Chakrabarti, D., Faloutsos, C.: Graph Mining: Laws, Generators, and Algorithms. ACM Computing Surveys 38(1), article 2, 69 pages (2006)
5. Coene, S., Filippi, C., Spieksma, F., Stevanato, E.: Balancing Profits and Costs on Trees. Networks **61**(3), 200–211 (2013)
6. 2012 Cost of Cyber Crime Study: United States. Ponemon Institute, research report, 29, October 2012
7. Dunlavy, D.M., Hendrickson, B., Kolda, T.G.: Mathematical Challenges in Cybersecurity. Sandia Report, February 2009
8. Hsieh, S.-Y., Chou, Ting-Yu.: Finding a weight-constrained maximum-density subtree in a tree. In: Deng, X., Du, D.-Z. (eds.) ISAAC 2005. LNCS, vol. 3827, pp. 944–953. Springer, Heidelberg (2005)
9. Johnston, R., La Fever, C.,: Hacker.mil, Marine Corps Red Team (Power- Point Presentation) (2012)
10. Lau, H.C., Ngo, T.H., Nguyen, B.N.: Finding a Length- constrained Maximum-sum or Maximum-density Subtree and Its Application to Logistics. Discrete Optimization **3**(4), 385–391 (2006)
11. Pfleeger, S.L.: Useful Cybersecurity Metrics. IT Professional **11**(3), 38–45 (2009)
12. Rue, R., Pfleeger, S.L., Ortiz, D.: A framework for clas- sifying and comparing models of cybersecurity investment to support policy and decision-making. In: Proceedings of the Workshop on the Economics of Information Security, p. 23 (2007)

13. Schneider, F.B.: Blueprint for a Science of Cybersecurity. The Next Wave **19**(2), 47–57 (2012)
14. Shiva, S., Roy, S., Dasgupta, D.: Game theory for cyber security. In: Proceedings of the ACM 6th Annual Cyber Security and Information Intelligence Research Workshop, 34, April 21–23, 2010
15. Sparrows, P.: Cyber Crime Statistics. hackmageddon.com, October 16, 2013
16. Hsin-Hao, S., Lung, C.H., Tang, C.Y.: An Improved Algorithm for Finding a Length-constrained Maximum-density Subtree in a Tree. Information Processing Letters **109**(2), 161–164 (2008)
17. Agnarsson, G., Greenlaw, R., Kantabutra, S.: On cyber attacks and the maximum-weight rooted-subtree problem. Acta Cybernetica (to appear)

Are Problems with Violence and the Lack of Public Safety a Barrier to Entrepreneurship?

Pablo Pinazo-Dallenbach[1], Norat Roig-Tierno[2], and Alicia Mas-Tur[3](✉)

[1] ESIC Business and Marketing School, Madrid, Spain
pablo.pinazo@esic.edu
[2] Polithecnic University of Valencia, Valencia, Spain
horoitie@upv.es
[3] University of Valencia, Valencia, Spain
alicia.mas@uv.es

Abstract. Scholars cite violence as a potential barrier to entrepreneurial activity in El Salvador. Using AHP, this research aims to rank the socioeconomic and political barriers to entrepreneurship in El Salvador. The analysis stresses the importance of citizen security as a barrier to entrepreneurial activity.

Keywords: Entrepreneurship · Barriers · Analytical Hierarchical Process

1 Introduction

Business creation is receiving increasing attention from scholars because of its potential as an engine of the economy and a source of economic growth (Chaston& Scott, 2012).Entrepreneurship is therefore particularly relevant in countries with profiles such as that of El Salvador.

This research identifies the types of barriers that pose problems for El Salvador's entrepreneurs when starting businesses. Specifically, the analysis focuses on two large groups of barriers: socioeconomic barriers and political barriers. These two groups comprise individual criteria that hinder the launching of a business. The criteria all fall into the category of citizen insecurity. Scholars cite violence as a hindrance to entrepreneurial activity. Violence forms a barrier to entrepreneurship because of resulting higher opportunity costs stemming from a lack of investment in fostering and promoting entrepreneurship(Acevedo, 2008).

This paper has the following structure. Following this introduction, the next section briefly examines the entrepreneurship literature, and defines the socioeconomic and social barriers for inclusion in the empirical analysis. The third section describes the Analytic Hierarchy Process (AHP) methodology, pioneered by Saaty in 1980. The AHP then provides the method to perform an analysis of the key barriers to business creation in El Salvador. The final section brings together the results, conclusions, and implication of the research.

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 77–83, 2015.
DOI: 10.1007/978-3-319-22204-2_7

2 Barriers to Entrepreneurship

Focusing on the definition of entrepreneurship, several authors consider business creation a process that begins with identifying and opportunity, continues with a phase of exploration, and culminates in the exploitation of this opportunity (Busenitz *et al.*, 2003). Before starting a business, the entrepreneur embarks on a creative process that is subject to the influence of social, personal, and technological factors. In particular, within the decision-making process, the barriers that the entrepreneur must face in starting his or her business play an important role (Krasniqi, 2007). In keeping with many studies of the barriers facing entrepreneurs when creating a business (Klapper, Laeven, & Rajan, 2006), these barriers form two broad groups: socieonomic and political. These groups comprise the following barriers.Ç

2.1 Socioeconomic Barriers

Education

The education system, as an arena for knowledge transfer, should propagate the cultural values to build the human resources necessary for entrepreneurship (Thornton et al., 2011). Likewise, the education and training on offer in a country must be suitable for the innovation needs of the local economy, accounting for its specific traits. A basic, general education is insufficient. Education must meet the specific needs of the local economy, foster creativity, and encourage the adoption of new technologies (Alburquerque, 2004).Education in El Salvador suffers from a deficiency in quality, unequal access dependent on social class, a high rate of school dropout, and a lack of suitability for the El Salvador labor market (UNDP, 2013).

Culture

The cultural environment, which derives from cultural values, exerts an influence on entrepreneurship (Thornton et al, 2011). The contribution of Hofstede (2003) in the field of entrepreneurship leads to a characterization of culture through four quantifiable dimensions: uncertainty avoidance, masculinity versus femininity, individualism versus collectivism, and power distance. Some researchers indicate that cultures with high levels of masculinity and individualism, but low levels of uncertainty aversion and power distance are conducive to entrepreneurial activity (Thornton *et al.*, 2011). Strong uncertainty avoidance and a low level of individualism are characteristics of El Salvador's culture. This cultural profile may discourage entrepreneurship because such a culture may hinder the undertaking of personal initiatives.

Social Environment

A favorable social environment is an enabler of entrepreneurship: The social context is inextricably linked to entrepreneurial activity in the same way that the flow of all economic exchanges takes place within society (Steyaert, 2007). Owing to their society's collectivistic nature, the citizens of El Salvador enjoy robust social networks. The inhabitants of El Salvador feel they belong to a group in which all citizens support one another, and confidence and loyalty among peers is fundamental. The presence of a medium–high power distance, however, illustrates that only the members of empowered social classes enjoy access to the resources necessary to engage in entrepreneurship. These resources include financial wherewithal, highly qualified human resources, or the social capital necessary to gain access to licenses or permits.

Economic Situation

Following Schumpeterian theory, Audretsch (2012) points out thattwo key elements define entrepreneurial behavior: the capability of identifying or creating an opportunity, and the exploitation of such an opportunity. A suitable economic situation has a growing GDP, which implies a high income level throughout the society and therefore high levels of demand and savings. This latter feature encourages investment (Audretsch, 2012). An economy's stability also leads to a reduction in uncertainty, a situation highly conducive to entrepreneurial activity. An economy in recession, on the other hand, implies high unemployment rates, which increases the rate of ventures stemming from necessity entrepreneurship (Klapper, 2011), whose chances of survival are very low. El Salvador has a low degree of opportunity entrepreneurship and a high degree of necessity entrepreneurship (Xavier et al., 2013).

Financing

Financing is one of the key needs of small business entrepreneurs (Kerr & Nanda, 2011). Hall (2008) identifies financing as one of the main barriers to innovation and growth. The study of this type of measure may therefore serve as a means of clarifying the lack of consensus on the efficacy of policies that provide financing to budding entrepreneurs. Access to capital and financing is paramount for the survival of small and medium-sized enterprises. Without sufficient financial resources, entrepreneurs are unable to develop new products and services, undertake expansion strategies, create jobs, and perform a whole host of other actions that are essential when creating a business (Kerr et al., 2011).

2.2 Political Barriers

Entrepreneurship and Innovation Policy

The need for intervention from public institutions is a consequence of market failures (Baba & HakemZadeh, 2012). A large number of these failures are the result of the young entrepreneurs' difficulties in accessing financial and non-financial resources (Hall, 2008). The use of such policies as a way of supporting new entrepreneurial ventures owes to two of the main barriers to the development of entrepreneurship. The first of these is the shortage of money supply from capital markets. The second is the lack of specific know-how, which suitable advisory services in business creation can mitigate.

Taxes and Regulations

Establishing policies to foster and promote new business initiatives is becoming particularly important for governments. The measures that governments are currently implementing include restricting the tax burden falling upon enterprises, the protection of intellectual property rights, and subsidies for new businesses (Aghion, 2011). In addition, through their policies and measures, governments are also attempting to raise the profile of entrepreneurs such that these key economic actors, as catalysts for economic growth and innovation, garner the acknowledgment they deserve (Van Praag, 2011). According to data from the Hofstede Center, one of the defining traits of El Salvador's culture is uncertainty avoidance. The implication of this finding is that El Salvador's society requires rules and regulations that convey a feeling that everything is under control. Currently, citizens have to deal with large amounts of bureaucracy, which affects entrepreneurial activity.

Citizen Insecurity

Scholars cite violence in Latin America as a barrier to entrepreneurial activity because the costs that relate specifically to violence cause a significant drop in the financial performance of firms in the region (IDB, 2014). El Salvador suffers from violence due to the *maras*(gangs) that are rife throughout the country. An evaluation of insecurity as an additional factor affecting entrepreneurship is therefore clearly necessary. Nevertheless, very few studies address the impact of violent conflicts on the microeconomic level or in entrepreneurship (Brück*et al.*, 2013).

Furthermore, although violence has social connotations and seemingly comes under the category of socioeconomic barriers, citizen security has its roots in politics. The research approach in this study is to consider this aspect from the point of view of citizen securitypolicies. Citizen security policies in settings such as El Salvador may therefore foster the creation of businesses much alike the entrepreneurship or innovation policies that appear in the discussion earlier in this section.

Citizen insecurity requires massive spending on the part of the entrepreneur. Entrepreneurs must invest heavily to safeguard their businesses against the negative effects of violence and to cover the extraordinary costs arising from the consequences of this violence. Following the UNDP's (2013) categorization, this study considers two type of citizen insecurity:

- **Objective insecurity:** Objective insecurity is an estimation about the actual degree of risk that threatens an individual. International convention states that the calculation for objective insecurity homicides/100,000 inhabitants and crimes/100,000 inhabitants (FUNDAUNGO, 2012).
- **Subjective insecurity:** Subjective insecurity is the estimation that each individual makes about the degree of risk that he or she faces in general. This measure of insecurity differs for each individual and derives from personal perceptions. The measure is subject to the influence of numerous rational and irrational factors, examples of which are temperament, experience, prejudice, objective information, and the opinions of others.

Figure 1 shows the model for this study, which is a result of the literature review.

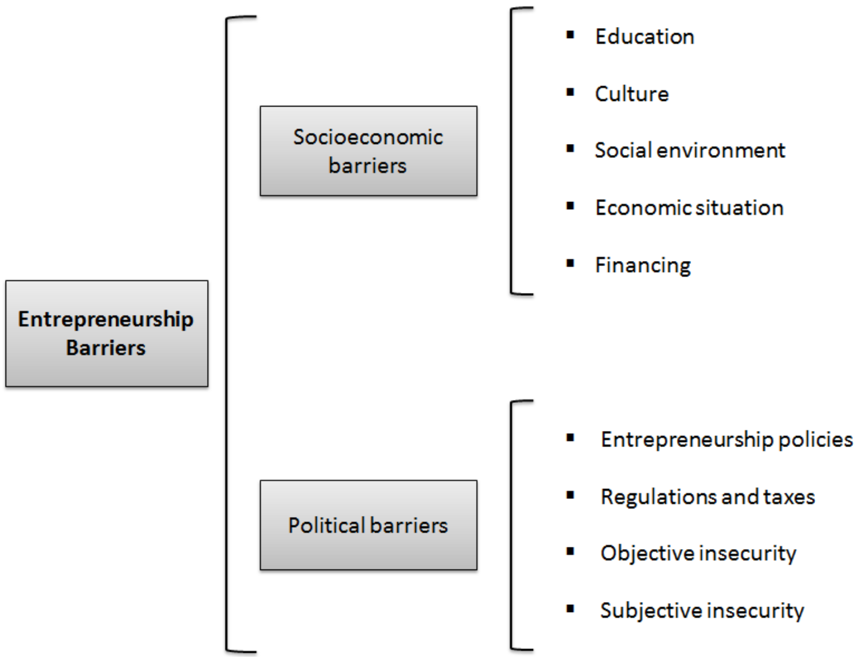


Fig. 1. Model capturing the main barriers to entrepreneurs when creating businesses in El Salvador

3 Methodology and Results

The *Analytical Hierarchy Process* (AHP), which Saatycreated in 1980, consists of defining a hierarchical model. Using pre-defined criteria and alternatives, this model is capable of first representing complex issues and then reaching the best decision possible. This procedure aims to break a complex decision into a series of simpler decisions, thereby facilitating the understanding and solution of the problem. The use of multi-criteria decision models thus allows for the selection, identification, or ranking of barriers to entrepreneurship. The AHP method does not require quantitative information about the alternatives. Instead, this method uses the value judgments of the decision makers. In this study, the experts are top managers of institutions in El Salvador. These institutions include the United Nations Development Program of El Salvador, the Central American University (UCA), the Foundation for Communal Cooperation and Development in El Salvador (CORDES), and the Cross-sector Association for Economic Development and Social Progress (CIDEP).

The AHP methodology admits the inclusion of quantitative variables, as is the case with traditional statistical analysis. In contrast with traditional statistical techniques, however, the AHP method allows for the inclusion of qualitative variables, which are difficult to study with traditional methods. The model under study thus includes factors—such as the current economic situation—that are difficult to measure with other types of analysis but that are measurable, through the opinions of the expert panel. Table 1 shows the results for the variables under study.

Table 1. Results of the AHP

Ranking	Criterion	Sub-criterion	Score
1	B. Socioeconomic (0.740)	Education (0.353)	26.12%
2	B. Socioeconomic (0.740)	Social environment (0.316)	23.38%
3	B. Political (0.260)	Subjective insecurity (0.448)	11.65%
4	B. Socioeconomic (0.740)	Economic situation (0.126)	9.32%
5	B. Socioeconomic (0.740)	Culture (0.125)	9.25%
6	B. Political (0.260)	Objective insecurity (0.337)	8.76%
7	B. Socioeconomic (0.740)	Fianancing(0.080)	5.92%
8	B. Political (0.260)	Entrepreneurship policy (0.124)	3.22%
9	B. Political (0.260)	Regulations and taxes (0.091)	2.38%

The results in Table 1 yield the following conclusions. First, the experts consider the socioeconomic barriers (0.74) much more important than the political barriers (0.26). Second, the sub-criteria that bear relation to education, social environment, and subjective insecurity explain more than 60% of the barriers to business creation in El Salvador.

4 Conclusions

This research aims to rank the barriers to business creation facing entrepreneurs in El Salvador. A review of the literature yields two groups of barriers: socioeconomic and political. The AHP method yields a ranking of the barriers under study (education, culture, social environment, economic situation, financing, entrepreneurship and innovation policies, objective security, and subjective security) according to the importance that experts attribute to each sub-criterion. The key barriers are those that relate to education, social environment, and objective insecurity. These three factors explain 60% of the barriers to business creation in El Salvador.

These results have political implications. Entrepreneurship policies in countries with profiles similar to that of El Salvador should seek to address the key barriers emerging from this analysis. Specifically, to ensure maximum efficacy of efforts to foster entrepreneurship, policymakers should allocate resources to policies that seek to improve education, stabilize the social environment, or reduce subjective insecurity. Public institutions should therefore make a special effort to improve the quality of the nation's education system, creating a system that suits the country's needs. Furthermore, policymakers should enable access to education for all citizens, thereby reducing social inequalities, improving inhabitants' chances of finding employment, and, consequently, minimizing the level of violence in the society.

Clearly, this study is not without limitations. These limitations represent opportunities for future research. The study took place in a region with highly specific traits, which prevents scholars from extrapolating these results to other geographies with different characteristics. In future research, investigators should focus on different regions to evaluate elsewhere the impact of the policies arising from the analysis herein.

References

1. Acevedo, C.: *Los costos económicos de la violencia en Centroamérica*. ObservatorioCentro Americano sobreViolencia (OCAVI) (2008)
2. Aghion, P.: Industrial policy, entrepreneurship and growth. In: Audstrech, D.B., Falck, O., Heblich, S., Lederer, A. (eds.) Handbook of Research on Innovation and Entrepreneurship, pp. 45–54. Edward Elgar Publishing Limited, Cheltenham (2011)
3. Alburquerque, F.: Desarrollo económico local y descentralización en América Latina. Revista de la CEPAL **82**, 157–171 (2004)
4. Audretsch, D.: Entrepreneurship research. Management Decision **50**(5), 755–764 (2012)
5. Baba, V.V., HakemZadeh, F.: Toward a theory of evidence based decision making. Management Decision **50**(5), 832–867 (2012)
6. Brück, T., Naudé, W., Verwimp, P.: Business under Fire Entrepreneurship and Violent Conflict in Developing Countries. Journal of Conflict Resolution **57**(1), 3–19 (2013)
7. Busenitz, L.W., West, G.P., Shepherd, D., Nelson, T., Chandler, G.N., Zacharakis, A.: Entrepreneurship research in emergence: Past trends and future directions. Journal of management **29**(3), 285–308 (2003)
8. Chaston, I., Scott, G.J.: Entrepreneurship and open innovation in an emerging economy. Management Decision **50**(7), 1161–1177 (2012)
9. FUNDAUNGO Violence Atlas in El Salvador(2005-2011). San Salvador, Fundación Dr. Guillermo Manuel Ungo (2012)
10. Hall, B.H.: The financing of innovation. In: Shane, S. (ed.) Blackwell Handbook of Technology and Innovation Management, pp. 409–430. Blackwell Publishers Ltd., Oxford (2008)
11. Hofstede, G.: Culture's consequences: comparing values, behaviors, institutions and organizations across nations. Sage Publications, Newbury (2003)
12. IDB IDB's Response to Key Challenges in Citizen Security, 1998-2012. Inter-American Development Bank (2014)
13. Kerr, W., Nanda, R.: Financing constraints and entrepreneurship. In: Audretsch, D., Falck, O., Heblich, S. (eds.) Handbook on Research on Innovation and Entrepreneurship. Edward Elgar, Cheltenham (2011)
14. Klapper, L., Richmond, C.: Patterns of business creation, survival and growth: Evidence from Africa. Labour Economics **18**, S32–S44 (2011)
15. Klapper, L., Laeven, L., Rajan, R.: Entry regulation as a barrier to entrepreneurship. Journal of Financial Economics **82**(3), 591–629 (2006)
16. Krasniqi, B.A.: Barriers to entrepreneurship and SME growth in transition: the case of Kosova. Journal of Developmental Entrepreneurship **12**(01), 71–94 (2007)
17. Steyaert, C.: 'Entrepreneuring' as a conceptual attractor? A review of process theories in 20 years of entrepreneurship studies. Entrepreneurship & Regional Development **19**(6), 453–477 (2007)
18. Thornton, P.H., Ribeiro-Soriano, D., Urbano, D.: Socio-cultural factors and entrepreneurial activity An overview. International Small Business Journal **29**(2), 105–118 (2011)
19. UNDP Informe sobre Desarrollo Humano El Salvador 2013. Imaginar un nuevo país. Hacerlo posible. Diagnóstico y propuesta. San Salvador: Programa delas Naciones Unidas para el Desarrollo (2013)
20. Van Praag, B.: Well-being inequality and reference groups: an agenda for new research. The Journal of Economic Inequality **9**(1), 111–127 (2011)
21. Xavier, S.R., Kelley, D., Kew, J., Herrington, M., Vorderwülbecke, A.: Global Entrepreneurship Monitor 2012 Global Report. London: Babson College. Universidad delDesarrollo, UniversitiTun Abdul Razak (2013)

The Development of ICTs and the Introduction of Entrepreneurial Capital

Gema Albort-Morant and Andrea Rey-Martí(✉)

University of Valencia, Valencia, Spain
{gema.albort,andrea.rey}@uv.es

Abstract. Building on an extensive literature review, this article presents a conceptual study of the relationships between information and communication technologies (ICTs) and intellectual capital (IC), placing special emphasis on entrepreneurial capital. IC comprises human capital, structural capital, and relational capital. Relational capital consists of two sub-components: social capital and organizational capital. Human capital's main elements are knowledge, experience, and education. Knowledge is a fundamental resource for any organization (Baden-Fuller & Pitt, 1996; Grant, 1996; Spender, 1996). Entrepreneurial capital was recently introduced as a component of human capital (Audretsch & Keilbach, 2004). A firm's entrepreneurial capital consists of employees who innovate and take risks to change how the firm acts. In addition to addressing IC, this research examines new ICT use. An ICT firm can be defined as a firm that is technologically connected in real time. Technology, information, and communication are the most powerful tools to develop firms (Hafkin & Taggart, 2001). As such, technology, information, and communication may also have profound links to entrepreneurial capital. ICTs and IC are two keys to entrepreneurship (Costa, 2012). ICT firms need their employees' intellectual capital, or else these firms will never achieve long-term sustainability (Madsen, Neergaard, & Ulhøi, 2003). Similarly, intellectual capital benefits from ICT firms to transfer knowledge via networks.

Keywords: ICT · Intellectual capital · Human capital · Entrepreneurial capital

1 Introduction

Authors have shown that successful firm management is built on basic concepts like intellectual capital and knowledge management (Huang & Liu, 2005; Tan, Plowman, & Hancock, 2007). To maximize their effectiveness, firms should integrate these concepts into their organization (Wiig, 1997).

Recent globalization has meant that information and communication technologies (ICTs) are playing an important role in today's society. They provide firms with computerized information, while allowing them to interact with other firms, industries, and countries. Within a context of globalization, ICTs have developed and have reduced labor costs (Audretsch & Thurik, 2001).

ICTs link sectors, and create competitive advantage (US Department of Commerce, 1999). Communication bridges the gap between countries and regions, and stimulates

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 84–92, 2015.
DOI: 10.1007/978-3-319-22204-2_8

collaboration between firms to gain more opportunities (Geldof & Unwin, 2005). The Internet has benefited the economy (Chen, 2004).

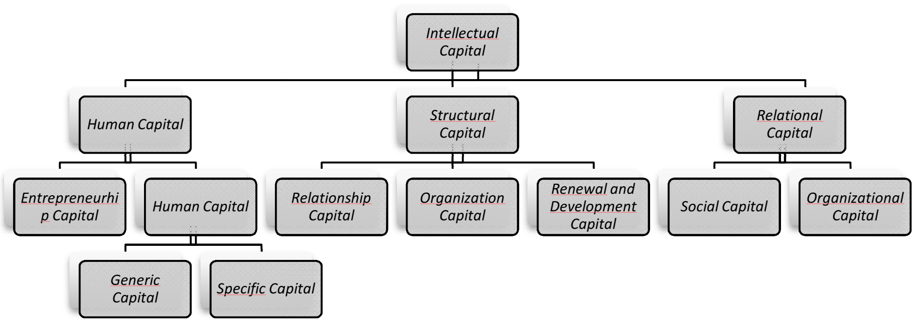
The literature implies that intellectual capital and ICTs are important for firms. Accordingly, this research explores the relationship between firms' intellectual capital and ICTs, while introducing a new intellectual capital component, namely entrepreneurial capital. This study contributes to the literature on ICTs and intellectual capital. Furthermore, the study investigates the concept of entrepreneurial capital—a concept that has been scarcely documented in the literature.

This article has four sections. Following this introduction, the second section defines intellectual capital and its components. The third section introduces ICTs and their relationships with intellectual capital. The fourth section presents conclusions and research opportunities.

2 Intellectual Capital

Intellectual capital refers to intangible resources within firms. Some managers are unaware that intangible assets such as creativity, employees' knowledge, know-how, and efficient management can create competitive advantage. Consequently, managers sometimes ignore these intangible assets in decision-making, even though these factors are essential to the firm (Collis, 1994; Davis, 2009).

According to the literature, intellectual capital comprises three components: human capital, relational capital, and structural capital. Figure 1 shows these components' structure. Each intellectual capital component comprises sub-components. In the following sub-sections, we describe all intellectual capital components and sub-components.



Source: Authors' own work

Fig. 1. Structure of intellectual capital components

2.1 Human Capital

Human capital is defined as knowledge stocks possessed by all individuals within a firm (De Pablos, 2014). Each individual provides his or her own knowledge to these knowledge stocks. Therefore, human capital is the sum of all employees' knowledge, which is inimitable and irreproducible. Employees contribute to the firm's intellectual capital by bringing to the firm their skills, education, competencies, and mental agility (De Pablos, 2004). Furthermore, scholars have shown that human capital is a source of competitive advantage (Lucas 1988; Nijkamp & Poot 1998; Romer, 1986, 1990).

As the human capital definition shows, personality is part of human capital, given that entrepreneurs are considered exceptional individuals. The characteristic that distinguishes them from others refers to the "entrepreneurial ego" and to their special behavior due to their need for independence and control (McCarthy & Leavy, 1998, 1999). Age, sex, and race have also been included in many studies on human capital (Cooper et al., 1994; Cressy, 1999).

Human capital has two sub-components: general and specific (Cressy, 1999). Education and experience are specific human capital factors. Conversely, socio-demographic factors such as age and personal experience are general human capital factors (Cressy, 1999). Age, sex, and race are personality factors that also form part of human capital (Cooper, Gimeno-Gascón, & Woo 1999). Thus, foreign languages, courses, or education type would be considered human capital (Becker, 1975).

Knowledge acquired by employees provides the firm with an intangible competitive advantage because employees can use their acquired knowledge in the firm's production. Therefore, each firm has different human capital because each firm has employees with distinct capabilities, skills, and knowledge in a different working environment. Thus, all these factors make human capital an inimitable advantage (Arrow 1962; Lucas 1988; Nijkamp & Poot 1998; Romer 1986, 1990).

Scholars have recently introduced a new concept in human capital: entrepreneurial capital. This concept has yet to be studied in depth (Audretesch & Keilbach 2004, 2005; Lasch, 2013). The concept of entrepreneurial capital has its roots in the theory of entrepreneurship, which posits that countries with higher levels of entrepreneurship have greater demand for information to assess risk (Schumpeter, 1934; Baron, 1998).

Entrepreneurial capital is what people with similar characteristics and behaviors possess. As most activities they perform aim at innovating, entrepreneurs use ICTs as fundamental tools to develop their firms. The characteristics that these people possess are tenacity, the search for new challenges with some calculated risk, commitment at work, and a high entrepreneurial level (Audretsch & Keilbach, 2004). Thus, a firm's entrepreneurial capital refers to employees who innovate and take risks to contribute to their firm's progress (Rwigema & Venter, 2004). Entrepreneurs act as agents of change. Typically, entrepreneurs discover opportunities, resources, and processes that allow their firms to bring innovations to market (Rwigema & Venter, 2004).

The region where the entrepreneur operates is vital for his or her firm to succeed. Depending on where the entrepreneur works, the government may perceive greater or smaller advantages (Audretsch & Keilbach, 2005). Success also depends on workers' knowledge. Depending on the region, workers' knowledge may vary. Diversity affects the level of knowledge in a region (Jacobs, 1969).

2.2 Relational Capital

The second intellectual capital component that we will examine is relational capital. The firm builds its relational capital when there is a transmission of knowledge among employees (De Pablos, 2004). The term relational capital also applies when two firms exchange information or establish a relationship with each other. Communication has bridged the gap between countries, regions, and collaboration between different firms to gain more opportunities, communicate to people, and create channels to develop firms (Geldof & Unwin 2005).

According to Nelson Abdul (2010), an individual's relational capital refers to the personal contacts network that the individual builds and maintains over time, thereby providing productivity and benefits to his or her firm. Relational capital includes social capital, which refers to connections between different individuals within a firm (Nahapiet & Ghospal, 1998). Social capital is noteworthy because it is one of the most powerful factors owing to the reciprocal relationships between individuals (Putman, 2000). An increase in social capital enables knowledge flow between partners and drives firms to succeed (Collins & Hitt, 2006; Freidman & Krackhardt, 1997; Hitt, Bierman, Shimizu, & Kochhar 2001; Mehra, Kilduff, & Brass, 2001).

In addition, organizational capital resides within relational capital. Organizational capital brings order, stability, and quality to firms because workers communicate with one another and coordinate their activities. A firm's organizational capital includes guidelines, databases, routines, organizational culture, and strategic alliances. These guidelines constitute part of organizational knowledge. Nevertheless, much organizational knowledge does not develop formally in the firm's memory, but rather resides in the routines and organizational culture that employees create daily (Fernández, Montes, & Vázquez, 1999). Organizational capital reflects the considerable growth of ICTs in firms. A database is not simply a set of unclassified data, but rather consists of an internal relationship structure that allows firms to capitalize fully on all information in the database (Stewart, 1997).

2.3 Structural Capital

The third and final intellectual capital component that we will study is structural capital, which refers to the knowledge stocks that remain within a firm when employees leave the firm (De Pablos, 2004). Structural capital can help employees to achieve optimum performance and thereby boost the company's overall performance (Chen, Zhu & Xie, 2004). Some structural capital elements are internal databases, bibliographic resources, management processes, trademarks, patents, organograms, and strategic process instructions (Roos et al., 1997), all of which facilitate information for the firm.

Databases tell firms which products and services to sell to clients, and they contain up-to-date records of purchases, products, and so forth. Such tools facilitate information management and reduce transaction costs for the firm. Chen et al. (2004) claimed that structural capital could be classified as the structures and procedures, organizational learning, organizational culture, and information systems that belong to a firm. In addition, there is an important relationship between structural capital and human capital because human capital is a key determinant of form of organization. However, structural capital is objectively independent once it has been influenced by human capital (Chen et al., 2004). According to Calabrese, Costa, and Menichini (2013), structural capital is subdivided into three subcomponents: "relations," which measures relationships with stakeholders; "organization," comprising organizational culture, routines, processes, and structure; and "renewal and development," which consists of new projects or products, innovations, and R&D.

3 Information and Communication Technologies (ICTs)

ICTs provide the technological infrastructure necessary for electronic commerce and management, and are thus the most powerful tools for development (Hafkin & Taggart, 2001) in countries that have reduced their business transaction costs. The use of ICTs is important to increase firm competitiveness (Sahlfeld, 2007). Although ICTs generate relationships between diverse sectors and can create competitive advantage (especially for entrepreneurs), ICTs lead to regional differences (e.g., between urban and rural areas) (US Department of Commerce, 1999).

In addition to creating competitive advantage, ICTs can reduce communication costs and time. For example, it is no longer necessary to travel to a certain region to know how an office functions. From their computers, managers can see in real time what is happening across the entire firm. Employee training in new technologies and new knowledge has made this real-time, overall supervision possible. New technologies also allow firms to communicate with clients, and deliver products or services.

ICTs are changing which technological advances are being fostered, combining traditional business skills and traits with business activities associated with innovation, technology, and information (Skinner, 2008). Thanks to this ICT development, intellectual capital grows in importance, and a firm's intangible resources can be distributed electronically so that they may be used by the whole organization.

Nevertheless, some barriers to ICT use exist: (1) disorganization in the ICT sector; (2) a shortage of financial resources; (3) a lack of ICTs in private and public institutions; (4) low ICT demand; and (5) a lack of entrepreneurial activity and legal reforms. Disorganization in the ICT sector owes to its youth as a sector (Mathew, 2010). The ICT sector is younger than most sectors (Nyeko, Kabaale, Moya, Amulen, & Mayoka, 2013). A lack of financial services is one of the biggest barriers that firms encounter. If firms lack financial resources, they encounter greater difficulties in installing ICTs. This inability to integrate ICTs leads to low ICT demand. ICTs are evolving: ways to foster technological advances are still in their infancy (Skinner, 2008). Although a lack of entrepreneurial activity and a scarcity of financial resources impedes growth in the ICT sector (Mathew, 2010).

The literature reveals two problems with intellectual capital: (1) quantitatively measuring intangible resources and (2) deciding how to balance the firm's assets. The first problem lies in the appearance of new methods to measure intangible resources, and—for intellectual capital especially—a shortage of accounting resources and a lack of accessibility to new technological methods hinders quantitative measurement of intangible resources. Therefore, many firms believe that accounting rules are insufficient to value these assets (Sveiby, 2001a; Sveiby, 2010b). Other authors have refuted this statement, however (Lev, 2003; Lev & Zambon, 2003; Morricone, Oriani, & Sobrero, 2010), because some methods such as qualitative comparative analysis or the analytic hierarchical process can quantify a firm's qualitative resources (Lev, 2003; Sveiby, 2001, 2010).

Another problem that has concerned firms is determining how to balance intellectual capital investments and evaluate the importance of intellectual capital components that may be essential. Because of this difficulty, firms sometimes invest too much in some resources and overlook others (Lev, 2003). Therefore, good intellectual capital management can increase firm competitiveness and value (Huang &

Liu, 2005; Tan, Plowman, & Hancock, 2007). Firms must coordinate workers to create knowledge and value in the firm (Spender, 1996). Monitoring software can help firms manage their intellectual capital. Using this software, each worker should explain his or her contributions at work, thereby measuring knowledge contributed to the firm.

To find solutions to these intellectual capital problems, we decided to establish a relationship between intellectual capital and ICTs. The relationship between ICTs and intellectual capital enhances value creation in organizations through actions such as attending ICT conferences and seminars, or using software that provides new knowledge to employees. Using the Solow residual (Solow, 1987) can improve measurement of productivity attributed to ICTs. ICTs provide competitive advantage by creating benefits to the firm (Skinner, 2008). Furthermore, ICT management enables firm personnel unfamiliar with the sector to perform their functions. Likewise, relations allow individuals to exchange overall, real-time knowledge and opinions about new ICT technologies, and thus increase skills in planning and managing their functions within the firm. These benefits are all thanks to ICTs. One clear example of such practices is video conferences between firms and clients or firms and suppliers.

Similarly, developed countries have reduced firm transaction costs by using ICTs. ICT use allows firms to increase firm competitiveness by better managing intangible resources (Sahlfeld, 2007).

Employees expand their knowledge of ICTs when they relate with contacts who explain ICTs and share personal experiences. Employees thus acquire knowledge that adds value to the firm. Cell phone use has reduced the time required to collect information in economies with low income (Tanbur & Singh, 2001).

4 Conclusions

This article explores relationships between intellectual capital and ICTs, and incorporates a new component within intellectual capital, namely entrepreneurial capital. According to the literature, intellectual capital comprises human capital, relational capital, and structural capital. Human capital consists of all people who work in a firm. We enrich the construct of human capital by proposing that human capital should include a new concept: entrepreneurial capital. Entrepreneurial capital is formed of highly innovative and creative people capable of using ICTs, who, thanks to these skills, engage in entrepreneurial activities. Entrepreneurial capital currently contributes to the firm's production and growth by yielding diverse knowledge (Audretsch & Keilbach, 2002). Employees' knowledge thereby becomes part of the firm's overall knowledge. Attitude, skills, and entrepreneurial skills along with all resources included within the company's intellectual capital can promote such relationship capital with ICTs.

ICTs help firms to rapidly transmit information to other firms, countries, or people. In this sense, ICTs are beneficial because they help to improve the productivity and competitiveness of companies employing these technological tools (Brynjolfsson & Hitt, 1995). ICTs also enhance intellectual capital, an intangible resource that stems from firm employees and that generates competitive advantage over other firms. By implementing an ICT with adequate resources, companies can strengthen their capabilities because ICTs provide additional information and new methods to effectively run the company and thereby improve performance.

ICT use and intellectual capital have provided advances in the way firms manage and administer their operations, while reducing labor costs, thereby permitting firms to differentiate themselves. Therefore, we conclude that the relationship between entrepreneurial capital and ICTs is favorable for companies because ICTs improve the company's efficiency and contribute to better performance. This is because ICTs with venture capital favor innovation (Iansiti & MacCormack, 1997) in the company's production processes. Thus, the two elements combined with the company's resources increase the company's value, which generates competitive advantage.

It would be interesting if future research studied how to measure entrepreneurial capital through certain factors such as GDP, investment, unemployment, regional integration levels, the proportion of young people in the labor force (more young people means greater entrepreneurial capital), public work, and all public aids. Entrepreneurial capital covers qualitative aspects (e.g., local culture), which are difficult to evaluate (Audretsch & Keilbach 2005) but could also be studied.

References

1. Arrow, K.: Economic welfare and the allocation of resources for innovation. In: Nelson, R. (ed.) The Rate and Direction of Inventive Activity, pp. 609–626. Princeton University Press, Princeton (1962)
2. Audretsch, D., Keilbach, M.: Entrepreneurship capital and economic performance. Regional studies **38**(8), 949–959 (2004a)
3. Audretsch, D.B., Keilbach, M.: Does Entrepreneurship Capital Matter? Entrepreneurship Theory and Practice **28**(5), 419–429 (2004b)
4. Audretsch, D.B., Keilbach, M.: Entrepreneurship capital and regional growth. The Annals of Regional Science **39**(3), 457–469 (2005)
5. Audretsch, D.B., Thurik, R.: What is new about the new economy: Sources of growth in the managed and entrepreneurial economies. Industrial and Corporate Change **10**(1), 267–315 (2001)
6. Baden-Fuller, C., Pitt, M.: The nature of innovating strategic management. In: Baden-Fuller, C., Pitt, M. (eds.) Strategic Innovation, London: Rutledge (1996)
7. Baron, R.A.: Cognitive mechanisms in entrepreneurship: Why and when enterpreneurs think differently than other people. Journal of Business venturing **13**(4), 275–294 (1998)
8. Becker, G.S.: Human capital. National Bureau of Economic Research, New York (1975)
9. Brynjolfsson, E., Hitt, L.: Information technology as a factor of production: the role of differences among firms. Economics of Innovation and New Technology **3**(3), 183–199 (1995)
10. Calabrese, A., Costa, R., Menichini, T.: Using Fuzzy AHP to manage Intellectual Capital assets: An application to the ICT service industry. Expert Systems with Applications **40**(9), 3747–3755 (2013)
11. Chen, J.A.: Comparative research on educational practice model of five countries. Curriculum. Teaching Material and Method **5**(18), 64–71 (2004)
12. Chen, J., Zhu, Z., Yuan Xie, H.: Measuring intellectual capital: a new model and empirical study. Journal of Intellectual capital **5**(1), 195–212 (2004)
13. Collins, J.D., Hitt, M.A.: Leveraging tacit knowledge in alliances: The importance of using relational capabilities to build and leverage relational capital. Journal of Engineering and Technology Management **23**, 147–167 (2006)

14. Collis, D.J.: Research note: how valuable are organizational capabilities? Strategic Management Journal **15**, 143–152 (1994)
15. Cooper, A.C., Gimeno-Gascon, F.J., Woo, C.Y.: Initial human and financial capital as predictors of new venture performance. Journal of business venturing **9**(5), 371–395 (1994)
16. Costa, R.: Assessing Intellectual Capital Efficiency and Productivity: an Application to the Italian Yacht Manufacturing Sector. Expert Systems With Applications **39**(8), 7255–7261 (2012)
17. Cressy, R.: Small business failure: failure to fund or failure to learn. Entrepreneurship. Small & Medium-Sized Enterprises and The Macroeconomy, 161–185 (1999)
18. Davis, M.: The value of knowledge management (2009)
19. De Pablos, P.O.: Las cuentas de capital intelectual como complemento del informe anual. Economía Industrial **357**, 63–74 (2004)
20. Fernández, E., Montes, J.M., Vázquez, C.J.: Typology and strategic analysis of intangible resources: a resource-based approach. Technovation **20**(2), 81–92 (2000)
21. Friedman, R.A., Krackhardt, D.: Social capital and career mobility: A structural theory of lower returns to education for Asian employees. Journal of Applied Behavioral Science **33**(3), 316–334 (1997)
22. Geldof, M., Unwin, T.: Becoming an information society: the role of new IT in development, Wilton Park Conference (2005)
23. Grant, R.M.: Prospering in dynamically competitive environments: Organizational capability as knowledge integration. Organization Science **7**(4), 375–387 (1996)
24. Hafkin, N., Taggart, N.: Gender, information technology and developing countries: An analytical study. Academy for Educational Development, Washington, D.C. (2001). http://learnlink.aed.org/Publications/Gender_Book/Home.htm
25. Hitt, M.A., Bierman, L., Shimizu, K., Kochhar, R.: Direct and moderating effects of human capital on strategy and performance in professional service firms: A resource-based perspective. Academy of Management Journal **44**(1), 13–28 (2001)
26. Huang, C.J., Liu, C.J.: Exploration for the relationship between innovation IT and performance. Journal of Intellectual Capital **6**(2), 237–252 (2005)
27. Iansiti, M., Maccormack, A.: Developing products on Internet time. Harvard Business Review **75**(5), 108–117 (1997)
28. Jacobs, J.: The economy of cities. Random House, New York (1969)
29. Lasch, F., Robert, F., Le Roy, F.: Regional determinants of ICT new firm formation. Small Business Economics **40**(3), 671–686 (2013)
30. Lev, B.: Remarks on the measurement, valuation, and reporting of intangible assets. Economic Policy Review **9**(3), 17–22 (2003)
31. Lev, B., Zambon, S.: Intangibles and Intellectual Capital: An introduction to a special issue. European Accounting Review **12**(4), 597–603 (2003)
32. Lucas, R.E.: On the mechanics of economic development! Journal of Monetary Economics **22**(1), 3–42 (1988)
33. Madsen, H., Neergaard, H., Ulhøi, J.P.: Knowledge Intensive Entrepreneurship and Human Capital. Journal of Small Business and Enterprise Development **10**(4), 426–434 (2003)
34. Mathew, V.: Women entrepreneurship in Middle East: understanding barriers and use of ICT for entrepreneurship development. International Entrepreneurship and Management Journal **6**(2), 163–181 (2010)
35. McCarthy, B., Leavy, B.: The entrepreneur, risk-perception and change over time: a typology approach. Irish Business and Administrative Research **19/20**(1), 126–140 (1998/1999)

36. Mehra, A., Kilduff, M., Brass, D.J.: The social networks of high and low self-monitors: Implications for workplace performance. Administrative Science Quarterly **46**(1), 121–146 (2001)
37. Morricone, S., Oriani, R., Sobrero, M.: The value relevance of intangible assets: evidence of mandatory adoption of international accounting standards (IAS/IFRS). In: Proceedings of the 33rd EAA Annual Congress, Istanbul (2010)
38. Nahapiet, J., Ghoshal, S.: Social capital, intellectual capital and the organizational advantage. Academy of Management Review **23**(3), 242–266 (1998)
39. Nijkamp, P., Poot, J.: Spatial perspectives on new theories of economic growth. Annals of Regional Science **32**, 7–37 (1998)
40. Nyeko, S., Kabaale, E., Moya, M., Amulen, C., Kituyi, G.M.: The role of information communication technology (ICT) small and medium enterprises (SMEs) in job creation in Kampala. Uganda. Journal of Business **1**(5), 75–82 (2013)
41. Putman, P.: Bowling Alone. Simon and Schuster, New York (2000)
42. Romer, P.: Increasing returns and long-run growth. Journal of Political Economy **94**(5), 1002–1037 (1986)
43. Romer, P.: Endogenous technological change. Journal of Political Economy **98**(5), 71–102 (1990)
44. Rwigema, H., Venter, R.: Advanced Entrepreneurship. Oxford University Press (2004)
45. Sahlfeld, M.: How does ICT work for development? A review of the challenges and opportunities. ATDF Journal **4**(1), 22–36 (2007)
46. Schumpeter, J.A.: The Theory of Economic Development (1934)
47. Skinner, G.D.: A study into fostering entrepreneurship in Information Communication Technology (ICT). International Journal of Computers and Communications **4**(4), 108–116 (2008)
48. Solow, R.M.: We'd better watch out. New York Times Book Review, **36** (1987)
49. Spender, J.C.: Making knowledge the basis of a dynamic theory of the firm. Strategic Management Journal **17**, 45–62 (1996)
50. Stewart, T.A.: Intellectual Capital. Doubleday Currency, New York (1997)
51. Sveiby, K.E.: Methods for measuring intangible assets (2001–2010). http://www.sveiby.com/articles/IntangibleMethods.htm
52. Tan, H.P., Plowman, D., Hancock, P.: Intellectual Capital and financial returns of companies. Journal of Intellectual Capital **8**(1), 76–95 (2007)
53. Tanburn, J., Singh, A.D.: ICTs and Enterprises in Developing Countries: Hype of Opportunity? In: Focus Programme on Boosting Employment through Small EnterprisE Development (SEED) Job Creation and Enterprise Department, International Labour Organisation, Working Paper No. 17 (2001)
54. Us Department of Commerce Performance And Innovation Unit, E-commerce@its.best.uk. PIU, London (1999)
55. Wiig, K.M.: Knowledge management: Where did it come from and where will it go? Expert Systems with Applications **13**(1), 1–14 (1997)

Analysis and Improvement of Knowledge Management Processes in Organizations Using the Business Process Model Notation

Alicia García-Holgado[1], Francisco José García-Peñalvo[1], Ángel Hernández-García[2(✉)], and Faraón Llorens-Largo[3]

[1] GRIAL Research Group, Research Institute for Educational Sciences, University of Salamanca, Salamanca, Spain
{aliciagh,fgarcia}@usal.es

[2] Departamento de Ingeniería de Organización, Administración de Empresas y Estadística, Universidad Politécnica de Madrid, Madrid, Spain
angel.hernandez@upm.es

[3] Departamento de Ciencia de la Computación e Inteligencia Artificial, Universidad de Alicante, Alicante, Spain
Faraon.Llorens@ua.es

Abstract. Successful knowledge management is one of the main challenges for any kind of organization. This paper aims to enhance knowledge management processes within companies and institutions, by analyzing different processes that are part of common stages along all knowledge management lifecycles described in the literature. The processes have been modeled using the Business Process Model and Notation with a high abstraction level, in order to cover a wide range of organizations. The paper also presents a possible evolution and enhancement of knowledge management processes using the Business Process Model and Notation diagrams, including the use of superior and better performing technological solutions to support knowledge management processes. As a result, we propose a set of improvements that can be extrapolated to other knowledge management-related business processes.

Keywords: Business processes · Knowledge management · Information systems · Business process modeling

1 Introduction

The importance of knowledge generation and preservation has been present since the Ancient World through different formats—e.g. paper [1]. Nowadays, technological evolution provides new tools to improve knowledge management processes within any kind of organization, from small and medium enterprises (SMEs) to the biggest corporations, and from training centers to universities.

Knowledge management can be defined as the planning, organizing, motivating, and controlling of people, processes and systems in the organization, oriented to ensure that its knowledge-related assets are improved and effectively employed. In an

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 93–101, 2015.
DOI: 10.1007/978-3-319-22204-2_9

organization, knowledge consists not only of electronic or printed documents: the knowledge in employee's mind and the knowledge embedded in the organization's processes are also part of the knowledge-related assets [2]. Uit Beijerse [3] defines knowledge management as the achievement of the organization's goals by making the knowledge factor productive; the knowledge factor includes all the systems used to manage the information within an organization. According to Jelenic [4], knowledge management is not only associated to managing knowledge as a resource, but also to managing business processes that use that resource.

Currently, knowledge management is one of the biggest challenges for any kind of organization. Regarding knowledge management in SMEs, Nunes, Annansingh, Eaglestone and Wakefield [5] conclude that SMEs cannot afford the investment needed to achieve a credible business value from knowledge management. Wickert and Herschel [6] highlight that small and medium-sized companies often experience erosion of knowledge due to the leaving of a key employee, whether via retirement or because he or she leaves the company to work for a competitor. Desouza and Awazu [7] show that SMEs do not manage knowledge in similar ways as larger organizations, given their understandable resource constraints, and hence they have to be creative and find smart workarounds to circumvent these limitations.

In larger organizations, it can be difficult to find who is an expert on a certain subject. Therefore, in large companies knowledge has to be systematically collected, stored in a corporate memory, and shared across the organization [8]. In their study to understand how companies manage the knowledge, Davenport, De Long and Beers [9] list eight specific factors that are common to knowledge projects: (1) link to economic performance or industry value; (2) technical and organizational infrastructure; (3) standard, flexible knowledge structure; (4) knowledge-friendly culture; (5) clear purpose and language; (6) change in motivational practices; (7) multiple channels for knowledge transfer; and (8) senior management support. Furthermore, they highlight that knowledge management can be very expensive, and this statement is very often agreed on in organizations, mainly when it is somehow linked to economic benefit or competitive advantage.

Knowledge management has a lifecycle known as the knowledge management process. There is not just one unique knowledge management process, but several knowledge management process models. Davenport and Prusak [10] identify four knowledge processes: knowledge generation (knowledge creation and knowledge acquisition), knowledge codification (storing), knowledge transfer (sharing), and knowledge application. Birkinshaw, Sheehan and Team [11] present the knowledge lifecycle as an S-curve with four stages: creation, mobilization, diffusion and commoditization, as well as their strategic implications to help companies navigating through each stage of the knowledge life cycle. According to Staab, Studer, Schnurr and Sure [12], the knowledge process has four steps: creation, capture, retrieval and access, and use. Ward and Aurum [13] propose a seven-stage model: knowledge creation, knowledge acquisition, knowledge identification, knowledge adaptation, knowledge organization, knowledge distribution and knowledge application. Nonaka [14,15] develops the knowledge creation cycle, also known as SECI cycle, comprising four activities: internalization, externalization, combination, and socialization.

Regardless of the organization's size or the knowledge management lifecycle, knowledge management systems consist of tools to support the knowledge management process and facilitate knowledge access and reuse [16]. Nowadays, due to the rapid changes and advances in the development of technological solutions, knowledge management systems are strongly related to, and dependent on, the idea, definition and implementation of technological ecosystems. A technological ecosystem can be viewed as a set of different components connected through information flows in a physical environment that supports such flows, and where users are part of the ecosystem [17,18,19]. From this technological ecosystem perspective, the Business Process Model and Notation (BPMN) [20] offers a way to describe business processes similar to activity diagrams from Unified Modeling Language (UML) for description of software modeling, and may help understanding and improving knowledge management processes.

Therefore, the main objective of this paper is to analyze different knowledge management processes within any kind of organization, using the BPMN, in order to improve those processes from a methodological and technological point of view. The paper has the following structure: Section 2 analyzes different knowledge management processes in real contexts through the use of BPMN. Section 3 proposes changes and adjustments to the BPMN to enhance knowledge management processes. Finally, section 4 summarizes the main conclusions from this study.

2 Knowledge Management Processes

Knowledge management processes can be very complex because they generally involve human, methodological and technological elements. Furthermore, knowledge management processes may differ greatly depending on the knowledge management lifecycle of each organization. BPMN diagrams allow describing these processes with a high abstraction level, and therefore they are useful to describe a wide range of organizations. BPMN is quite simple and it has a very high power of expression to model business processes [21].

A comparison of the different knowledge management process models described in the reviewed literature reveals that there are two common stages in all the models: knowledge creation and knowledge sharing or distribution [10-15].

The knowledge management processes presented in this section describe business processes that are part of common stages in all knowledge management life cycles. Moreover, the processes modeled are based on real experiences working with different kind of organizations—universities, Public Administration, companies, etc. In a first step, we shall cover an example of a knowledge management process that takes place within a department, and then we will describe a knowledge management process that takes place across internal and external boundaries of an organization.

Companies and institutions follow different organizational structures, depending on their objectives. Typically, the organizational structure allocates responsibilities, processes and resources, both human and material, to different entities such as departments or areas. Business processes, in particular those related to knowledge management, may involve one or several departments—intradepartmental and interdepartmental business processes, respectively. Regarding knowledge management, sometimes the departments are like black boxes: they do not share any knowledge about their internal business processes, only their inputs and outputs. In this context, the departments create knowledge following one of the four modes of knowledge creation described by Nonaka [14]—socialization, internalization, externalization and combination—but they do not share that knowledge or transfer it to other departments, even though sharing that knowledge, by means of reciprocity, might also improve their processes through the acquisition of knowledge generated by other departments. If we extrapolate this case to an institution with offices in different places with similar departments in each office, the problem would only increase in magnitude.

The knowledge embedded in the organization's processes is one of the main components of knowledge management [2,4]. When a group of employees manages a business process, it is possible that they end up improving that process. The knowledge created from this experience is known as best practices, and it can be transferred to other employees. Best practices usually remain confined to the boundaries of the department or the office where they have been created, following the black box concept described above. If the enhanced process is common to other departments, they will not be able to access to the best practices related to this process because knowledge sharing or transfer between departments does not exist. Fig. 1 describes this scenario, where department A improves process N and the best practices generated are not accessible to department B, where process N is applied, too.

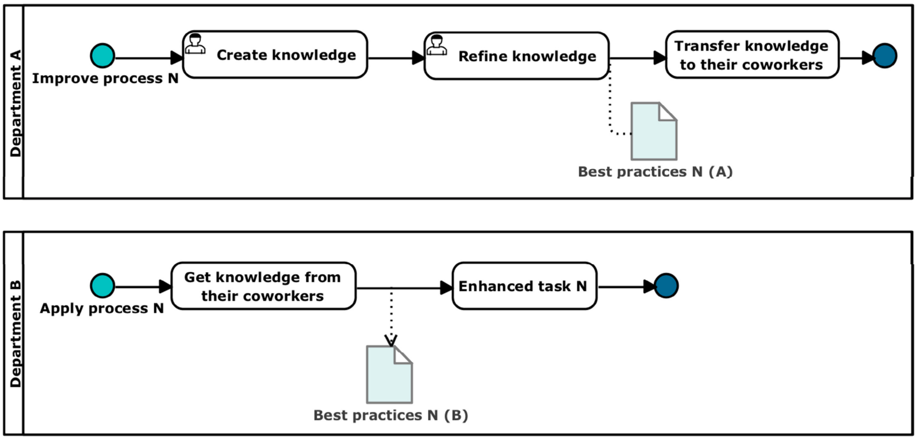


Fig. 1. BPMN diagram describing knowledge creation within a black box department

In order to have wide organizational impact, knowledge must be transferred or shared [2]. Davenport and Prusak [10] highlight that sharing knowledge between people and groups in an organization may be the most daunting task in knowledge management, and they distinguish between formal and informal knowledge transfer [22]. The TRAILER project proposes a methodology supported by a technological ecosystem to facilitate informal knowledge management within any kind of organization through tagging, recognition and acknowledgement of informal learning activities [23-28]. Conde, García Peñalvo, Fernández-Llamas and García-Holgado [21] define the methodology stages through several BPMN, in order to describe all the possible scenarios. Kalpič and Bernus [29] believe that BPMN is an important tool for knowledge management that enables the transformation of informal knowledge into formal knowledge, and that facilitates its externalization—in the form of knowledge artifacts—, sharing and subsequent internalization.

Fig. 2 describes a business process that gives visibility to the knowledge beyond organizational boundaries. The employee or employees with a webmaster role receive the knowledge generated by other employees in the form of a document. The webmaster would then publish the document in the organization's repository and give it public dissemination through the organization's website in case the new knowledge generated is suitable to be accessed outside the organization.

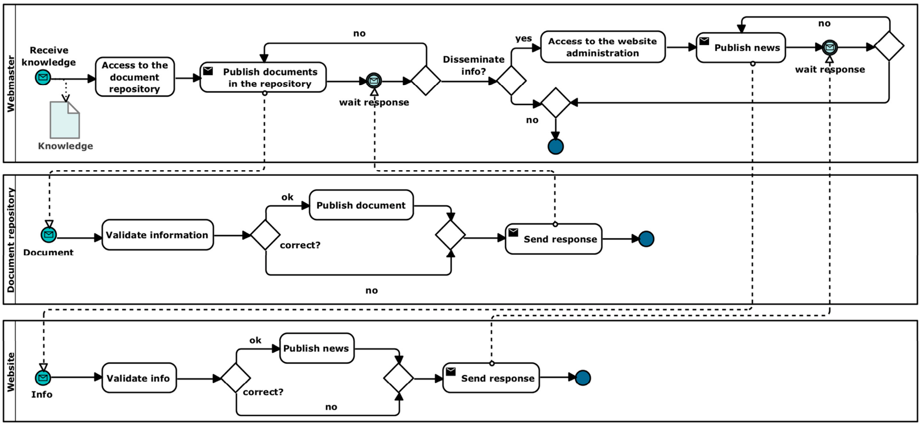


Fig. 2. BPMN diagram describing knowledge diffusion outside of the organization

3 Improvement of Knowledge Management Processes Based on BPMN Diagrams

The BPMN diagrams in the Fig. 1 and Fig. 2 show some of the knowledge management problems that commonly appear in organizations. The analysis of these specific processes provides means to enhance knowledge management processes in order to improve the methodology and the technological solutions that support them. According to García-Holgado and García-Peñalvo [19], knowledge management within an institution or organization depends on a large number of factors, both internal (employees' profile, workflows, etc.) and external (cultural contexts, market, etc.), that have a direct influence on the definition and evolution of the technological ecosystem that supports such knowledge management.

Technological solutions are an important element for the improvement of knowledge management within both companies and institutions [9, 30], and methodology plays an important part in the definition of the technological solutions and the business processes. Therefore, both technology and methodology solutions have to be taken into account for enhancement of knowledge management processes when using BPMN.

The problem represented earlier in Fig. 1 may be easily resolved by defining new business processes oriented to establishing workflows between departments or offices, and supported by adequate technology. Although this problem can be considered a trivial issue, there are examples of large institutions that are in similar situations; for instance, the Spanish Public Administration [18].

Fig. 3 shows a possible solution to the problem. The department where the best practice is generated should share it with other departments in the form of document through a repository that supports the storage of both public and confidential documents. Later on, the best practice can be retrieved from the repository and applied in other departments. Note that, from a BPMN perspective, this solution is achieved simply by adding a new component—a new process—that ultimately relies on the inclusion of a new technology to support knowledge sharing processes.

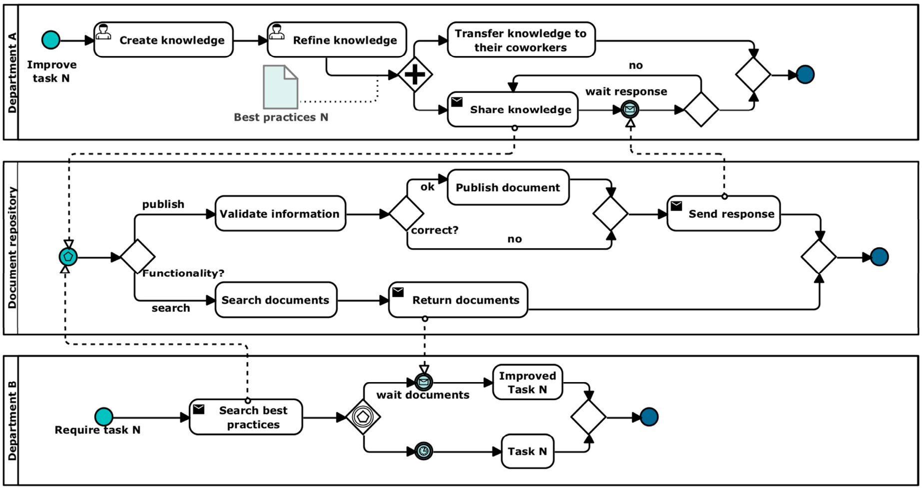


Fig. 3. BPMN diagram describing improved knowledge creation and transfer between departments

Finally, the problem detected in the Fig. 2 is not a technological problem because the tools supporting the knowledge sharing process are already available. Therefore, it is a methodological problem that requires a redefinition of the business process in order to change the role of the employee that should be responsible of sharing the knowledge to the public. Any kind of organization generates a huge amount of knowledge, and part of this knowledge is suitable to be shared publicly. If this task is assigned to just one person, or a very few people, the process will be prone to suffer a bottleneck. However, if knowledge sharing is transformed into an automated task, the bottleneck disappears (Fig. 4). In the proposed business process, a student, employee, public servant or any person inside the organization who generates knowledge, shares it on the repository and the tool is in charge of publishing the information on the website if it is marked as public.

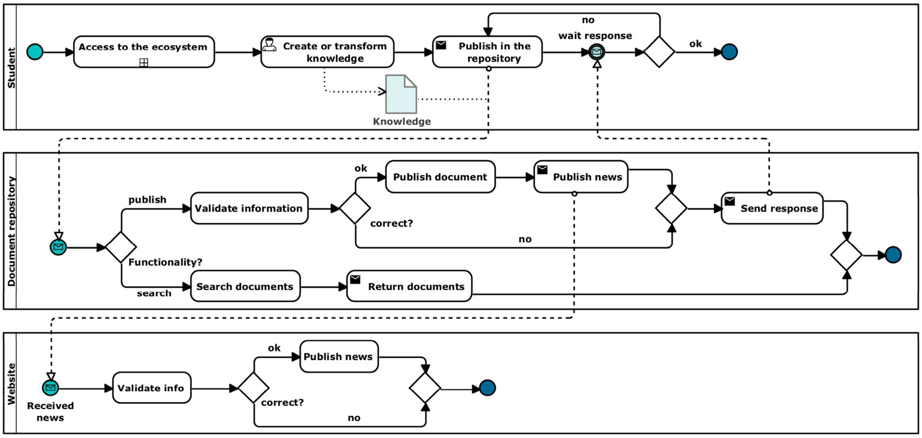


Fig. 4. BPMN diagram describing improvements in knowledge sharing or diffusion

4 Conclusion

At the present time, knowledge management is one of the most critical elements of success for all kind of organizations, from SMEs to large corporations or public institutions. Knowledge encompasses not only documents, both printed and electronic, but also people, processes and supporting technologies. BPMN diagrams provide visual analysis to facilitate description of business processes involving people instead of describing processes as relations between technological systems.

This paper shows how the use of BPMN for analysis of different scenarios involving knowledge management within and across organizations may help detecting problems in knowledge management processes, and how the information from the BPMN may be used to solve these problems and improve knowledge management processes.

Acknowledgements. This research is made within the University of Salamanca PhD Programme on Education in the Knowledge Society scope (http://knowledgesociety.usal.es).

References

1. Posner, E.: Archives in the ancient world. Harvard University Press, Cambridge (1972)
2. King, W.R.: Knowledge Management and Organizational Learning. In: King, W.R. (ed.) Knowledge Management and Organizational Learning, vol. 4, pp. 3–13. Springer US (2009)
3. Uit Beijerse, R.: Knowledge management in small and medium-sized companies: knowledge management for entrepreneurs. Journal of Knowledge Management **4**, 162–179 (2000)
4. Jelenic, D.: The importance of knowledge management in Organizations–with emphasis on the balanced scorecard learning and growth Perspective. In: International Conference on Management, Knowledge and Learning (2011)

5. Nunes, M.B., Annansingh, F., Eaglestone, B., Wakefield, R.: Knowledge management issues in knowledge-intensive SMEs. Journal of Documentation **62**, 101–119 (2006)
6. Wickert, A., Herschel, R.: Knowledge-management issues for smaller businesses. Journal of Knowledge Management **5**, 329–337 (2001)
7. Desouza, K.C., Awazu, Y.: Knowledge management at SMEs: five peculiarities. Journal of Knowledge Management **10**, 32–43 (2006)
8. Borges, L.D.M.S., Falbo, R.: Managing software process knowledge. In: Proceedings of the International Conference on Computer Science, Software Engineering, Information Technology, e-Business, and Applications (CSITeA 2002), pp. 227–232 (2002)
9. Davenport, T.H., De Long, D.W., Beers, M.C.: Successful knowledge management projects. Sloan Management Review **39**, 43–57 (1998)
10. Davenport, T.H., Prusak, L.: Working knowledge: How organizations manage what they know. Harvard Business Press (1998)
11. Birkinshaw, J., Sheehan, T., Team, L.Y.: Managing the Knowledge Life Cycle. Cambridge (2003)
12. Staab, S., Studer, R., Schnurr, H.-P., Sure, Y.: Knowledge processes and ontologies. IEEE Intelligent Systems 26–34 (2001)
13. Ward, J., Aurum, A.: Knowledge management in software engineering-describing the process. In: Proceedings of the 2004 Software Engineering Conference, Australian, pp. 137–146. IEEE (2004)
14. Nonaka, I.: A dynamic theory of organizational knowledge creation. Organization Science **5**, 14–37 (1994)
15. Nonaka, I., Takeuchi, H.: The knowledge-creating company: How Japanese companies create the dynamics of innovation. Oxford University Press (1995)
16. Natali, A.C.C., Falbo, R.: Knowledge management in software engineering environments. In: Proceedings of the XVI Brazilian Symposium on Software Engineering (SBES 2002), pp. 238–253 (2002)
17. García-Holgado, A., García-Peñalvo, F.J.: The evolution of the technological ecosystems: an architectural proposal to enhancing learning processes. In: Proceedings of the First International Conference on Technological Ecosystem for Enhancing Multiculturality (TEEM 2013), Salamanca, Spain, November 14–15, pp. 565–571. ACM, New York (2013)
18. García-Holgado, A., García-Peñalvo, F.J.: Knowledge management ecosystem based on drupal platform for promoting the collaboration between public administrations. In: García-Peñalvo, F.J. (ed.) Proceedings of the Second International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM 2014), Salamanca, Spain, October 1–3, pp. 619–624. ACM, New York (2014)
19. García-Holgado, A., García-Peñalvo, F.J.: Architectural pattern for the definition of eLearning ecosystems based on Open Source developments. In: Sierra-Rodríguez, J.L., Dodero-Beardo, J.M., Burgos, D. (eds.) Proceedings of 2014 International Symposium on Computers in Education (SIIE), Logroño, La Rioja, Spain, November 12–14, pp. 93–98. Institute of Electrical and Electronics Engineers. IEEE Catalog Number CFP1486T-ART (2014)
20. Business Process Model: Notation (BPMN) Version 2.0. OMG Specification, Object Management Group (2011)
21. Conde, M.Á., García Peñalvo, F.J., Fernández-Llamas, C., García-Holgado, A.: The Application of Business Process Model Notation to describe a Methodology for the Recognition, Tagging and Acknowledge of Informal Learning Activities. International Journal of Engineering Education (IJEE) **31**, 1–9 (2015)

22. Choo, C.W.: Perspectives on Managing Knowledge in Organizations. In: Williamson, N.J., Beghtol, C. (eds.) Knowledge Organization and Classification in International Information Retrieval. Haworth Press, New York (2003)
23. García-Peñalvo, F.J., Zangrando, V., García-Holgado, A., Conde-González, M.Á., Seoane Pardo, A.M., Alier, M., Janssen, J., Griffiths, D., Mykowska, A., Alves, G.R.: TRAILER project overview: Tagging, recognition and acknowledgment of informal learning experiences. In: Proceedings of 2012 International Symposium on Computers in Education (SIIE), Andorra La Vella, Andorra, October 29–31, pp. 1–6. Institute of Electrical and Electronics Engineers. IEEE Catalog Number CFP1486T-ART (2012)
24. Conde, M.Á., García-Peñalvo, F.J., Fernández-Llamas, C.: Modeling TRAILER project methodology for the recognition, tagging and acknowledge of informal learning activities. In: Proceedings of the First International Conference on Technological Ecosystem for Enhancing Multiculturality, pp. 105–110. ACM, Salamanca (2013)
25. García-Peñalvo, F.J., Conde, M.Á., Johnson, M., Alier, M.: Knowledge Co-Creation Process Based on Informal Learning Competences Tagging and Recognition. International Journal of Human Capital and Information Technology Professionals (IJHCITP) **4**, 18–30 (2013)
26. García-Peñalvo, F.J., Conde-González, M.Á., Zangrando, V., García-Holgado, A., Seoane Pardo, A.M., Alier, M., Galanis, N., Brouns, F., Vogten, H., Griffiths, D., Mykowska, A., Alves, G.R., Minović, M.: TRAILER project (Tagging, recognition, acknowledgment of informal learning experiences). A Methodology to make visible learners' informal learning activities to the institutions. Journal of Universal Computer Science 19, 1661–1683 (2013)
27. Conde, M.Á., García-Peñalvo, F.J., Rodríguez-Conde, M.J., Alier, M., García-Holgado, A.: Perceived openness of Learning Management Systems by students and teachers in education and technology courses. Computers in Human Behavior **31**, 517–526 (2014)
28. Viegas, C., Marques, M., Alves, G., Mykowska, A., Galanis, N., Alier, M., Brouns, F., Janssen, J., García-Peñalvo, F.J., García-Holgado, A., Zangrando, V., Conde-González, M.Á.: TRAILER: A Tool for Managing Informal Learning. International Journal of Human Capital and Information Technology Professionals (IJHCITP) **5**, 1–17 (2014)
29. Kalpič, B., Bernus, P.: Business process modeling through the knowledge management perspective. Journal of Knowledge Management **10**, 40–56 (2006)
30. Quintas, P., Lefrere, P., Jones, G.: Knowledge management: A strategic agenda. Long Range Planning **30**, 385–391 (1997)

Re-examining the Consistency in fsQCA

Kun-Huang Huarng(✉)

Department of International Trade, Feng Chia University, Taichung, Taiwan
khhuarng@mail.fcu.edu.tw

Abstract. Fuzzy set Quality Comparative Analysis (fsQCA) is gaining popularity in social studies. FsQCA uses set theory to describe the sufficient relationship between the combination of antecedents and outcome. Hence, the assessment of the relationship is very important. One of the functions is called consistency. FsQCA consider the sufficient relationship as a subset relationship, which is different from the relationship in logic. This study aims to re-examine the function of consistency and propose a new function. A data set is used to demonstrate process. The new consistency suits logic theory and yields more combinations of antecedents than those of the current consistency.

Keywords: Consistency · Fuzzy implication · Fuzzy mapping

1 Introduction

Quality Comparative Analysis (QCA) or fuzzy set QCA (fsQCA) has long been applied to create new theory in social science. FsQCA is an extension to QCA by adopting the values from 0 or 1 to the values between 0.0 and 1.0. Ragin [3] raises two concerns for the conventional statistical methods: First, the combination of 3 to 6 independent variables present a level of complexity not easily implemented in statistical modeling of three- to six-way interactions in MRA. Second, the relationships of independent variables and dependent variables are often asymmetric. Figure 1 shows the asymmetric data relationships that there are high X for high Y and there are also low X for high and low Y.

FsQCA is different from the conventional statistical methods in four aspects [3]. First, the statistical methods focus on correlational connections while fsQCA focuses on set-theoretic associations. The statistical methods process the measured observation directly while fsQCA needs to calibrate the data into values between 0.0 and 1.0, (named calibrated data) and processes on the calibrated data. The statistical methods emphasizes on independent variables while fsQCA emphasizes on configurational of conditions. Last, the statistical methods create the analysis of net effects while fsQCA provides the analysis of causal complexity.

FsQCA uses set theory to analyze the relationship between independent variables (or often named antecedents in fsQCA) and dependent variable (or named outcome in fsQCA). FsQCA considers the antecedent or the combination of antecedents a sufficient condition for the outcome. However, in the calculation of the relationship, the antecedent or the combination of antecedents are considered as a subset of the

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 102–109, 2015.
DOI: 10.1007/978-3-319-22204-2_10

outcome. However, the sufficient condition in logic theory is not a subset relationship. Hence, this study intends to re-examine the calculation of an important function in fsQCA and proposes a more proper counterpart. To that end, Section 2 reviews and discusses the function (named consistency) in fsQCA. Section 3 proposes a new consistency. Section 4 uses the data set in a previous study to demonstrate how the new consistency works and what the results the new consistency yields. Section 5 wraps this article.

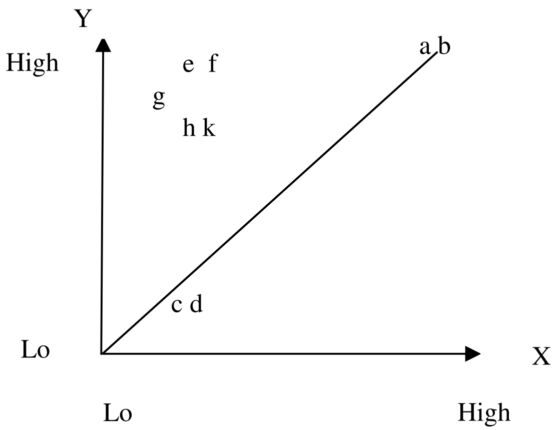


Fig. 1. Asymmetric relationship between X and Y

2 Consistency in fsQCA

FsQCA is an analytic tool that uses fuzzy set theory and Boolean logic [3]. The data of the target problem need to be calibrated into values between 0.0 and 1.0, where 0.0 represents full non-membership and 1.0 full membership. Usually thresholds are taken into consideration for calculation. For example, the calibrated data smaller than 0.05 are considered as full non-membership and greater than 0.95 as full membership [1]. Discussions are provided on how to perform calibrations [3,7].

After processing the calibrated data, fsQCA provides results such as

$$X \rightarrow Y \quad (1)$$

where Y is the outcome (or dependent variable in conventional statistics). X can be an antecedent(independent variable) or combination of antecedents. A combination of antecedents is equivalent to X1*X2*X3…, where X1, X2, X3, … are individual antecedent, * represents logic AND. Equation (1) means that X is a sufficient condition for the outcome Y. Of course, there can be multiple sufficient conditions for the same outcome.

The DM of X is equal to the minimum of all the DMs of X1, X2, X3, …

$$DM_X = \min(\mu_{X1}(X1), \mu_{X2}(X2), \mu_{X3}(X3) \ldots) \quad (2)$$

Two important functions are used to evaluate if the sufficient conditions for the outcome are satisfactory: coverage and consistency. Coverage is an assessment of the way the antecedent combinations "cover" observed cases [4]. On the other hand, consistency expresses the degree (subsethood) with the subset relation, usually with the goal of establishing that an antecedent combination is sufficient for a given outcome [4].

Suppose X and Y contain data of x_i and y_i(i=1, …n), respectively. Both functions are defined as follows [3]:

$$\text{Coverage} = \frac{\sum \min(x_i, y_i)}{\sum y_i} \quad (3)$$

$$\text{Consistency} = \frac{\sum \min(x_i, y_i)}{\sum x_i} \quad (4)$$

Studies stress the importance of achieving high consistency over the high coverage [3,5]. Hence, this study only focuses on examining the calculation of consistency in fsQCA.

The calculation of consistency is similar to that of fuzzy inference in fuzzy logic. Similar to calibration, membership functions are used to fuzzify data into degree of membership (DM) in fuzzy logic. The subsequent process in fuzzy logic is based on DM. Suppose there is a fuzzy rule: A→B, where A is the condition and B is the conclusion (or outcome) of a fuzzy rule.

If A represents A1*A2*A3, the DM of A is equal to the minimum of the DMs of A1, A2 and A3 which is the same as Equation (2):

$$DM_A = \min(\mu_{A1}(A1), \mu_{A2}(A2), \mu_{A3}(A3)) \quad (5)$$

There are two major types of calculations for fuzzy rules in fuzzy logic: fuzzy mapping and fuzzy implication [8]. For fuzzy mapping, the calculation of DM in a fuzzy rule takes the minimum of both those of the condition and the outcome. In other words,

$$DM_{A\to B} = \min(\mu_A(A), \mu_B(B)) \quad (6)$$

μ_A and μ_B are the membership functions for A and B, respectively.

The calculation of consistency in Equation (4) basically follows fuzzy mapping, taking the minimal of X and Y. More precisely, Equation (6) is the nominator in Equation (4). That calculation can be depicted as in Figure 2. The shaded area is the focus of the consistency in fsQCA. Obviously, fuzzy mapping has no connection to "sufficient" relationship between the condition and outcome of a fuzzy rule.

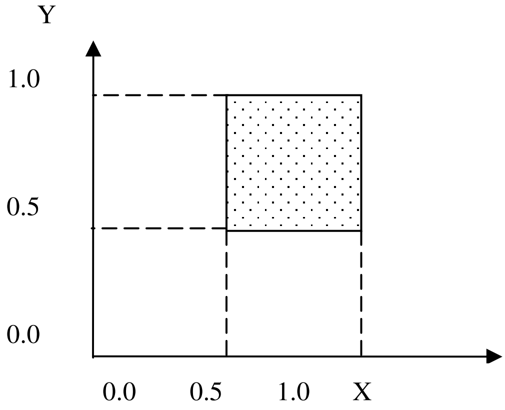


Fig. 2. The existing consistency

In logic, A→B is equivalent to ~A+B, where ~ means logic NOT and + means logic OR. The equivalence between the two expressions can be explained in the truth table in Table 1.

Table 1. Truth Table of A→B

Case	A	B	A→B	~A	~A OR B
1	T	T	T	F	T
2	T	F	F	F	F
3	F	T	T	T	T
4	F	F	T	T	T

To express the sufficient relationship between condition and outcome, fuzzy logic uses implication rule to calculate DM. And this study considers that the implication rule is more proper to for calculating the consistency in fsQCA.

$$DM_{A\to B} = \max(1 - \mu_A(\mathrm{A}), \mu_B(\mathrm{B})) \quad (7)$$

3 New Consistency

To justify the claim of expressing the "sufficient relationship" in fsQCA, instead of using the current consistency (Equation (4)), this study suggests a new consistency. The new consistency is to calculate the average of Equation (7):

$$\text{New Consistency} = \frac{\sum_{i=1}^{n} \max\,[1-\mu_X(x_i), \mu_Y(y_i)]}{n} \quad (8)$$

Equation (6) becomes the new consistency, can be depicted as in Figure 3.

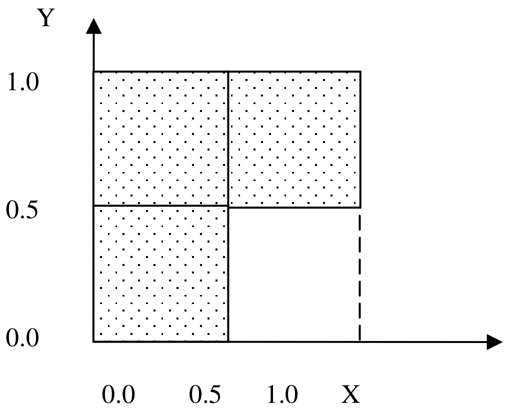


Fig. 3. The new consistency

4 Empirical Results

To demonstrate how the new consistency generates the analysis results, this study adopts the data from [2], as listed in Table 2. There are totally 18 cases, where A, B, C, D, E are the individual antecedent and a, b, c, d, e are their negative counterparts. Hence, AbCDe represents A AND (NOT B) AND C AND D AND (NOT E). Orepresents the outcome.

To calculate the new consistency, Table 3 shows ~X OR Y on the first row; for example, ~AbCDe+O. Then, Table 3 lists all the values by Equation (7). The new consistency for each antecedent combination is listed on the bottom row.

Table 2. Data

Case	O	AbCDe	ABCDE	abCdE	AbCdE	AbCDE	ABCDe	abcde	abCde	abcdE
1	0.95	0.57	0.12	0.19	0.27	0.43	0.12	0.01	0.19	0.01
2	0.05	0.02	0.89	0	0	0.11	0.02	0	0	0
3	0.11	0.02	0.58	0.02	0.02	0.02	0.09	0.02	0.02	0.02
4	0.88	0.01	0.01	0.84	0.16	0.01	0.01	0.02	0.09	0.02
5	0.23	0.08	0.03	0.42	0.58	0.08	0.03	0.01	0.42	0.01
6	0.05	0.05	0.03	0.02	0.19	0.81	0.03	0.01	0.02	0.01
7	0.95	0.21	0.31	0.04	0.04	0.21	0.69	0.01	0.04	0.01
8	0.94	0.04	0.04	0.13	0.04	0.04	0.04	0.57	0.13	0.43

Table 2. (*Continued.*)

Case	O	AbCDe	ABCDE	abCdE	AbCdE	AbCDE	ABCDe	abcde	abCde	abcdE
9	0.58	0.07	0.07	0.13	0.07	0.07	0.07	0.12	0.84	0.12
10	0.08	0.01	0.01	0.28	0.72	0.01	0.01	0.02	0.05	0.02
11	0.95	0.34	0.1	0.41	0.34	0.34	0.1	0.42	0.41	0.53
12	0.05	0	0.94	0	0	0	0.01	0	0	0
13	0.88	0	0	0	0	0	0	0.41	0.59	0
14	0.95	0.01	0.01	0.01	0.01	0.01	0.01	0.89	0.01	0.01
15	0.79	0	0	0.17	0.01	0	0	0.16	0.16	0.83
16	0.94	0.03	0.03	0.09	0.03	0.03	0.03	0.7	0.09	0.2
17	0.05	0.09	0.13	0.05	0.33	0.67	0.09	0.01	0.05	0.01
18	0.05	0.01	0.98	0	0	0.01	0.02	0	0	0

There is only one antecedent combination with new consistency below 0.8. For the rest antecedent combinations with new consistency greater than 0.8, there are AbCDe, abCdE, AbCdE, AbCDE, ABCDe, abcde, abCde, and abcdE. These antecedent combinations can be further minimized as follows.

AbCDe + abCdE + AbCdE + AbCDE + ABCDe + abcde + abCde + abcdE
= (AbCDe +ABCDe) + (AbCdE + AbCDE) + (abCdE + abCde) + (abcde + abcdE)
=ACDe + AbCE + (abCd + abcd)
=ACDe + AbCE + abd

Following the current consistency, the complex solution obtained is ACDe+abd [2]. Obviously, the new consistency yields more antecedent combinations.

Table 3. Causal Combination

~AbCDe+O	~ABCDE+O	~abCdE+O	~AbCdE+O	~AbCDE+O	~ABCDe+O	~abcde+O	~abCde+O	~abcdE+O
0.95	0.95	0.95	0.95	0.95	0.95	0.99	0.95	0.99
0.98	0.11	1	1	0.89	0.98	1	1	1
0.98	0.42	0.98	0.98	0.98	0.91	0.98	0.98	0.98
0.99	0.99	0.88	0.88	0.99	0.99	0.98	0.91	0.98
0.92	0.97	0.58	0.42	0.92	0.97	0.99	0.58	0.99
0.95	0.97	0.98	0.81	0.19	0.97	0.99	0.98	0.99
0.95	0.95	0.96	0.96	0.95	0.95	0.99	0.96	0.99

Table 3. (*Continued.*)

~AbCDe+O	~ABCDE+O	~abCdE+O	~AbCdE+O	~AbCDE+O	~ABCDe+O	~abcde+O	~abCde+O	~abcdE+O
0.96	0.96	0.94	0.96	0.96	0.96	0.94	0.94	0.94
0.93	0.93	0.87	0.93	0.93	0.93	0.88	0.58	0.88
0.99	0.99	0.72	0.28	0.99	0.99	0.98	0.95	0.98
0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
1	0.06	1	1	1	0.99	1	1	1
1	1	1	1	1	1	0.88	0.88	1
0.99	0.99	0.99	0.99	0.99	0.99	0.95	0.99	0.99
1	1	0.83	0.99	1	1	0.84	0.84	0.79
0.97	0.97	0.94	0.97	0.97	0.97	0.94	0.94	0.94
0.91	0.87	0.95	0.67	0.33	0.91	0.99	0.95	0.99
0.99	0.05	1	1	0.99	0.98	1	1	1
0.9163	0.7437	0.8695	0.8284	0.8411	0.9152	0.9089	0.8621	0.9147

5 Conclusions

FsQCA is used to show how configural analysis can complement statistical analysis in management studies [6] and becomes a popular research method for social science. FsQCA is set-theoretic and yields sufficient relationships between antecedents (or antecedent combinations) and outcome. Two important functions are used to evaluate the relationships between antecedents and outcome: coverage and consistency. Coverage assesses how the antecedent combinations cover the cases; consistency expresses the degree of that an antecedent combination is sufficient for a given outcome.

The calculations in fsQCA are very similar to those in fuzzy logic. There are two types of calculations for fuzzy rules: fuzzy mapping and fuzzy implication. The implication rule follows the equivalence of logic. A→B is equivalent to ~A OR B. In other words, implication can express the spirit of sufficient relationship.

However, the current consistency follows the fuzzy mapping, which may not be able to reflect the sufficient relationships. Hence, this study proposes a new consistency by following implication rule. The new consistency can express the sufficient relationships and is more proper than the current consistency. The new consistency yields more antecedent combinations than the current one.

Ackowledgment. The author acknowledges financial support of the National Science Council, Taiwan, ROC under grant NSC 102-2410-H-035-038-MY2 and Ministry of Science and Technology, Taiwan, ROC under grant MOST 104-2410-H-035-027.

References

1. Huarng, K.-H.: Configural theory for ICT development. Journal of Business Research **68**(4), 748–756 (2015)
2. Mendel, J.M., Korjani, M.M.: Charles Ragin's fuzzy set qualitative comparative analysis (fsQCA) used for linguistic summarizations. Information Sciences **202**, 1–23 (2012)
3. Ragin, C.: Redesigning Social Inquiry: Fuzzy Sets and Beyond. Chicago University Press, Chicago (2008)
4. Rihoux, B., Ragin, C.C. (eds.): Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques. SAGE, LosAngeles (2009)
5. Woodside, A.G.: Moving beyond multiple regression analysis to algorithms: Calling for a paradigm shift from symmetric to asymmetric thinking in data analysis and crafting theory. Journal of Business Research **63**, 463–472 (2013)
6. Woodside, A.G., Schpektor, A., Xia, X.: Triple sense-making of findings from marketing experiments using the dominant variable based-logic, case-based logic, and isomorphic modeling. International Journal of Business and Economics **12**(2), 131–153 (2013)
7. Woodside, A.G., Zhang, M.: Cultural diversity and marketing transactions: Are market integration, large community size, and world religions necessary for fairness in ephemeral exchanges? Psychology & Marketing **30**(3), 263–276 (2013)
8. Yen, J.: Fuzzy logic-A modern perspective. IEEE Transactions on Knowledge and Data Engineering **11**(1), 153–165 (1999)

A Web Services-Based Application for LMS Data Extraction and Processing for Social Network Analysis

Julián Chaparro-Peláez(✉), Emiliano Acquila-Natale, Santiago Iglesias-Pradas, and Ignacio Suárez-Navas

Departamento de Ingeniería de Organización, Administración de Empresas y Estadística, Universidad Politécnica de Madrid, Madrid, Spain
{julian.chaparro,emiliano.acquila,s.iglesias}@upm.es, i.suarezn@alumnos.upm.es

Abstract. The emergence of learning analytics as a discipline of its own has given way to a diverse subset of research fields offering very different approximations to the topic. One of the most recent and active approaches is social learning analytics, which focuses primarily on the application of social network analysis (SNA) techniques and visualizations to study and help understanding interactions in online courses as a key pillar of social construction of learning. However, and despite this interest, current tools for analysis and visualization are very limited for advanced social learning analytics, and SNA applications cannot directly process data from learning management systems. This paper presents a technical view of the design and implementation of a web services-based application that aims to overcome these limitations by extracting and processing educational data about forum interactions in online courses to generate the corresponding social graphs and enable advanced social network analysis on SNA software.

Keywords: Learning analytics · LMS · Social network analysis · Data extraction · Data processing

1 Introduction

In the past decade, widespread use of IT across organizations—both within the organization itself and across organizational boundaries—has led to the generation of a vast amount of data originating from business processes, known as big data. Big data can be defined as “high volume, high velocity, and/or high variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization” [1], and the urgent need to manage these data has given birth to the emergence of disciplines such as business intelligence and business analytics. While business intelligence and business analytics have been constantly evolving in the past years [2], the application of analytics to the educational landscape has not been much of a concern for researchers and practitioners until recently, despite the high growth of Virtual Learning Environments (VLEs) and learning management systems (LMS) adoption for online and blended learning (e-learning and b-learning, respectively).

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 110–121, 2015.
DOI: 10.1007/978-3-319-22204-2_11

Despite early efforts from the educational data mining field—cf. Ventura & Romero [3,4]—only in the past five years has the educational community realized of the potential value of educational data analysis for the optimization of educational processes and, more specifically, for the improvement of learning. In this context, the celebration of the First Conference International Conference on Learning Analytics and Knowledge (LAK'11) formalizes the birth of a new discipline, learning analytics, which aims to translate the concepts present in business analytics to ICT-supported education [5]. Thus, a broad definition of the concept describes learning analytics as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs." [6].

Although early research on learning analytics focuses on the study of LMS logs for prediction of student success or at-risk student detection in online instruction, mostly relying on regression analysis—cf. [7]–, more recent research on this field has brought novel approaches that try to go beyond statistical analysis and offer other informative and decision-oriented perspectives, such as visualization–e.g., [8]—or social learning analytics–e.g., [9].

This study focuses on the latter, and more specifically on how to facilitate detailed social learning analytics from LMS data. In order to do so, a basic definition of the concept of social learning analytics will be provided in Section 2, along with a brief description of the most popular tools used for social learning analytics, and their advantages and disadvantages. From the description of these tools in section 2 we conclude that there is a need for development of new tools capable of LMS data extraction and processing for advanced social learning analytics. Section 3 will cover the design and implementation of such a tool—named GraphFES, a web services-based application—from a software engineering perspective, and will therefore describe the functional and software requirements, the system design process, system architecture, system implementation and operation. Finally, Section 4 will briefly illustrate the operation of the application with an example.

It must be emphasized again at this point that the main goal of this study is not to offer an in-depth study on social learning analytics, the use of social learning analytics tools, or the application of social network analysis to educational data, but rather to thoroughly describe the design and implementation of a tool that makes it possible to narrow the gap between educational data available in formal LMS and the tools that facilitate social learning analytics. Therefore, next section will only briefly cover and address relevant concepts that are necessary to comprehend the potential of GraphFES for education.

2 Social Learning Analytics

In formal learning environments, the learning process takes place generally in learning management systems (LMS). LMS allow students to develop individual, self-directed learning through access to learning resources—documents, videos, external links, etc.—and assessment instruments, such as quizzes or essays, but they also provide means to communicate with their peers and instructors to make up for the lack of physical contact and to make social construction of knowledge possible. This is especially critical in collaborative learning, where social learning is positioned at the center of the process. Social learning theory establishes that cognitive processes take place in a social context, by reciprocal interaction between behavior and controlling conditions, both individual and environmental [10], and that knowledge is created and constructed by the interactions of individuals in a given society [11]. This perspective brings attention to knowledge creation by participation and engagement in the discourse—e.g. communities of practice [12]. Course forums are an essential part of social learning in formal contexts—i.e. LMS—, and therefore understanding the dynamics of interactions in course forums is key to explain social learning.

Buckingham-Shum and Ferguson [13] make a distinction between inherently social analytics, which only makes sense in a collective context, and socialised analytics, as personal analytics that have new attributes in a collective context. Among inherently social analytics, they propose two strands of analytics focusing on interpersonal relationships—social network analytics—and language analysis for social construction of knowledge–discourse analytics–, respectively.

From this perspective, it is evident that explaining social learning from an analytics perspective requires novel approaches relying on social network analysis (SNA) of educational data. SNA helps understanding the social dynamics of a given group. In formal educational settings SNA focuses mainly in the interactions that take place in bounded spaces for collaboration, primarily course forums. The main uses of SNA of educational data include identification of relevant learning agents, such as at-risk students, knowledge brokers or influential students [9].

One of the most distinctive characteristics of SNA is that it may provide meaningful information in two different ways: analysis and visualization. Analysis focuses on calculation of SNA parameters and metrics for each node—see Freeman [14] for further information about centrality measures, and Hernández-García [15] (p. 156) for further information about SNA metrics for learning analytics—and network overall parameters. Visualization of social networks, on the other hand, provides graphical information to facilitate understanding of the different relationships among agents. The purpose of this study is to facilitate advanced SNA analysis and visualization of educational data, and thus the next section will give an overview of three popular tools to perform SNA of data from the leading open-source LMS, Moodle [16].

Tools for Social Learning Analytics

SNAPP is a web browser bookmark let that extracts information about message board activity from LMS, and then builds up the resulting social network in a Java applet. SNAPP displays social network graphs from LMS forum data by parsing forum contents—i.e. it does not use information from the LMS logs–and allows basic manipulation and filtering, as well as temporal representation and evolution of the graphs and graph export features. SNAPP also provides basic centrality SNA measures, such as degree, in- and out-degree, betweenness and eigenvector centrality, and network density. However, it requires advanced security permissions and lacks support for newer versions of Moodle.

Forum Graph is a Moodle's report plug-in that displays the resulting social graph from activity in a single forum. Forum graph is therefore integrated in Moodle and it is easy to install; nevertheless it does not allow filtering and graph manipulation, and it does not provide SNA metrics, limiting its suitability for advanced SNA.

Meerkat-ED is a Java application that can load forum and post information from Moodle backup files, and then extracts it and builds the resulting social graph. Meerkat-ED includes both social network analytics and discourse analytics capabilities. Regarding SNA, Meerkat-ED facilitates basic graph manipulation, capabilities to visualize temporal evolution and basic SNA metrics.

From the above, it is manifest that these tools, albeit useful for basic analysis, lack capabilities for advanced SNA: SNAPP and Forum Graph provide little information other than visualization of the network topology, but Meerkat-ED shows how external apps may improve analysis and visualization by separating the data layer from Moodle logs and the process and presentation layer done in the application.

Given these limitations, the next logical step is to consider the use of SNA specific software tools instead, such as Gephi, which do have the necessary functionalities in terms of visualization—including complex manipulation—and advanced analysis of SNA metrics. However, the way LMS store data is not adapted to the format used by SNA applications, and therefore data pre-processing is necessary. The following section presents our solution to this problem by using a web service-based application named GraphFES (Graph Forum Extraction Service) that extracts forum interaction data from Moodle logs and creates a graph that can be analyzed in Gephi, and gives a detailed explanation of the system design and implementation.

3 GraphFES: Design and Implementation

3.1 Software Requirements Specification and Project Design

Functional and Technical Requirements

The main objective of GraphFES is to extract data related to forum activity from Moodle logs and create the resulting social graph for SNA in Gephi. In order to make it independent of LMS changes, the first requirement is that GraphFES will be an external application. In Moodle, this means that it is necessary to create a local plug-in that implements external functions to extract database information. This ensures that structure and order of the LMS architecture is preserved. The local plug-in exposes these functions, but it also requires activation of web services in Moodle in order to make the functions accessible to external applications.

Once access to the database from an external application is possible, it is necessary to create said application, which must execute the queries to the database for data retrieval. After collection of all relevant data—only forum data—, the application must be able to process them and to create a social graph in a format that the SNA application—i.e. Gephi—can read; in this case, and in order to be able to use all of Gephi's potential, the format chosen is Gephi's native format: GEXF, an extensible markup language (XML). Apart from data extraction and processing, the application should also have a simple graphic user interface for user interaction.

Using web services to perform the database queries requires the use of HTTP requests to Moodle, otherwise data extraction would not be possible. Because data is transmitted in JSON, it is necessary that the application can handle JSON.

There are three additional desirable characteristics in the final system: 1) compatibility with different versions of the LMS, to avoid falling in the same problems as SNAPP; 2) client platform independence, so that it may be used in different operating systems; and 3) high processing speed, for increased performance.

Project Design

After identification of the main system requirements, the next step is to address the software project design. By reviewing the literature on software engineering, different design options are considered. The simpler one is the waterfall model [17]; the waterfall model structures the different stages of the software development in a sequential way. While the waterfall model is a good choice for small projects, it does not allow changes during the project and prototypes of the system are not available until the latest stages. Prototyping [18] helps overcoming these limitations, by defining the initial specifications for the creation of a prototype; the prototype is a basic product that includes only the essential characteristics of the final product. Prototypes give an idea of how the final product will look like, and allow revision of requirements for next iterations. While such an approach might seem adequate to the development of GraphFES, it might increase the duration of the project because GraphFES comprises different modules. The spiral model [19] is a generalization of prototyping that can shorten project duration, incorporating the sequential stages from the waterfall model but with a series of evolutionary deliverables that further refine the prototype after each iteration. Unfortunately, the spiral model is suitable for more complex projects, adding too much work overhead to small projects. Finally, iterative and incremental development [20] is the pillar of the Unified Process and other agile methodologies. Iterative and incremental development uses short iteration cycles that minimize risks in software development. The iterative and incremental development model is suitable to the design of GraphFES because it facilitates development of its different components along different iterations, with different system prototypes that make it easier to evaluate functional and technical requirements, and introduce changes in case it is necessary.

GraphFES comprises different components but, since they are dependent, they should be implemented in a given order. The collective application model [21], useful for learning analytics purposes [22], has a cyclical nature that suits both the iterative and incremental development model and GraphFES, comprising of three stages: information gathering—select and capture—, information processing—aggregate and process—and information presentation—display. Therefore, the first development iteration must cover the local Moodle extension because it handles data extraction and delivery to the application. The second iteration should then cover the web application that collects the data and processes them to create the graphs. A final third iteration would cover system requirements revision and prototype changes. During the software implementation process, however, it was detected that from Moodle version 2.6 onward the log system had been changed, and therefore a new iteration was included to make the necessary changes to ensure compatibility of GraphFES with different versions of Moodle. The introduction of this new iteration confirms the suitability of the iterative and incremental model, which allowed redefinition of requirements and introduction of new characteristics seamlessly, and with low impact for subsequent iterations.

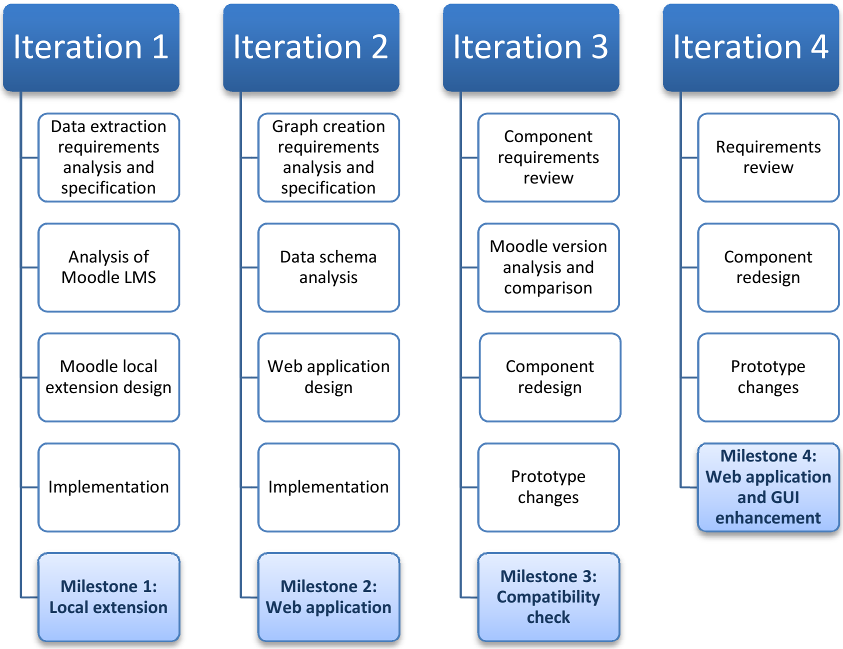


Fig. 1. GraphFES project design

3.2 System Architecture

Upon the project design explained in the previous section and summarized in Fig. 1, it is necessary to describe GraphFES architecture, comprising of two main components: Moodle local plug-in and web application (Fig. 2).

The local plug-in enables implementation of the two external functions that access Moodle database logs, both the old (*Legacy Log*) and new (*Standard Log*). These functions, together with other pre-installed functions, establish a communication using the REST protocol with the web application through a web service. The web application makes the data request to the LMS; this request is handled via the local plug-in, which gives a response with the necessary data using JSON. After data reception, the web application processes the data and generates the resulting social graphs in GEXF format, making it readily available for SNA using Gephi.

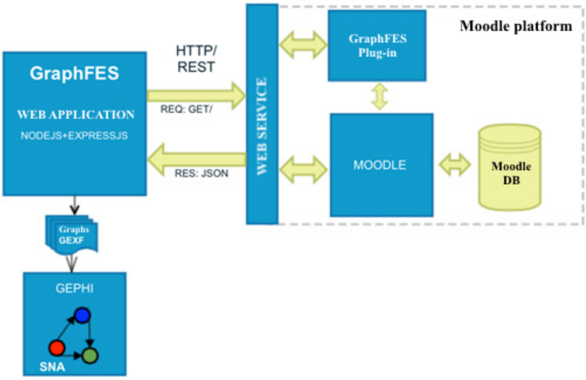


Fig. 2. GraphFES system architecture

3.3 System Implementation

Technology

Development of the local plug-in requires the use of PHP programming language —the same as Moodle, because it has to be included in an external folder in the LMS. There are two main components of the local plug-in: a file called *services.php*, that declares the external functions of the web service, and a file called *externallib.php*, which implements the external functions and performs the database query.

The web application, on the other hand, was developed in a cross-platform language—*Node.js* with the *Expressjs* framework—to ensure that it would operate in different systems, and both from a local or remote host. Node.js also improves application speed and performance because it is an event-oriented programming language that allows a high number of concurrent connections. Two additional JavaScript libraries were needed for graph generation after data processing: *elementtree*, for GEXF generation, and *Sigmajs*, for graph pre-visualization—pre-visualization was introduced in iteration 4 as a graphical user interface enhancement.

Use Case Scenario

A use case describes system operation in a specific scenario, and how the different actors interact with the system. The use of GraphFES is oriented to instructors and course administrators, and therefore the following use case scenario analyzes the interaction of a teacher with GraphFES:

1. A teacher with a valid user in Moodle LMS accesses GraphFES. GraphFES then prompts for logon credentials: username, password, URL of the Moodle LMS and name of the web service.
2. After authentication, the web interface of GraphFES shows a list of the available courses that the teacher may analyze.
3. The teacher chooses one course and GraphFES starts graph generation.

4. Once the data is processed, the graphs in GEXF format are available for pre-visualization in GraphFES and for download and SNA in Gephi.

The use case presents very few variations. For instance, GraphFES should show a system error in case the authentication data is incorrect. The following section gives a higher degree of detail of the use case scenario proposed in this section by analyzing the sequential operation of GraphFES.

Sequential Operation of GraphFES

A sequence diagram gives a temporal and dynamic representation of the interactions between the different components of a software system, and it highlights the functionality of each component in the process. Therefore, the sequence diagram facilitates understanding of what functions to implement on each component so that the whole process gives a successful output.

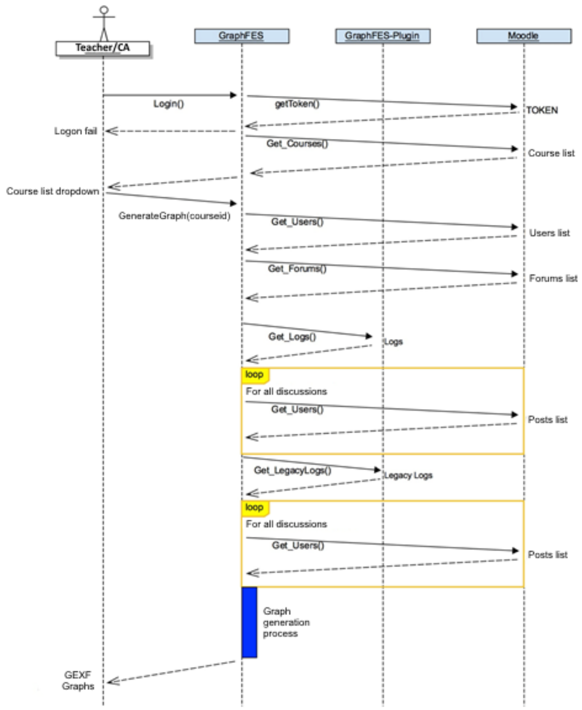


Fig. 3. Sequential operation of GraphFES

For a better understanding of GraphFES operation, the local plug-in and the web application have an independent representation in Fig. 3. Hence, the diagram shows separate calls to the plug-in external functions so that it is easier to differentiate the role of each of GraphFES's components. However, it should be noted that the communication is established between the web application and the web service deployed in Moodle.

The process depicted in Fig. 3, which summarizes GraphFES operation, can be explained in the following sequential stages:

1. The user (most likely, a teacher or course administrator) introduces logon credentials, including URL of Moodle and name of the web service (Note: the web service has to be activated in Moodle; web service activation in Moodle is a straightforward process, but it is omitted in this study due to length limitation. We refer the reader to the following URL for further information: https://docs.moodle.org/29/en/Using_web_services).
2. The web application requests the user's token.
3. If logon credentials are correct, Moodle returns the token that the system will use for the following petitions; else, GraphFES shows a logon error message.
4. Using the token, the web application requests the list of courses available for that user in Moodle.
5. Moodle returns the list of courses in JSON format. The list may be empty if the user cannot access any course or no course exists in the Moodle LMS.
6. The web application shows the list of courses for the user to choose one.
7. The user selects a course and triggers the graph generation process.
8. The web application requests the list of users enrolled in the course and the list of course forums.
9. Moodle returns the lists of users and forums in JSON format.
10. The web application requests course logs for the forum module.
11. Moodle returns the record from the Standard Log in JSON format.
12. For each discussion thread, the web application requests all the posts included in that thread.
13. Moodle returns the list of posts included in each thread in JSON format.
14. Steps 10-13 are repeated for the Legacy Log.
15. After collection of all data, the graph generation process starts.
16. When graph generation has ended, three graph files are stored on disk, in order to make them available to the user. GraphFES generates three different graphs, known as *Views, Replies* and *Messages.* As mentioned in the introductory section, the analysis of the resulting graphs from GraphFES processing is out of the scope of this paper. We refer to [15] for more information about these three types of graphs and how to use them for SNA in Gephi.
17. The web application shows a table with the different graphs generated, and allows the user to download them for SNA in Gephi or make a Force Atlas pre-visualization on the web browser.

System Testing

Mandatory testing follows the development of GraphFES, including three different tests: plug-in tests, web application tests and integration tests. Plug-in tests comprise intensive correct access and log data extraction checks, detection of incorrect input parameters and exception launching as response. Web application tests include error reporting after introduction of erroneous access data, correct GEXF checks, generation of graphs with no logs, no course forums, no posts and no post views, generation of graphs with both Standard and Legacy Log data and correct graph pre-visualization. Finally, integration tests include real course data graph generation and performance tests. For reference, generation of the three graphs in a course with 18 users, 159 messages and 1033 message views takes approximately 3.5 seconds to process in an Intel's Core i5, 2.4 GHz computer, while generation of the three graphs with vast amounts of data (126 users, 9241 messages, 41550 message views) takes approximately 82 seconds.

4 GraphFES: An Illustrated Example

Finally, this section illustrates the operation of GraphFES from the user interface perspective, and shows the results of the process using real data—anonymized—from a computer-supported collaborative learning course (CSCL) with strong focus on teamwork and intensive use of forums. For instance, Fig. 4 depicts the web application interface for authentication, course selection, program execution summary and pre-visualization, while Fig. 5 displays log records as generated by the Moodle reporting module (top) and the visualization of the three graphs generated by GraphFES in Gephi.

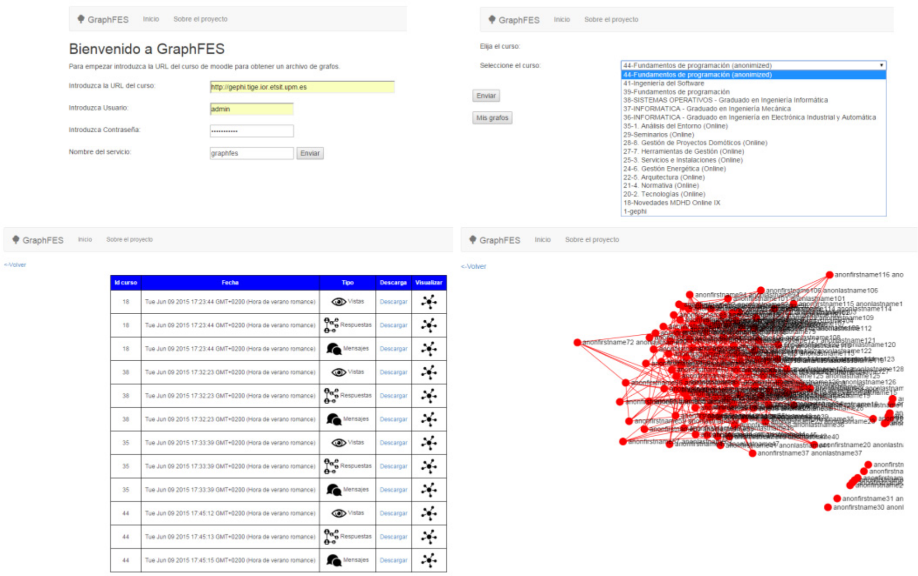


Fig. 4. Left to right, and top-down: GraphFES logon, course selection, graph generation summary and graph pre-visualization screens

Fig. 5. Top: one of the most active teamwork forums and Moodle forum activity report. Bottom: Views, Replies and Messages graphs of that forum in Gephi, with the corresponding SNA metrics returned by Gephi.

5 Conclusion

This paper highlights the need for new solutions and approaches in the emergent field of learning analytics and, more specifically, social learning analytics. In order to do so, the study stresses the current limitations of tools for SNA of educational data, and proposes a new type of tool able to circumvent such limitations: GraphFES, a web service based Moodle data extraction and graph generation tool for SNA in Gephi. Throughout the paper, we have explained the software design process and the technical and architectural principles for the development of such tool. We believe that the implementation of GraphFES has superior potential to that of existing tools and we hope that its future use will accelerate the development of in-depth and advanced social learning analytics.

References

1. Beyer, M.A., Laney, D.: The Importance of 'Big Data': A Definition. Gartner (2012)
2. Chen, H., Chiang, R.H.L., Storey, V.C.: Business intelligence and analytics:from big data to big impact. MIS Quarterly **36**(4), 1165–1188 (2012)
3. Romero, C., Ventura, S.: Educational data mining: A survey from 1995 to 2005. Expert Systems with Applications **33**, 135–146 (2007)
4. Romero, C., Ventura, S.: Educational Data Mining: A Review of the State of the Art. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews **40**(6), 601–618 (2010)

5. van Barneveld, A., Arnold, K.E., Campbell, J.P.: Analytics in Higher Education: Establishing a Common Language. EDUCAUSE ELI Paper **1**, 1–11 (2012)
6. Long, P., Siemens, G.: Penetrating the Fog: Analytics in Learning and Education. EDUCAUSE Review **46**(5), 31–40 (2011)
7. Agudo-Peregrina, Á.F., Iglesias-Pradas, S., Conde-González, M.Á., Hernández-García, Á.: Can we predict success from log data in VLEs? Classification of interactions for learning analytics and their relation with performance in VLE-supported F2F and online learning. Computers in Human Behavior **31**, 542–550 (2014)
8. Gómez-Aguilar, D.A., Hernández-García, Á., García-Peñalvo, F.J., Therón, R.: Tap into visual analysis of customization of grouping of activities in eLearning. Computers in Human Behavior **47**, 60–67 (2015)
9. Hernández-García, Á., González-González, I., Jiménez-Zarco, A.I., Chaparro-Peláez, J.: Applying social learning analytics to message boards in online distance learning: A case study. Computers in Human Behavior **47**, 68–80 (2015)
10. Bandura, A.: Social learning theory. General Learning Press, New York (1971)
11. Berger, P.L., Luckman, T.: The Social Construction of Reality: A Treatise in the Sociology of Knowledge. Penguin Books, Harmondsworth (1967)
12. Lave, J., Wenger, E.: Situated Learning: Legitimate Peripheral Participation. Cambridge University Press, Cambridge (1991)
13. Buckingham-Shum, S., Ferguson, R.: Social Learning Analytics. Journal of Educational Technology & Society **15**(3), 3–26 (2012)
14. Freeman, L.C.: Centrality in social networks: Conceptual clarification. Social Networks **1**(3), 215–239 (1979)
15. Hernández-García, Á.: Usare Gephi per visualizzare la partecipazione nei corsi online: un approccio di Social Learning Analytics. Tecnologie Didattiche **22**(3), 148–156 (2014)
16. Edutechnica: LMS Data – Spring 2015 Updates. (2015). http://edutechnica.com/2015/03/08/lms-data-spring-2015-updates
17. Royce, W.: Managing the development of large software systems. In: Proceedings of IEEE WESCON, pp. 1–9 (1970)
18. Brooks Jr., F.P.: No Silver Bullet Essence and Accidents of Software Engineering. Computer **20**(4), 10–19 (1987)
19. Boehm, B.W.: A spiral model of software development and enhancement. Computer **21**(5), 61–72 (1988)
20. Larman, C., Basili, V.R.: Iterative and incremental developments: A Brief History. Computer **36**(6), 47–56 (2003)
21. Dron, J., Anderson, T.: On the design of collective applications. In: Proceedings of the 2009 International Conference on Computational Science and Engineering, vol. 4, pp. 368–374 (2009)
22. Rayón, Á.: SCALA: Supporting competency assessment through learning analytics. PhD Dissertation. University of Deusto (2015)

Fault Tolerance Patterns Mining in Dynamic Databases

Delvi Ester and Guanling Lee(✉)

Department of Computer Science and Information Engineering,
National Dong Hwa University, Shoufeng, Taiwan, R.O.C.
guanling@mail.ndhu.edu.tw

Abstract. Mining of frequent patterns in database has been studied for several years. However, real-world data tends to be dirty and frequent pattern mining which extracts patterns that are absolutely matched is not enough. An approach, called frequent fault-tolerant pattern (FT-pattern) mining, is more suitable for extracting interesting information from real-world data that may be polluted by noise. Previous research on frequent fault-tolerant pattern mining has been widely studied. However, all of the researches focus on static database. In this paper, we propose an efficient framework to analyze the frequent FT-patterns mining in dynamic database. To avoid re-scanning the whole database, beside of keeping the fault-tolerance pattern, we will also keep the potential fault-tolerance pattern that has higher possibility of becoming a fault-tolerance pattern. The experimental results show that by re-using the existing pattern that had been generated, the proposed algorithms are highly efficient in terms of execution time and maximum memory usage for mining fault-tolerance frequent pattern in dynamic database compare to FFM algorithm.

Keywords: Item support · FT support · Fault-tolerant frequent pattern · Data mining · Dynamic database

1 Introduction and Related Work

Frequent pattern mining from a transactional datasets with support greater than a certain user defined threshold plays an important role in many data mining applications such as finding web log pattern, intrusion detection, etc. However, real-world databases contain noise that can make important information ambiguous; resulting in it will not appear in the mining result. Therefore, we need a method that copes with such variations in an association pattern (within predefined limits), which is called a fault-tolerant pattern. For example, coughing, fever, a headache, and a sore throat are all signs of catching a cold. However, these symptoms are seldom present at the same time, and hence a doctor will not diagnose the disease exactly following the rule RI: {coughing, fever, headache, sore throat} → {catch a cold}. Instead, a better rule corresponding to the real world situation would be R2: Patients who have at least three of the following symptoms {coughing, fever, headache, sore throat} are catching a cold. R2 requires matching just part of the data, which illustrates the sense of allowing for fault tolerance in data mining.

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 122–130, 2015.
DOI: 10.1007/978-3-319-22204-2_12

[5] is the first to propose the discovering of frequent FT pattern to find frequent groups of transactions instead of just focusing on the item themselves. Unfortunately, their approach may generate sparse patterns, which may contain sub-patterns that do not appear frequently. [4]developed FT-Apriori for frequent FT-pattern mining which allows a complete set of FT-patterns to be mines out. [1]uses bit vector representation to represent data and developed a vector-based mining algorithm, VB-FT-Mine. [2] introduces the problem of mining proportional FT-pattern which number of faults tolerable in the pattern is proportional to the pattern length. Moreover, the concept and proposed methods are demonstrated in [3] for predicting epitopes of spike proteins of SARS-CoV and concludes that the patterns reported by proportional FT-patterns mining are more concise than that of fixed FT-patterns mining for this application. [6][7]propose a proportional and fixed FT-pattern with candidate pruning that produce a better result than previous research. However, all the previous papers related to fault-tolerant are assume that the rules having been found in the datasets are valid all the time and do not change, as it consider as a static database.

Mining for association rules between items in a large database of transactions is an important database mining problem. However, all the previous researches related with fault-tolerant pattern were conducted in static database. That is, when new transactions are added or old transaction are deleted, the mining process must start all over again, without taking the advantages of previous execution and results of the mining algorithm. In this paper, we propose an efficient framework to analyze the frequent FT-patterns mining in dynamic database. This framework can solve the problems of mining patterns that tolerate fixed numbers of faults as well as to avoid re-scanning of entire database when there are new additional data or deletion of necessary transactions. The remainder of this paper is organized as follows. Section 2 introduces the problem definition and preliminaries. Section 3 describes the main idea and the proposed algorithms in detail. Section 4 discusses the experimental results and analysis. Conclusions are finally drawn in Section 5.

2 Problem Definition and Analysis

The goal of this work is to find the frequent FT-pattern if there are new transactions coming in or any deletion in the databases without the need of re-scanning the entire database.We use the following definitions and lemmas to explain the main idea of *dynamic frequent FT-pattern*.

Definition 2.1 (Frequent Fault Tolerance patterns/ FFT)[6]
Let P be a pattern and a given FT parameter δ is defined as a fixed number ($smaller\ than$ 0.5 x $|P|$). A transaction T = (tid, X) is said to be FT-contain pattern Piff there exists $P' \subseteq P$ such that $P' \subseteq X$ and $|P'| \geq \lceil |P| - \delta \rceil$.The number of transactions in a database FT-containing pattern P is called the FT-support of P, denoted as sup^{FT} (P).

Let B(P) be the set of transactions FT-containing pattern P. Given a frequent item-support threshold min_sup^{item} *and a FT-support threshold* min_sup^{FT}*, a pattern P is called a frequent FT-pattern if*

1. $sup^{FT}(P) \geq min\_sup^{FT}$*; and*
2. *for each itemp* $\in P$*,* $sup^{item}_{B(P)}(p) \geq min\_sup^{item}$*, where* $sup^{item}_{B(P)}(p)$ *is the number of transactions in B(P) containing item p.*

Table 1. An example TDB

TID	Items
10	a, b, c, f
20	c, d, e, f
30	e, f, g
40	e, f, h
50	a, b, c, d
60	a, b, d, e
70	a, b, d
80	e, f, g, h
90	f, g, h, i, j
100	j, x, y, z

Example 2.1 (FFT). Table 1 shows a transaction database *TDB*. Suppose that the FT-support threshold $min\_sup^{FT} = 4$, the minimal item-support threshold $min\_sup^{item} = 2$, and the FT parameter $\delta = 2$. For pattern $P = abcde$, $B(P)$ includes transaction 10, 20, 50, 60, 70, since they all FT-contain *P*, we have $sup^{FT}(P) = 5$. Each item of *P* appears in at least two transactions of $B(P)$. Therefore, pattern *P* is a frequent FT-pattern and recorded as 5 | 3 4 3 4 2 (FT support | array of item support) or *abcde* = 5 | 3 4 3 4 2, alternatively.
To avoid rescanning the whole database when data insertion and deletion, except the information of frequent fault tolerance patterns, we also record the information of *potential frequent fault tolerance pattern* (*PFFT*, in short). Following is the definition of *PFFT*.

Definition 2.2 (Potential Frequent Fault Tolerance patterns/PFFT)
*Let α(itm) and α(FT) (0<α(itm), α(FT)<1) denote Potential item support and Potential FT support, respectively. Given a potential frequent item-support threshold Pmin_supitem= α(itm) * Pmin_supitem and potential FT-support threshold Pmin_supFT= α(FT) * Pmin_supFT, a pattern P is called a potential frequent FT-pattern if*

1. $sup^{FT}(P) \geq Pmin\_sup^{FT}$*; and*
2. *for each item* $p \in P$*,* $sup^{item}_{B(P)}(p) \geq Pmin\_sup^{item}$*, where* $sup^{item}_{B(P)}(p)$ *is the number of transactions in B(P) containing item p.*

In our approach, we use *D*, d^+ and d^- to indicate the original, inserted and deleted databases, respectively. Moreover, we use *FFT(H)* and *PFFT(H)* to indicate the set of *FFT* and *PFFT* mined out from database *H*, respectively.

The following lemmas show the relationship between FFT and $PFFT$.

Lemma 1. *If a pattern* X' *belongs to* $FFT(d^+)$*, and does not belong to* $FFT(D)$ *or* $PFFT(D)$*,* X' *might belong to* $PFFT(D \cup d^+)$.

Lemma 2. *If a pattern* X' *belongs to* $FFT(D)$*, and does not belong to* $FFT(d^+)$ *or* $PFFT(d^+)$*,* X' *might belong to* $PFFT(D \cup d^+)$.

Lemma 3. *If a pattern* X' *belongs to* $FFT(D)$ *and* $FFT(d^+)$*, it must belong to* $FFT(D \cup d^+)$.

Lemma 4. *If a pattern* X' *belongs to* $PFFT(D)$ *and* $PFFT(d^+)$*, it must belong to* $PFFT(D \cup d^+)$.

3 Dynamic Fault Tolerance Pattern Mining

The whole process of proposed approach can be decomposed into two separate algorithms. The first algorithm, Patterns Generation (Patterns-Gen) Algorithm, is based on the main concept of Frequent Fault Tolerance Pattern mining algorithm (*FFM*) proposed in [6]. The major difference is that we not only mine out the *FFT(D)*, we also record the information of *PFFT(D)* during the mining process. The second algorithm is the Dynamic Fault Tolerance Patterns (*DFT*) Algorithm. In the second algorithm, we will get all the patterns generated from *FFM* algorithm for both *D* and d^+/d^-, combine it, recalculating the supports and get the Final Frequent Fault Tolerance Pattern (Final *FFT*) and Final Potential Frequent Fault Tolerance Pattern (Final *PFFT*). Because of the space limitation, we only explain the second algorithm in detail in this article.

When new transactions are added into the original database; or current transactions being deleted, we will re-execute Pattern-Gen algorithm in order to find the FFT and $PFFT$ from the modified database. After re-executing, we will have two sets of FFT and $PFFT$ from *D* and d^+/d^-.In this algorithm, the mining process is decomposed into three parts. The first part is database merging, to merge the FFT and $PFFT$'s results from both databases into combined temporary results as candidates' patterns. The second part is checking candidates' pattern. We are going to check and determine the final FFT and final $PFFT$ based on the minimum supports. The last part is to update the current bitmap and that had being loaded from file into the memory by adding/deleting transactions from incremental database |*d*|. The updated bitmap is then saved back to the file for future FT-pattern mining.

A detailed description of *DFT* (Dynamic Fault Tolerance Algorithm) for mining frequent FT-pattern in adding algorithm and deleting algorithm while avoid re-scanning the original/existing database is described in Figure 1. We explain the further detail of *DFT* algorithm in three sub parts below.

3.1 Merging Databases

In line 2, we read original/latest bitmap, *FFT*, *PFFT* as well as all minimum supports (min_sup^{FT}, min_sup^{item}, $Pmin\_sup^{item}$, $Pmin\_sup^{item}$) from previous generated database. Then in lines 3 ~ 9, we merge all patterns found from each original/existing database *D* and incremental database |*d*|. The result is then saved to a temporary variable called *tmp.* While merging, we also update the *FT* support of each pattern $sup^{FT}(P)$ and item support for each item in each pattern $sup^{item}B(P)$. After merging, we re-count all minimum supports (min_sup^{FT}, min_sup^{item}, $Pmin\_sup^{item}$, $Pmin\_sup^{item}$) from merging database as described in lines 10 ~ 19.

3.2 Checking Candidates' Pattern

All candidates' pattern in *tmp* are then checked for their $sup^{FT}(P)$ and $sup^{item}{}_{B(P)}(x)$ to determine whether pattern *P*is still a *FFT* or *PFFT*in the modified database. After getting the pattern support, the next step is to check whether the support of pattern is complied with the minimum support. In line 21, by checking the status " if $sup^{FT}(P) < Pmin\_sup^{FT}$", the boolean variable named is Discarded value is set to true and no further checking is required as pattern with support smaller than potential support. For the pattern whose $sup^{FT}(P) \geq min\_sup^{FT}$, we will check whether the pattern is frequent or potential FT-pattern. For each item *x* in pattern *P*, we compare item support $sup^{item}B(P)(x)$ with minimum support. If $sup^{item}B(P)(x) \geq min\_sup^{item}$ of each item, the pattern might be a *FFT* and we increase the variable $countSup^{Itm}(P)$ by 1; otherwise if $sup^{item}B(P)(x) \geq Pmin\_sup^{item}$,thenit might be a *PFFT* pattern, and we increase variable $countPSup^{Item}(P)$ by 1 (lines 22 ~ 28). At the end, described in lines 29 ~ 38, we determine whether the added pattern is truly *FFT.*

After getting the merged patterns of Final *FFT* and Final *PFFT*, we check is Discarded variable to determine whether the discarded pattern is *PFFT* pattern. This variable is used to comply with Lemmas 1-4. As describes in lines 39 ~ 49, we only check the patterns that is Discarded. Therefore, only small part of bitmap for pattern *P*is extracted from bitmap(*D*). For pattern whose $sup^{FT}(P) \geq Pmin\_sup^{FT}$, we will check the possibility that the pattern will be a potential FT-pattern. After that, we compare the support count with the minimum item support. If $sup^{item}{}_{B(P)}(x) \geq Pmin\_sup^{item}$, for each item, the pattern might be a *PFFT* pattern and therefore we increase variable $countPSup^{Itm}(P)$ by 1. Finally line 51 checks whether $countPSup^{Itm}(P) \geq |P|$, therefore we can insert pattern *P* to Final *PFFT.*

3.3 Updating Bitmap

This section will be executed after we got all the appropriate final *FFT* and *PFFT.* Line 49 is performed to merge the bitmaps. During the bitmap updating process, for new coming transactions, we insert the data into the last row in the bitmap. And for new coming item, we create a new bitmap's column and set the entrances to 0 for the original transactions (i.e., the transactions of *D*). Furthermore, for those transactions which are deleted, we eliminate transactions row in the original database based on the user input.

Algorithm 2. (Dynamic Fault Tolerance Algorithm (DFT))

Input: additional database $|d|$
Minimum item-support threshold: min_sup^{item}
Minimum FT support threshold: min_sup^{FT}
Minimum Potential item-support threshold: $Pmin\_sup^{item}$
Minimum Potential FT support threshold: $Pmin\_sup^{FT}$
FT parameter: δ
TID from and to for transaction rows to be delete from database D
Output: bitmap(D ∪ |d|), Final FFT and Final PFFT
Method:

Execute Patterns-Gen Algorithm for additional/delete database
//read latest bitmap, latest FFT, PFFT and minimum supports from files
tmp← $FFT^{D} \cup PFFT^{D} \cup FFT^{|d|} \cup PFFT^{|d|}$
if AddingData {
$supFT(P) = supFT(P)\ D + supFT(P)\ |d|$;
$supitemB(P) = supitemB(P)\ D + supitemB(P)\ |d|$;}
if DeletingData {
$supFT(P) = supFT(P)\ D - supFT(P)\ |d|$;
$supitemB(P) = supitemB(P)\ D - supitemB(P)\ |d|$;}
if Adding Data {
$min\_sup^{item} = min\_sup\ D^{FT} + min\_sup\ |d|^{item}$;
$min\_sup^{FT} = min\_sup\ D^{FT} + min\_sup\ |d|^{FT}$;
$Pmin\_sup^{item} = Pmin\_sup\ D^{FT} + Pmin\_sup\ |d|^{item}$;
$Pmin\_sup^{FT} = Pmin\_sup\ D^{FT} + Pmin\_sup\ |d|^{FT}$;}
if Deleting Data {
$min\_sup^{item} = min\_sup\ D^{FT} - min\_sup\ |d|^{item}$;
$min\_sup^{FT} = min\_sup\ D^{FT} - min\_sup\ |d|^{FT}$;
$Pmin\_sup^{item} = Pmin\_sup\ D^{FT} - Pmin\_sup\ |d|^{item}$;
$Pmin\_sup^{FT} = Pmin\_sup\ D^{FT} - Pmin\_sup\ |d|^{FT}$;}
for each pattern P in *tmp* {
if $supFT(P) < Pmin\_supFT$
isDiscarded;
else if $supFT(P) \geq min\_supFT$
for each item support of x in $supitemB(P)$ {
if $supitemB(P)(x) \geq min\_supitem$
countSupItm = countSupItm + 1;
else if $supitemB(P)(x) \geq Pmin\_supitem$
countPSupItm = countPSupItm + 1;
}
if countSupItm≥$|P|$; add P to Final *FFTi*;
else if (countPSupItm + countSupItm) ≥$|P|$; add P to Final *PFFTi*;
else isDiscarded;
else if $supFT(P) \geq Pmin\_supFT$

Fig. 1. DFT Algorithm

```
            for each item support of x in supitemB(P) {
                  if supitemB(P)(x) ≥Pmin_ supitem
                              countPSupItm = countPSupItm + 1;
            }
            if countPSupItm≥|P| then add P to Final PFFTi;
            else isDiscarded;
   if is Discarded and P ∈ FFT^|d|   and Adding Data
      if P ∈ FFT^|d|   and P ∉ FFT^|D|
            Extract bitmap(P) from bitmap(D);
       if P ∈ FFT^D   and P ∉ FFT^d
            Extract bitmap(P) from bitmap(d);
      get XsupFT(P) and XsupitemB(P) from bitmap(P) ;
      supFT(P) = supFT(P) d + XsupFT(P) ;
      if supFT(P) ≥Pmin_ supFT
          for each item count of   x in P from supitemB(P) d + XsupitemB(P)){
            if (supitemB(P)(x) + XsupitemB(P)(x))   ≥Pmin_ supitem
               countPSupItm = countPSupItm + 1;
          }
          if countPSupItm≥ |P| then add P to Final PFFTi;
  }
Merge bitmap from both DB and |d|;
Save bitmap, FFT, PFFT and all minimum support to file
```

Fig.1. (*Continued.*)

4 Experimental Results

In this section, a set of simulations were performed to show the benefit of our approach. The test data was generated by using IBM synthetic-data generator. All experiments were performed by an Intel i 5 3.2 GHz computer with 4GB of memory, running Windows 7. Table 2 lists the parameter settings for generating the test datasets and evaluating our approach with prior works. Moreover, we split the proposed *DFP* algorithm into two parts, data insertion and data deletion, to make an easier comparison.

Figures 2 and 3 show the effects of number of distinct items in the database. Refer to figure 2, the execution times increases as the number of distinct items in the database increases for both approaches. The reason is that the larger the number of items in the database, the larger the number of patterns will be generated during the mining process which result in longer execution time. Moreover, our approach outperforms the *FFM* algorithm due to the reason that we need not to rescan the whole database. Figure 3 shows the memory usages for both approaches. Because we only need to check the patterns belong to “is Discarded” type, only a small part of bitmap is extracted from bitmap(D). Therefore, our approach outperforms the previous approach.

Table 2. Parameter Settings for FFM and DFP algorithm

Notation	Meaning	Default	Range
TLEN	Average length of a transaction	10	
I	Number of distinct items	15	10 ~ 30
N	Total number of transactions	100000	-
n	Total number of added/deleted transactions	10000	1000 ~ 200000
δ	FT parameter	1	-
min_sup^{item}	Minimum item support threshold	0.075	
min_sup^{FT}	Minimum FT support threshold	0.1	
$Pmin\_sup^{item}$	Potential minimum item support threshold	0.05625	
$Pmin\_sup^{FT}$	Potential Minimum FT support threshold	0.075	

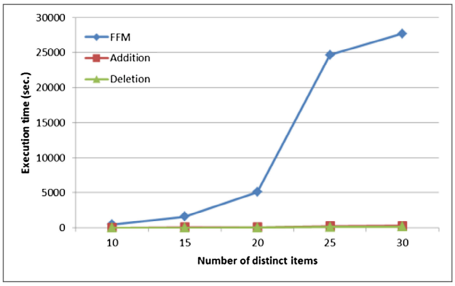


Fig. 2. Execution times

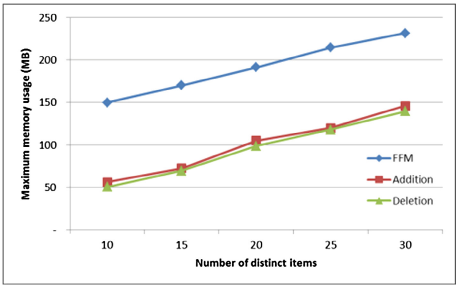


Fig. 3. Maximum memory usages

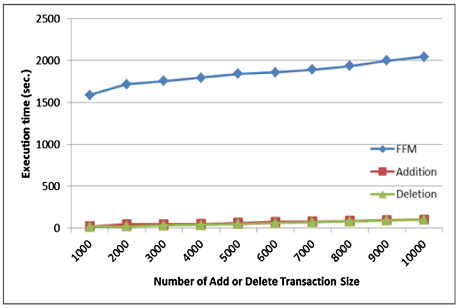


Fig. 4. Execution times

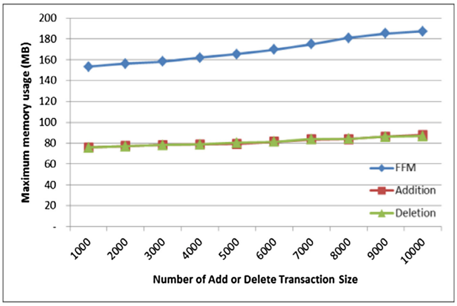


Fig. 5. Maximum memory usagesvs. the modification database sizevs. the modification database size.

Figures 4 and 5 show the effects of the modification database sizes. As shown in the results, the execution times and memory usages increase as the database modification sizes increase for both approaches. Obviously, our approach outperforms the previous one due to that we avoid rescanning the whole database and only load part of the bitmap during the mining process.

5 Conclusion and Future Works

In this paper, a framework is proposed to handle database updates while keeping the performance on hand. To avoid rescanning the whole database, in our approach, we generate the frequent fault tolerance patterns and potential frequent fault tolerance patterns in the original databases and re-using it by merging the patterns with the updated patterns when database is modified. The whole process of the approach can be decomposed into two separate algorithms. The first algorithm, Patterns Generation (Patterns-Gen) Algorithm, is based on the main concept of Frequent Fault Tolerance Pattern mining algorithm(*FFM*). And, the second algorithm is the Dynamic Fault Tolerance Patterns (*DFT*) Algorithm. In the second algorithm, we will get the information of the patterns generated from *FFM* algorithm for both *D* and d^+/d^-, combine it, recalculating the supports and get the Final Frequent Fault Tolerance Patterns and Final Potential Frequent Fault Tolerance Patterns. Experimental results show that by re-using the existing pattern that had been generated, the proposed algorithms are highly efficient in terms of execution time and maximum memory usage for mining fault-tolerance frequent pattern in dynamic database.

Acknowledgements. The authors would like to thank the anonymous referees for their helpful suggestions. This research was partially supported by the Ministry of Science and Technology of the Republic of China under Contract No. MOST 103-2221-E-259-022.

References

1. Koh, J.-L., Yo, P.-W.: An efficient approach for mining fault-tolerant frequent patterns based on bit vector representations. In: Zhou, L.-z., Ooi, B.-C., Meng, X. (eds.) DASFAA 2005. LNCS, vol. 3453, pp. 568–575. Springer, Heidelberg (2005)
2. Lee, G., Lin, Y.-T.: A study on proportional fault-tolerant data mining. In: Proc. of Int. Conf. Innovation in Information Technology, Dubai, pp. 1–5, November 2006
3. Lee, G., Peng, S.-L., Lin, Y.-T.: Proportional Fault-tolerant Data Mining with Applications to Bioinformatics. Special Issue of Knowledge Discovery and Management in Biomedical Information Systems with the journal of Information Systems Frontiers (2009 to appear)
4. Pei, J., Tung, A.K.H., Han, J.: Fault-tolerant frequent pattern mining: problems and challenges. In: DMKD 2001, Santa Barbara, CA, May 2001
5. Yang, C., Fayyad, U., Bradley, P.S.: Efficient discovery of error-tolerant frequent item sets in high dimensions. In: Proceedings of the Seventh ACM SIGKDD International Conference On Knowledge Discovery And Data Mining, August 2001
6. Zeng, J.-J., Lee, G., Lee, C.-C.: Mining fault-tolerant frequent patterns efficiently with powerful pruning. In: Proc. of ACM, pp. 927–931 (2008)
7. Tseng, C.-C., Lee, G.: A depth-first search approach for mining proportional fault-tolerant frequent pat-terns efficiently in large database. In: International Conference on Information Management, February–March 2015

A Unified Approach for the Longest Path Problem on Some Tree-Like Graphs

Ang-Lin Dong and Sheng-Lung Peng(✉)

Department of Computer Science and Information Engineering,
National Dong Hwa University, Shoufeng, Taiwan, R.O.C.
slpeng@mail.ndhu.edu.tw

Abstract. In a graph, a maximal biconnected component is called a block. A graph is called a block (resp., cactus and probe block) graph if its every block is a clique (resp., an edge or cycle, and complete split graph). In this paper, we propose a unified approach for the longest path problem on block, cactus, and probe block graphs. As a result, the longest path problem can be solved in linear time on block and probe block graphs, and in quadrat time on cactus graphs.

Keywords: Longest path problem · Block graphs · Cactus graphs · Probe block graphs

1 Introduction

Let $G = (V, E)$ be a simple and undirected graph, where V and E denote the vertex and edge sets of G, respectively. A subset $U \subseteq V$ is an *independent set*, respectively, a *clique* if no two, respectively, every two vertices of U are adjacent. A complete graph (respectively, path and cycle) with n vertices is denoted by K_n (respectively, P_n and C_n). For a vertex $v \in V$ we write $N(v)$ for the set of its neighbors in G. For a subset $U \subseteq V$ we write $G[U]$ for the subgraph of G induced by U and $G-U$ for the graph $G[V-U]$; for a vertex v we write $G-v$ rather than $G[V \setminus \{v\}]$.

A vertex v is a *cut* vertex if $G-v$ is disconnected. A *block* of a graph G is a maximal connected subgraph of G that has no cut vertex. In general, a block is a biconnected component of G. Note that a connected graph with no cut vertex does not have to be biconnected since it can be K_1 or K_2. The *block-cutpoint graph* of a graph G is a bipartite graph H in which one partite set consists of the cut vertices of G and the other has a vertex b_i for each block B_i of G. The edge (v,b_i) belongs to H if and only if $v \in B_i$[11].

A *split graph* is one whose vertex set can be partitioned into a clique Q and an independent set S. For convenience, a split graph is denoted as $G=(Q+S,E)$. In particular, if every vertex in S is adjacent to every vertex in Q, then G is called *complete split graph*. For convenience, we call a block as *probe clique* if it induces a complete split graph. A graph G is called a *block* (respectively, *cactus* and *probe block*) graph if every block of G is a clique (respectively, an edge or a cycle, and probe clique). Block and cactus graphs are studied for a long time. Recently, Le and Peng [5] showed that the probe block graphs can be recognized in linear time.

D. Palacios-Marqués et al. (Eds.): GIKA 2015, LNBIP 222, pp. 131–136, 2015.
DOI: 10.1007/978-3-319-22204-2_13

Given a graph G=(V,E), the longest path problem on G is to find a longest path in G. It is well-known that the longest path problem is NP-hard [2]. However, it can be solved in polynomial time for some special classes of graphs. For trees, the first polynomial-time algorithm was proposed by Dijkstra in 1960. Later, Bulterman showed that Dijkstra's algorithm can be implemented in linear time [1]. By generating Dijkstra's algorithm, Uehara and Uno proposed a linear-time algorithm for weighted trees and reduced a block graph into a weighted tree such that the longest path problem on block graphs can be solved in linear time [9]. The idea of the algorithm is to transform the block graphs into a weighted tree, and then do Breath-First Search starting from a cut vertex to find the furthest leaf, and finally do Breath-First Search starting from the leaf and find the path to the furthest leaf to obtain the longest path. In the same paper they also showed that the longest path problem on cactus graphs can be solved in $O(n^2)$ time where n is the number of vertices in the given graph. Recently, this result is improved to linear [6].

In addition, Uehara and Valiente solved the longest path problem on bipartite permutation graphs in linear time and space in 2007 by using the linear structure of bipartite graphs [10]. An $O(n^3(m + n \log n))$ algorithm was also proposed on interval biconvex graphs where m is the number of edges in the given graph [10].In 2008, on ptolemaic graphs, it takes $O(n^5)$ time for solving this problem by Takahara[8]. In recent years, this problem was solved on cocomparability graphs in polynomial time by Ioannidou[3]. Later, he presented an $O(n^4)$ algorithm on interval graphs [4]. Finally, a polynomial-time algorithm on circular-arc graphs was proposed by Mertzios[7].

In this paper, we propose $O(n+m)$, $O(n+m)$, and $O(n^2)$ algorithms for solving the longest path problem on block graphs, probe block graphs, and cactus graphs, respectively. By considering their block-cutpoint graphs, our algorithms run in a unified approach. The main difference is in the formula for each type of blocks. Although the time complexities of our algorithms are the same as the previous results in [1] and [9], our algorithms run in a general manner on these three classes of graphs. That is, our algorithms are simpler than previous ones'.

2 A Unified Algorithm

In this section, we propose algorithms for solving the longest path problem on block, probe block, and cactus graphs. The idea of our algorithm is first to transform the given graph G into its block-cutpoint graph H which is a tree. Then, in order to apply the dynamic programming approach, we choose a block vertex of H as a root, *i.e.*, we treat H as a rooted tree. Next, we give each vertex an initial value (d_1=0, d_2=0) where d_1 stores the length of current longest path toward to its parent and d_2 stores the length of the longest path occurred in the current subtree. Then, we process each vertex $v \in H$ according to the proposed formula for each type of blocks from leaves to the root. Finally, we scan all values and find the maximum one for obtaining the longest path. The following is our main algorithm.

```
Algorithm. Longest_path
Input: A connected graph G = (V, E)
Output: The length of a longest path in G
Method:
Construct the block-cutpoint graph H of G;
Choose a block vertex of H as a root;
Initially, each vertex stores the value (d1=0, d2=0)
forall v in H from leaves to the root do
    if v is a leaf block vertex then
        v(d1, d2) = initial_block(v);
    if v is an internal block vertex then
        v(d1, d2) = compute_block(v);
    if v is a cut vertex then
        v(d1, d2) = compute_cut(v);
Find the vertex with the maximum d1 or d2;
return this maximum value;
```

For each vertex v in H, the longest path of G has two possibilities, *i.e.*, a path from a descendant vertex through v to v's parent, or a path with two end-vertices in vertices of blocks in the subtree rooted at v. Since we store two maximum values of these two situations, it is not hard to see that these two values are both local optimal. The following lemmas play an important role in our algorithm.

Lemma1. *Let B be a block vertex of H. Assume that $|B|=k$. If B is a clique, then the length of the longest path for B is $k-1$.*

Lemma 2. *Let B be a block vertex of H. Assume that $|B|=k$. If $B=(Q+S, E')$ is a probe clique, then the initial length of the longest path for B can be determined according to the following cases.*

1. *if $|Q|>|S|$, then the longest length is $k-1$.*
2. *if $|Q|=|S|$, then we have the following two cases.*
   (a) *the length is $k-2$ if both end-vertices are in Q.*
   (b) *the length is $k-1$, otherwise.*
3. *if $|Q|<|S|$, then we have the following three cases.*
   (a) *the length is $2|Q|-1$ if one end-vertex is in Q and the other one is in S.*
   (b) *the length is $2|Q|-2$ if both end-vertices are in Q.*
   (c) *the length is $2|Q|$ if both end-vertices are in S.*

Proof. By the definition, in B, each vertex in S can only connect to any vertex in Q, and each vertex in Q can connect to any vertex in B. Thus, the length of the longest path depends on the number of vertices in Q or S. We have the following three cases.

1. $|Q|>|S|$: No matter the starting vertex or ending vertex is in Q or S, we can connect all vertices together into a path. Thus, the length of the longest path is $k-1$.

2. $|Q|=|S|$: There are two possibilities. If there is one end-vertex in S, by a similar argument of Case 1, the longest length is $k-1$. However, if both two end-vertices are in Q, it is not hard to check that one vertex in S cannot be connected in a longest path. Thus, the length of the longest path in this subcase is $k-2$.

3. $|Q|<|S|$: In this case, it is not hard to see that we should connect as more as possible vertices in Q to obtain a longest path. The first subcase is that both of the two end-vertices are in different set. Thus, we can connect at most $2|Q|$ vertices to form a longest path. Hence, the length is $2|Q|-1$. For the subcase that both end-vertices are in Q, at most $|Q|-1$ vertices in S can be included in the longest path. That is, the length is $2|Q|-2$. For the final subcase, it is easy to check that $|Q|+1$ vertices can be included in a longest path. Therefore, the length is $2|Q|$. □

Lemma 3. *Let B be a block vertex of H. Assume that $|B|=k$. If B is a cycle and vertices in B are numbered from 1 to k in a consecutive ordering in the cycle, then the length of the longest path for B can be determined according to the following cases. Assume s and t are the two end-vertices of the longest path.*

1. *the length is $k-|s-t|$ if $|s-t| < \lceil k/2 \rceil$.*
2. *the length is $|s-t|$ if $|s-t| \leq \lceil k/2 \rceil$.*

Proof. Since B is a cycle, the longest path from s to t is either in clockwise or in counterclockwise on the cycle. That is, the length is either $|s-t|$ or $k-|s-t|$. Of course, the maximum occurs when s and t are neighbors in B. □

According to Lemmas 1, 2, and 3, the detailed procedures are as follows.

Algorithm. ***Initial_block***
Input: A vertex v of H
Output: $v(d_1, d_2)$
Method:
if v is a clique or cycle **then**
    $d_1=k-1$ where k is v's block size;
    $d_2=k-1$
if v is a probe clique **then**
    Choose a starting vertex s in S and the cut vertex as the target t;
    Compute d_1 and d_2 according to Lemma 1;
return v (d_1, d_2);

The detail of Algorithm **compute_block** and **compute_cut** are as follows.

Algorithm. ***Compute_block***

Input: A block vertex v of H
Output: $v(d_1, d_2)$
Method:
1. **if** v is a clique **then**
2. d_1=the maximum d_1 among all cut vertices in $N(v)$ plus k–1 (by Lemma 1);
3. d_2=the summation of the largest two d_1's among all cut vertices in $N(v)$ plus k–1 (by Lemma 1);
4. **if** v is a probe clique **then**
5. Let p be the parent node of v, *i.e.*, a cut vertex;
6. d_1= the maximum distance between all cut vertices to p according to Lemma 2;
7. d_2= the maximum distance between any two cut vertices in N(v) according to Lemma 2;
8. **if** v is a cycle **then**
9. Let the vertices in v be numbered by 1, 2, …,k in clockwise ordering;
10. Let p be the parent node of v, i.e., a cut vertex;
11. d_1= the maximum distance between all cut vertices in $N(v)$ to p according to Lemma 3;
12. d_2= the maximum distance of any two cut vertices in $N(v)$ according to Lemma 3;
13. **return** $v(d_1, d_2)$;

Algorithm. ***Compute_cut***

Input: A cut vertex v of H
Output: $v(d_1, d_2)$
Method:
1. d_1= the largest d_1 of v's children;
2. a_1=the sum of the largest d_1 and the second largest d_1 of v's children;
3. a_2=the largest d_2 of v's children;
4. d_2=**max** $\{a_1, a_2\}$;
5. **return** $v(d_1, d_2)$;

Finally, by Lemmas 1, 2, and 3, we obtain the following theorem.

Theorem 1. *Algorithm* ***Longest_path*** *solves the longest path problem on block graphs, probe block graphs and cactus graphs.*

The best time complexity of the longest path problem on block graphs is $O(n+m)$ [9]. Our algorithm on block graphs only scanned vertices in H once and check the neighborhood of a vertex in G. Thus its time complexity is also in $O(n+m)$.

For cactus graphs, Uehara and Uno proposed an algorithm whose time complexity is $O(n^2)$ for the longest path problem [9]. In our algorithm, since it cannot just deal with maximum vertex in a cycle. Thus, we need to deal with all combinations of any two vertices in cycle B. Thus, the time complexity is also in $O(n^2)$. Note that this result is improved to linear recently [6].

Finally, in the probe block graphs, it is similar to the block graphs. We just need to scan once to find two maximum vertices in Q and S, and then we can find the longest path. Therefore, the time complexity is $O(n+m)$.

3 Conclusion

In this paper, we propose a unified and simple algorithm to solve the longest path problem on block, probe block, and cactus graphs. The time complexity for the three classes of graphs are $O(n+m)$, $O(n+m)$, and $O(n^2)$, respectively. Although the best algorithm on cactus graphs is better than ours, our approach is more general and simpler than the previous results.

Acknowledgements. This work was partially supported by the Ministry of Science and Technology of Taiwan, under Contract No. MOST 103-2221-E-259-030.

References

1. Bulterman, R., van der Sommen, F., Zwaan, G., Verhoeff, T., van Gasteren, A., Feijen, W.: On computing a longest path in a tree. Inf. Process. Lett. **81**, 93–96 (2002)
2. Garey, M.R., Johnson, D.S.: A guide to the theory of NP- completeness. Computers and Intractability, p. 338 (1979)
3. Ioannidou, K., Nikolopoulos, S.D.: The longest path problem is polynomial on cocomparability graphs. Algorithmica **65**, 177–205 (2013)
4. Ioannidou, K., Nikolopoulos, S.D., Mertzios, G.B.: The longest path problem has a polynomial solution on interval graphs. Algorithmica **61**, 320–341 (2011)
5. Le, V.B., Peng, S.-L.: Characterizing and recognizing probe block graphs. Theoretical Computer Science **568**, 97–102 (2015)
6. Markov, M., Andreica, M.I., Manev, K., Tapu, N.: A linear time algorithm for computing longest paths in cactus graphs. Serdica J. Computing **6**, 287–298 (2012)
7. Mertzios, G.B., Bezakova, I.: Computing and counting longest paths on circular-arc graphs in polynomial time. Electronic Notes in Discrete Mathematics **37**, 219–224 (2011)
8. Takahara, Y., Teramoto, S., Uehara, R.: Longest path problems on ptolemaic graphs. IEICE Transactions on Information and Systems **91-D**, 170–177 (2008)
9. Uehara, R., Uno, Y.: On computing longest paths in small graph classes. Int. J. Found. Comput. Sci. **18**, 911–930 (2007)
10. Uehara, R., Valiente, G.: Linear structure of bipartite permutation graphs and the longest path problem. Inf. Process. Lett. **103**, 71–77 (2007)
11. West, D.B.: Introduction to Graph Theory, 2nd edn. Prentice Hall (2001)

Author Index