



# Information Technology Certification: A Student Perspective

Tanya McGill

School of Information Technology, Murdoch University, Australia

Michael Dixon

School of Information Technology, Murdoch University, Australia

## ABSTRACT

*Certification has become a popular adjunct to traditional means of acquiring information technology skills and employers increasingly specify a preference for those holding certifications. This paper reports on a study designed to investigate student perceptions of both the benefits and risks of certification and its importance in obtaining employment. Certification was perceived as an important factor in achieving employment and students undertaking it anticipate that it will lead to substantial financial benefits. Yet higher salaries are not seen as the most important benefit of certification. The potential benefits that students believe are most important relate to 'real world' experience. The respondents were aware of the possible risks of certification but did not appear to be overly concerned about them. The risk considered most important was the potential for the rapidly changing knowledge base to mean that certification is not of lasting value.*

## INTRODUCTION

Certification has become a popular adjunct to traditional means of acquiring information technology (IT) skills and increasing numbers of job advertisements specify a preference for those holding certifications. Certification intends to establish a standard of competency in defined areas. Unlike traditional academic degrees, certifications tend to be specific to narrow fields or even to individual products. They are designed to provide targeted skills that have immediate applicability in the workplace.

Vendors such as Microsoft and Cisco Systems dominate the vendor specific certification market worldwide with qualifications such as the Microsoft Certified Systems Engineer (MCSE), Cisco Certified Network Associate (CCNA) and Cisco Certified Internetwork Expert (CCIE). Vendor neutral certifications such as those provided by the Institute for Certification of Computing Professionals (ICCP), the Computer Technology Industry Association and the Disaster Recovery Institute also play a role. It has been reported that there are over 300 IT certifications available and that approximately 1.6 million people have earned approximately 2.4 million certifications (Nelson & Rice, 2001), and no doubt these figures have already increased dramatically. Gabelhouse (2000) quoted an IDC report that found that the IT training and testing industries had revenues of \$2.5 billion in 1999 and were expected to reach \$4.1 billion by 2003.

Vendors create certifications as a way of promoting widespread adoption of their products and technologies, but they have also become important for educational institutions in attracting students and placing graduates (Brookshire, 2000). This paper explores the perceptions of students who are undertaking courses of study that can lead to certification. It reports on a study designed to investigate student perceptions of both the benefits and risks of certification and its importance in obtaining employment.

## Benefits of Certification

Numerous benefits have been proposed to result from IT certification. As Nelson and Rice (2001) note, many of the claims of benefits have originated in the brochures and web sites of certification agencies;

however, there seems also to be a wider recognition of their importance. The major benefits that have been claimed can be categorized as relating to employers, educational institutions and students (i.e. potential employees). The major benefit for employers is believed to be the provision of more capable employees (Ray & McCoy, 2000), and one in eight IT job advertisements have been found to mention certifications (Clyne, 2001; Nelson & Rice, 2001). Some support for the benefit of employee certification to employers is provided by a study by IDC, Inc. (1999) which found that 92% of managers surveyed said that they realized all or some of the benefits they expected from their certified employees. The major benefits expected of certified employees were found to be:

- Greater knowledge and increased productivity
- A certain level of expertise and skill
- Improved support quality
- Reduced training costs
- Higher morale and commitment.

The major benefit proposed for educational institutions is the opportunity to extend program content and to have an increased assessment capability (Ray & McCoy, 2000). Institutions that successfully offer certifications can become known for their expertise in these areas and attract more students and employers for their graduates (Brookshire, 2000). Student performance on certification exams also provides additional and generalizable measures of student competencies.

The greatest benefits of certification are believed to accrue to students (Ray & McCoy, 2000). Marketability is proposed as a major benefit. Students are marketable if their programs of study contain content considered valuable by employers. For example, holders of Cisco certifications should have substantial experience as network administrators, designers and troubleshooters on real networks. Alexander (1999) describes the results of a survey of 470 IT contractors that found that 83% of the participants believed that certifications were important for their career advancement. Higher salaries are also commonly cited as a benefit, and there is evidence to support this. A survey conducted by Certification Magazine (Gabelhouse, 2000) reported that on average certification resulted in a 12% increase in income. This study also reported varying values for different certifications. For example, a MCSE led to an average increase in income of 12.6%, a Cisco CCNA to a 16.7% increase and a Novell CNA to a 13.3% increase. However, Alexander (1999) speculates that increased supply of people with the most popular certifications (such as MCSE) means diminished value in the market place. Other proposed benefits that are associated with increases in marketability and salary include increased self-confidence and increased credibility (Karr, 2001).

## Risks Associated With IT Certification

Despite these benefits, various concerns have been expressed about the current popularity of IT certification. Ray and McCoy (2000) identify the heavy involvement of vendors as an issue for concern, citing

the absence of unbiased neutral groups for determining content, creating exams and authorizing examiners. They also recognize that the rapidly changing knowledge base might mean that certification is not of lasting value. Wilde (2000) also highlights the fact that some certifications don't require practical or real world experience, thus limiting the claims of usefulness.

As IT certifications are increasingly offered by universities and colleges, concerns have been raised that academics might be uncomfortable with the loss of control over content that arises when certification exams determine the content of courses and academic programs (Nelson & Rice, 2001; Ray & McCoy, 2000). Academics might also be uncomfortable with the pressure to maintain their own proficiency levels and certification status.

Given the increasing pervasiveness of certification in the IT profession, more research is needed to verify the benefits of IT certification and to determine the importance of the proposed risks.

## THE RESEARCH PROJECT

The exploratory study reported on in this paper contributes to the need for further research on the risks and benefits of IT certification by investigating student perceptions of both the benefits and risks of certification focusing particularly on Cisco certification. This research was conducted by survey. Participants in the study were students enrolled in several electronic commerce, telecommunications management and information technology courses at an Australian university. Students who have successfully completed these particular courses can also pursue Cisco certification as the courses make use of the Cisco curriculum. Participants were recruited during class and completed a questionnaire on the spot. It was stressed that the completion of the questionnaire was voluntary and that it formed no part of their assessment in the course.

The questionnaire was designed to be easy to read and understand and to require no more than ten minutes to complete. The questionnaire contained four main groups of items. The first section asked about:

- Age
- Gender
- Amount of previous work experience (both total and IT experience)
- Whether the skills provided by their degree are those employers require.

The second group of questions related to the perceptions of the participants about the importance of industry certification for employment. Those participants who were not currently working in the IT industry were firstly asked to rate the importance of industry certification for obtaining their initial IT employment. This item was measured on a 5 point scale ranging from (1) 'Not Important' to (5) 'Vital'. They were then asked to indicate how much higher (as a percentage) than the average graduate starting salary they believed their starting salary would be if they obtained various certifications. The list of certifications included those currently available to the participants and several other popular certifications (see Table 2 for a list of the certifications included).

Those participants who were currently working in the IT industry were instead asked to rate the importance of industry certification for getting ahead in their current employment. This also used a 5 point scale ranging from (1) 'Not Important' to (5) 'Vital'. They were then asked to indicate how much they thought their salary (as a percentage) would increase if they obtained the various IT certifications.

The third group of questions related to the participants' perceptions of the importance of various proposed benefits of seeking certification. A list of eleven benefits proposed for IT certification was developed from the literature on IT certification (e.g. Alexander, 1999; IDC Inc., 1999; Karr, 2001; Nelson & Rice, 2001; Otterbourg, 1999). Each potential benefit was rated for importance on a 5 point scale ranging from (1) 'Not Important' to (5) 'Very Important' (see Table 3 for a list of the proposed benefits included).

The fourth group of questions related to the participants' perceptions of the importance of various concerns about certification. A list

Table 1: Background information about participants

	Number	Percentage
Gender		
Male	124	85.5
Female	21	14.5
Degree level		
Undergraduate	130	89.7
Postgraduate	15	10.3
Work experience* (mean = 5.8 years)		
No	75	51.7
Yes	70	48.3
IT work experience (mean = 3.4 years)		
No	97	66.9
Yes	48	33.1

\* Work experience includes both IT and non-IT experience

of potential risks of reliance on IT certification was drawn from the literature on certification (e.g. Nelson & Rice, 2001; Ray & McCoy, 2000; Wilde, 2000). Each potential risk was rated for importance on a 5 point scale ranging from (1) 'Not Important' to (5) 'Very Important' (see Table 5 for a list of the proposed risks included).

The participants in the study were 145 students with an average age of 23.4 years (with a range from 18 to 48). Twenty one of the participants (14.5%) were female and 124 (85.5%) were male. The gender proportions in this study are consistent with the low representation of females in IT courses around the world (Downes & Hobbs, 2000; Fitzsimmons, 2000; Klawe & Leveson, 1995). Participants were at either undergraduate level (130 students or 89.7%) or postgraduate level (15 students or 10.3%). The participants who had previously been employed had on average 5.8 years work experience of which 3.4 years was in the IT industry. Table 1 summarizes some of the background information about the participants in this study.

## RESULTS AND DISCUSSION

### Benefits

IT certification was perceived as very important both for obtaining initial IT employment and for getting ahead if currently employed in the IT industry. The average importance rating given to IT certification by those not currently employed in IT was 4.09 (out of 5) and it was 3.75 (out of 5) for those currently employed in the IT industry (see Table 2 below). These perceptions of students who were not yet certified are consistent with results of a survey of 470 IT contractors described by Alexander (1999). In that study, 83% of the contractors believed that IT certifications were either 'very important' or 'somewhat important' to their prospects for career advancement. Thus, student perceptions of the importance of certification appear to be consistent with industry

Table 2: Perceived importance of certification

	N	Mean	SD	Min.	Max.
Importance of certification for initial job	119	4.09	1.00	1	5
Importance of certification for current job	24	3.75	1.26	1	5
Anticipated percentage increase in starting salary (if not currently in IT employment)					
CCNA certification	99	18.87	21.46	0	100
CCNP certification	97	25.27	23.85	0	100
Security certification	96	22.88	21.61	0	100
Wireless certification	95	21.27	21.95	0	100
Unix certification	96	21.47	20.55	0	100
MCSE certification	98	19.77	21.26	0	100
Anticipated percentage increase in salary if currently in IT employment					
CCNA certification	19	6.32	4.96	0	15
CCNP certification	20	16.60	14.30	0	50
Security certification	20	19.20	23.31	0	100
Wireless certification	19	10.68	10.19	0	30
Unix certification	18	16.72	23.37	0	100
MCSE certification	18	9.28	14.90	0	60

perceptions. The majority of student participants in the current study also believed that the studies they were undertaking would provide the skills required by employers (yes: 64.5%, not sure: 32.4%, no: 2.8%).

In general, participants perceived that obtaining certification would lead to clear financial benefits. The average increases that students who were not currently working in the IT industry believed they would receive from obtaining certification ranged from a high of 25.27% for CCNP certification down to 18.87% for CCNA certification (see Table 2). The range of increases anticipated by participants was very large, with some suggesting that no increase would result, up to a maximum of 100% for all of the certifications. This wide range of responses suggests that this group of participants did not have a good sense of the value of these certifications in the marketplace. It would be reasonable to expect this for those qualifications that are not currently available to them as part of their program of study, but more surprising for the CCNA and CCNP as these certifications are readily available to the participants, and the potential financial benefit resulting from them could be assumed to have influenced their decisions to undertake the courses being surveyed. This lack of knowledge about the financial value of certification is also reflected in the large number of participants who did not provide answers to these items (around 20% did not respond to at least one of the questions about salary). Instructors have a major role to play in providing up to date information about employers' needs and likely outcomes of obtaining certification. They need to be highly accessible and to ensure that their knowledge of the marketplace that graduates will enter remains current so that they can help guide their students (McGill & Dixon, 2003).

Those participants who were currently working in the IT industry also anticipated financial gains from certification, but the average percentage gains they suggested were lower than those anticipated by students not working in the IT industry. The percentage increases anticipated by those who were currently employed were consistent with the figures available from surveys such as the one conducted by Certification Magazine (Gabelhouse, 2000), suggesting that employed students have realistic expectations. There was also a narrower range of responses provided, suggesting less confusion about likely financial outcomes resulting from certification. Presumably those working in the IT industry would have received better quality information from their work colleagues, than would those without IT work experience who would have been receiving information from a pool of people with perhaps limited direct IT industry experience (McGill & Dixon, 2003).

Table 3 presents the average perceived importance of each potential benefit of IT certification. The ratings of benefits are ranked by perceived importance. All benefits were ranked relatively highly, with averages above the midpoint of the scale. The two most highly ranked benefits were practical experience with real networking tasks, and experience with real equipment. Almost 97% of the respondents considered practical experience with real networking tasks to be impor-

tant or very important. This finding reflects that fact that the participants were primarily undertaking Cisco certifications. Wilde (2000) comments that Cisco Systems has the most 'realistic' certification program, requiring those undertaking certification to perform real tasks, using real equipment. Wilde also raises concerns that some certifications do not emphasize practical skills.

The fifth and sixth ranked proposed benefits relate to the role of certification in improving opportunities to obtain jobs. The ability to apply for the increasing number of jobs that require certification was ranked fifth, and obtaining a formal marketable qualification was ranked sixth. Improving employment opportunities is clearly important to those who undertake certification, but the higher rankings of practical experience and improving knowledge and skill suggest that employment is not the sole motivation for undertaking certification. The perceived importance of practical experience obtained goes beyond just improving marketability.

Confidence in the knowledge of those who teach certification programs was ranked as the seventh most important benefit. Whilst having knowledgeable instructors is clearly important (with an average of 4.08 out of 5), the relative ranking perhaps suggests that students perceive those who teach them to be well qualified for the job regardless of whether the unit of study involves a certification and hence requires instructor certification.

Higher salaries was ranked eighth in terms of importance. Whilst potential salaries perhaps receive the most publicity in terms of benefits to holders of certifications, this ranking suggests that salary is not the major driving factor for students. The ninth and tenth ranked benefits relate to the importance of certification for how students see themselves. Increased credibility and self-confidence did not appear to be major reasons for undertaking certification. The lowest ranked of the proposed benefits was the flexibility of study enabled because of online curriculums. Whilst certification providers such as the Cisco Networking Academies pioneered delivery of quality e-learning material, online materials are now routinely available to IT students whether or not they are attempting certifications (McCormick, 2000; Peffers & Bloom, 1999), thus reducing the perceived importance of this benefit.

Several themes appear to emerge from the examples of benefits that have been proposed. To determine the number and nature of factors underlying the various benefits identified from the literature, a principal components factor analysis with varimax rotation was performed in SPSS 11.5 using the data from the 145 respondents. Three factors with eigenvalues of greater than one emerged indicating the existence of three underlying dimensions (see Table 4 for factor loadings).

Examination of the benefits associated with each factor led to naming the factors as follows:

- marketability benefits - which relate to desirability in the eyes of employers

Table 3: Benefits of certification

Rank	Benefits	N	Mean	SD	Min.	Max.
1	Practical experience with real networking tasks	143	4.57	0.60	2	5
2	Experience with real equipment	143	4.55	0.62	2	5
3	Widely recognized qualification	142	4.39	0.71	1	5
4	Greater knowledge/skill	143	4.29	0.64	2	5
5	Able to apply for the increasing number of jobs that require certification	143	4.19	0.75	1	5
6	Obtaining a formal marketable qualification	143	4.11	0.85	1	5
7	Academics that teach certifications must be certified, so you can be confident of their knowledge	143	4.08	0.84	1	5
8	Higher salaries	143	4.00	0.88	1	5
9	Increased credibility	143	3.99	0.77	1	5
10	Increased self-confidence	143	3.89	0.97	1	5
11	Flexibility of study because of online curriculum	142	3.62	0.97	1	5

Table 4: Factor loadings of benefits

	Marketability Benefits	Personal Benefits	Learning Benefits
Experience with real equipment	0.10	0.18	<b>0.90</b>
Practical experience with real networking tasks	0.21	0.18	<b>0.89</b>
Obtaining a formal marketable qualification	<b>0.75</b>	0.13	0.26
Greater knowledge/skill	0.48	0.13	<b>0.52</b>
Higher salaries	<b>0.76</b>	0.28	0.06
Widely recognized qualification	<b>0.71</b>	0.27	0.20
Flexibility of study because of online curriculum	0.12	<b>0.78</b>	0.16
Increased credibility	0.34	<b>0.78</b>	0.16
Increased self-confidence	0.17	<b>0.80</b>	0.19
Able to apply for the increasing number of jobs that require certification	<b>0.60</b>	0.46	0.11
Academics that teach the Cisco curriculum must be certified, so you can be confident of their knowledge	0.43	<b>0.53</b>	0.06
Percent of variance explained	24.04%	23.20%	18.99%

- personal benefits - which relate to the impact of the certification on the way in which the student perceives themselves and to the ease of their study
- learning benefits - which relate to intrinsic fulfillment from the type of learning.

It appears that these factors summarize the major types of benefits that students anticipate will accrue from certification.

### Risks

Table 5 presents the average perceived importance of each of the potential risks of, or concerns about, IT certification. The ratings of risks are ranked by perceived importance. The average importance ratings for the risks are mostly well below those of the benefits discussed above. So whilst the participants were conscious of the potential risks, they did not appear to be overly concerned about them.

The highest ranked risk was that the rapidly changing knowledge base might mean that certification is not of lasting value. IT has been changing rapidly over a long period and this rate of change is likely to continue or increase (Benamati & Lederer, 2001; Fordham, 2001). Organizations find it difficult to obtain personnel with the appropriate knowledge and skills in order to meet the growing demands for IT services (Doke, 1999). This rapid rate of change is one of the factors that have contributed to the desirability of certified employees, as they provide a way for employers to obtain a pool of employees with up to date skills. However, the rapidly changing knowledge base also means that certification may not be of lasting value, and means that recertification is necessary. Gabelhouse (2000) found that 75% of certification holders shoulder some of the costs of certification, with 45% paying for everything themselves. If regular recertification is required, the costs and investments of time can become prohibitive.

The middle group of risks relate to the potential for bias in certification. The second ranked risk was the absence of an unbiased neutral group for creating exams and approving examiners, and the third ranked risk was the absence of an unbiased neutral group for determining content. The fourth ranked risk was heavy involvement of vendors. Whilst vendor neutral certifications do exist, most certifications are linked to vendors and this has been raised as an issue of concern (Ray & McCoy, 2000). Again, students appear to be aware of the issue, but not overly concerned about it. They appear to accept the central role of vendors in the IT industry.

Concerns have been raised by several authors (Nelson & Rice, 2001; Ray & McCoy, 2000) that academics might not be comfortable with the loss of control over content that occurs because of the role of certification exams. They might also be uncomfortable with the pressure to maintain their own proficiency levels and certification status. Not surprisingly, these concerns are the two lowest ranked concerns of the students surveyed in this study.

### CONCLUSION

IT certifications are a popular adjunct to traditional means of preparing for a career in IT. Many educational institutions offer a range of IT certifications. This study explored the perceptions of students

Table 5: Risks of certification

Rank	Risks	N	Mean	SD	Min.	Max.
1	The rapidly changing knowledge base might mean that the certification is not of lasting value	138	3.91	0.82	1	5
2	The absence of an unbiased neutral group for creating exams and approving examiners	139	3.58	0.78	1	5
3	The absence of an unbiased neutral group for determining content	140	3.49	0.81	1	5
4	Heavy involvement of vendors	139	3.47	0.81	1	5
5	Academics might be uncomfortable with the pressure to maintain their own proficiency levels and certification status	138	3.34	0.79	1	5
6	Academics might be uncomfortable with the thought that certification exams determine content of courses and academic programs	138	3.30	0.79	1	5

currently undertaking courses of study that could lead to IT certification. Certification was perceived as an important factor in achieving employment and students undertaking it anticipate that it will lead to substantial financial benefits. Yet higher salaries are not seen as the most important benefit of certification. The potential benefits that students believe are most important relate to the 'real world' experience that is part of some certifications. They also value the potential improvement in knowledge and skill to which certification should lead.

Those respondents who were currently working in the IT industry had realistic perceptions of the likely salary increases available once certification was obtained, but those students with no IT experience appeared to overestimate the potential financial benefits. Instructors should ensure that they have current information about salaries and employers' skill requirements so that they can help guide their students.

The respondents were aware of the possible risks of certification but did not appear to be overly concerned about them. The issue considered most important was the potential for the rapidly changing knowledge base to mean that certification is not of lasting value.

Obtaining IT certification has become an important consideration for the IT profession. More research is needed to understand the benefits of IT certification and to determine the importance of the proposed risks. The study reported on in this paper has provided a starting point, but future research should extend it to holders of IT certifications and to employers.

### REFERENCES

- Alexander, S. (1999). Sorting out certifications. *Computerworld* (Dec 13).
- Benamati, J., & Lederer, A. L. (2001). Coping with rapid changes in IT. *Communications of the ACM*, 44(8), 83-88.
- Brookshire, R. G. (2000). Information technology certification: Is this your mission? *Information Technology, Learning, and Performance Journal*, 18(2), 1-2.
- Clyne, M. (2001). Employee recruitment & retention - certification's role. *Professional Certification Magazine*.
- Doke, E. R. (1999). Knowledge and skill requirements for information systems professionals: An exploratory study. *Journal of IS Education*, 10(1), 10-18.
- Downes, S., & Hobbs, V. (2000). An exploratory study of the representation and performance of females in Information Technology at Murdoch University. *Proceedings of the International Information Systems Education Conference (ISECON)*, Philadelphia.
- Fitzsimmons, C. (2000). Doing IT for themselves. *Information Age* (April).
- Fordham, D. R. (2001). Forecasting technology trends. *Strategic Finance*, 83(3), 50-54.
- Gabelhouse, G. (2000). *CertMag's Salary Survey*. Retrieved 9 July, 2003, from [http://www.certmag.com/issues/dec00/feature\\_gabelhouse.cfm](http://www.certmag.com/issues/dec00/feature_gabelhouse.cfm).
- IDC Inc. (1999). *Benefits and Productivity Gains Realized Through IT Certification*. Retrieved 9 July, 2003, from [http://www.ecertifications.com/idcrep\\_itcert.html](http://www.ecertifications.com/idcrep_itcert.html).
- Karr, S. S. (2001). IT certification pays off. *Financial Executive* (December), 60-61.
- Klawe, M., & Leveson, N. (1995). Women in computing where are we now? *Communications of the ACM*, 38(1), 29-35.
- McCormick, J. (2000). The new school. *Newsweek*, 135(17), 60-62.
- McGill, T., & Dixon, M. (2003). How do IT students stay up to date with employer' skill requirements. In T. McGill (Ed.), *Current Issues in IT Education* (pp. 144-152). Hershey, PA: IRM Press.
- Nelson, M. L., & Rice, D. (2001). Integrating third party-certification with traditional computer education. *The Journal of Computing in Small Colleges*, 17(2), 280-287.
- Otterbourg, S. D. (1999). Cisco Systems and Hewlett-Packard prepare the workforce for the future. *Education + Training*, 41(3), 144-145.



Peppers, K., & Bloom, S. (1999). Internet-based innovations for teaching IS courses: The state of adoption, 1998-2000. *Journal of Information Technology Theory and Application*, 1(1), 1-6.

Ray, C. M., & McCoy, R. (2000). Why certification in information systems? *Information Technology, Learning, and Performance Journal*, 18(1), 1-4.

Wilde, C. (2000). Demand for IT pros drives vendor certification growth — but multiple-choice tests aren't always a true measure of skills and experience. *Information Week* (Sept 25), 214.

0 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:

[www.igi-global.com/proceeding-paper/information-technology-certification/32360](http://www.igi-global.com/proceeding-paper/information-technology-certification/32360)

## Related Content

---

### What Have We Learned from Almost 30 Years of Research on Causal Mapping? Methodological Lessons and Choices for the Information Systems and Information Technology Communities

Gerard P. Hodgkinson and Gail P. Clarkson (2005). *Causal Mapping for Research in Information Technology* (pp. 46-80).

[www.irma-international.org/chapter/have-learned-almost-years-research/6745](http://www.irma-international.org/chapter/have-learned-almost-years-research/6745)

### Forecasting Water Demand With the Long Short-Term Memory Deep Learning Mode

Junhua Xu (2024). *International Journal of Information Technologies and Systems Approach* (pp. 1-18).

[www.irma-international.org/article/forecasting-water-demand-with-the-long-short-term-memory-deep-learning-mode/338910](http://www.irma-international.org/article/forecasting-water-demand-with-the-long-short-term-memory-deep-learning-mode/338910)

### FLANN + BHO: A Novel Approach for Handling Nonlinearity in System Identification

Bighnaraj Naik, Janmenjoy Nayak and H.S. Behera (2018). *International Journal of Rough Sets and Data Analysis* (pp. 13-33).

[www.irma-international.org/article/flann--bho/190888](http://www.irma-international.org/article/flann--bho/190888)

### Navigating Complex Systems Design with the PEARL Framework

Donna Champion (2016). *International Journal of Information Technologies and Systems Approach* (pp. 19-31).

[www.irma-international.org/article/navigating-complex-systems-design-with-the-pearl-framework/144305](http://www.irma-international.org/article/navigating-complex-systems-design-with-the-pearl-framework/144305)

### A Hierarchical Hadoop Framework to Handle Big Data in Geo-Distributed Computing Environments

Orazio Tomarchio, Giuseppe Di Modica, Marco Cavallo and Carmelo Polito (2018). *International Journal of Information Technologies and Systems Approach* (pp. 16-47).

[www.irma-international.org/article/a-hierarchical-hadoop-framework-to-handle-big-data-in-geo-distributed-computing-environments/193591](http://www.irma-international.org/article/a-hierarchical-hadoop-framework-to-handle-big-data-in-geo-distributed-computing-environments/193591)