Application of the Analytic Hierarchy Process on Data Warehouse System Selection Decisions for Small and Large Enterprises in Taiwan

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Abstract

The study investigates the practice of data warehouse system selection decisions for small and medium-sized enterprises (SMEs) and large enterprises (LEs) in Taiwan. The increasing number of companies looking for data warehousing solutions to gain a significant business advantage has created a need for systematic method for choosing appropriate data warehouse system. The aim of this study is to determine the significant factors that influenced data warehouse system selection of LEs and SMEs. In this paper, both technical and managerial factors are considered to structure an evaluation hierarchy based on the Analytic Hierarchy Process (AHP). The AHP is used to examine the relative importance of data warehouse system selection criteria and subcriteria. The results indicate that SMEs selecting data warehouse systems mainly concentrate on cost and vendor criteria, and LEs focus on technical criteria.

Keywords: Multiple Criteria Decision Aid, Analytic Hierarchy Process (AHP), Data Warehouse System, Software Selection, Small and Large Enterprise.

1. Introduction

The continuously growing competition on the global market has forced many companies to adopt and use information systems and technologies. Information systems (IS) can extremely transform business processes to achieve major improvements in quality, performance and productivity through the optimal use of information technologies (IT). The continuing improvements and the rising use of advanced information systems help enterprises to improve operating efficiency and reduce costs. Information systems have long been used by large enterprises (LEs) to automate business processes. In recent years, there are more and more small and medium-sized enterprises (SMEs) implemented enterprise-wide software systems such as ERP systems to obtain potential benefits [52, 75, 86].

Owing to the complexity and diversity of software systems, selecting the best or most appropriate software package to satisfy an organization's requirements is a particularly difficult problem. The demand for high-quality and reliable software conforming to international standards, and integrated with existing information systems and infrastructure is increasing continuously.

Because of the popularity of implementing different information systems within companies, the number of information system applications available on the market is also increasing exponentially. However, the total cost of information systems, including acquisition cost, operation cost, training cost and maintenance cost, is also rising dramatically.

With the implementation of business processes automation software in enterprises, data are piled up quickly enterprise-wide. To organize the data and help companies make sensible business decision, data warehousing implementation is expected to grow quickly [49, 71, 89]. When implemented correctly, a data warehouse (DW) system enables companies to enjoy benefits and obtaining timely information for decision-making [22]. However, due to the complicated and variety of functionality of available data warehouse systems, it has been a burdensome task for many companies to evaluate and select data warehouse system that fit into their requirements within the given budget constraints and limited time. Although the concept of data warehousing has been around for more than one decade, it has largely remained the domain of the large enterprises. In spite of large enterprises had higher adoption rate of data warehouse systems in Taiwan [28], the data warehouse system still remains an illusive information system for most small and medium-sized enterprises.

The literature revealed that there is a relationship between firm size and information system implementation [29, 61]. The previous research argued that research findings based on large enterprises cannot be generalized to small enterprises as the inherent differences between small and large businesses [7, 14]. Due to their limited sources, IT adoptions of SMEs differ from large enterprises [19, 81]. The limited knowledge and experiences with IT may influence the ability to adopt information systems effectively for SMEs. According to the research conducted by Chau [11], SMEs tended to focus on selecting of software packages provided by vendors rather than developing information systems in-house, and SMEs relied more on packaged software than large enterprises do [26]. This has caused SMEs depend more extensively than large businesses on external support.

Software selection is not a technical task, but instead a subjective and uncertain decision process [73]. Selecting the optimum software system among many products available depends on the assessment of their objective, measurable criteria (e.g., acquisition cost and training cost) and subjective criteria (e.g., compatibility, vendor selection and technical factors). The software selection decision involves not only simultaneously considering multiple criteria, but also considering multiple tangible and intangible factors affecting software selection, and making priorities among those factors can be hard. Kimball et al. [36] suggested some evaluation areas, process and criteria for data warehouse products selection. The two key components that drive the selection of products are business and technical requirements. But it lacks a systematic decision-aid method for choosing appropriate data warehouse system. Given the differences of organizational, decisional, psycho-sociological, informational and technological between LEs and SMEs [1, 7], this study makes an assumption that the selection decisions of data warehouse systems will differ between LEs and SMEs.

The analytic hierarchy process (AHP) is one widely used multi-criteria decision-making method introduced by Saaty [64]. The AHP structures a decision problem into a hierarchy and evaluate multi-criteria tangible and intangible factors systematically. AHP has been applied in numerous fields [20, 87, 93], including many software selection decisions. The objective of this paper is to propose a framework of decision criteria for evaluating and selecting data warehouse systems enterprises in Taiwan based on the analytic hierarchy process, and finds the decision differences between LEs and SMEs.

Taiwan has mainly relied on its small and medium-sized enterprises to compete in international markets since the 1970s. In Taiwan, there were 1,130,525 SMEs in 2002 which accounted for 97.72% of all enterprises. In terms of numbers, persons employed by SMEs was 7,361 thousand (77.86% of the total) and total sales for all SMEs in 2002 came to 7495.3 billion New Taiwan Dollar (29.51% of the total) [27]. There is no generally accepted definition of a SME. The commonly used criterion for defining a SME is number of employees; however this number varies from country to country [16, 21, 29, 46]. The definition of a SME for this study is in accord with Taiwanese legislation. The Ministry of Economic Affairs defines SMEs as companies employing fewer than 200 people.

The rest of the paper is organized as follows: Section 2 gives an overview of the AHP methodology and its applications on software selection. Section 3 describes the selection criteria for data warehouse systems. The applying of the AHP for evaluation data warehouse systems for LEs and SMEs is presented in Section 4. Finally, Section 5 concludes the study and proposes for further research.

2. Literature Review

2.1 The Analytic Hierarchy Process

AHP first developed by Saaty [64] resolves decision-making problems by structuring each problem into a hierarchy with different levels of criteria. Pairwise comparisons are performed with the criteria in a hierarchy by means of scale of measurement. The scale of relative importance measurement consists of judgments ranging from equal importance to extreme importance (equal, moderate, essential or strong, demonstrated, extreme) corresponding to the numerical judgments (1, 3, 5, 7, 9) and compromises (2, 4, 6, 8) between these values [65, 67]. The decision-maker needs to judge the relative importance of each criterion and then specify a preference on each criterion for decision alternatives.

The AHP method involves four steps to solve a decision problem [44, 77, 93]:

Step 1: Structuring the decision problem

The first step involves developing a hierarchical structure of the problem. The number of levels in the hierarchy depends on the complexity of the decision problem. The typical hierarchy of the AHP model consists of focus, criteria, subcriteria and alternatives [66, 68]. The highest level of the hierarchy is the overall goal or focus. The intermediate levels consist of the criteria and subcriteria for judging the alternatives. The need of intermediate levels depends on the decision problem and experiences of the AHP and domain knowledge for decision makers. The bottom level of the hierarchy contains alternatives from which the choice is to be made. There should not include too many criteria in a hierarchy [66].

Step 2: Creating pairwise comparison matrix

Creating a pairwise comparison matrix is an attempt to find the relative importance among the criteria. The nine-point scale is used to obtain a concise pairwise comparison of all criteria at each level of the hierarchy [56, 67]. The pairwise comparison judgments are made with respect to elements of one level of hierarchy given the element of the next higher level of hierarchy, starting from the top level down to the bottom level. For a group decision setting, every team member assigns his or her own pairwise comparison. Four methods can combine the individual pairwise comparison matrix to obtain the consensus pairwise comparison matrix for the entire team: consensus; vote or compromise; geometric mean approach, and separate models or players [17].

Step 3: Determining normalized weights

The eigenvector derived from the matrix created in Step 2 measures of relative importance among the criteria and is used to determine the normalized and unique priority weights for each criterion. In order to check the consistency in setting priorities for pairwise comparison with respect to criteria, the AHP uses a consistency ratio to measure the consistency of judgments. Saaty [66] suggested the consistency ratio should be 0.1 or less.

Step 4: Synthesize the priorities

The final step is to synthesize the solution for the decision problem - to obtain the set of overall priorities for alternatives. The normalized local priority weights of criteria and subcriteria obtained from Step 3 are aggregated to produce global composite weights which used to evaluate decision alternatives.

2.2 Software Selection by Using AHP

Decision-making in software selection has become more complex due to a large number of software products in the market, ongoing improvements information technology, and multiple and sometimes conflicting objectives. Decision-makers in diverse sectors have made software selection decisions. The literature reviewed was limited to software selection applications of AHP. The review of software selection cases cannot be claimed as comprehensive; however it demonstrates the diversity of software selection applications where AHP is used.

All software selection decision problems involved an optimal choice from a set of alternatives. All most software decisions included alternatives of different software systems or packages for selection. The only exception was the selection of workflow management systems [33]. The evaluation was performed for eleven industries in South Korean, but not for different workflow management software packages. The types of software system for decision making are office automation software [5, 69], accounting information system [70], database management system [92], computer operating systems [63], expert systems [34, 94], logistics software [47], automated manufacturing systems (AMS) [48], manufacturing simulation software [42], workflow management systems [33], AHP software [54], Enterprise Resource Planning (ERP) systems [78] and multimedia authoring systems (MAS) [39, 40].

3. Criteria for Selecting Data Warehouse System

Due to the fact that software selection is an important issue for many organizations; previous studies stated their preferred AHP hierarchies of criteria and subcriteria for software selections. Appendix A shows details of criteria and subcriteria for software selections in the major literature reviewed. For the literature reviewed of 15 published papers between 1981 and 2002, a proposed list of criteria can generally be grouped into several evaluation categories. This study groups the reviewed criteria into the following four major evaluation categories:

- Technical: These criteria are limited to the capabilities and technical requirements of the software system to improve diversity of operations, and the integration capability and flexibility of software systems.
- Managerial: These criteria are concerned with the administration features of software systems which satisfy the goals of decision makers.

- Cost: The different costs associated with the software acquisition, maintenance and use.
- Vendor: The issues that needed to be addressed in evaluating software vendors include vendor reputation, confidence and stability; and support of system installation, training services and maintenance.

Table 1 lists the evaluation categories of criteria and sub-criteria, and the authors who have introduced them. As showed in Table 1, the technical, managerial, cost and vendor criteria have been adopted by many software selection decisions. Hence, in this study, we adapt Lai et al. [39, 40] suggestions and classify the decision criteria into two categories, namely technical and managerial issues. Technical issues examine if system features fit companies needs and how effective it can be integrated with existing systems. Managerial criteria consider the issues of cost and vendor quality which are not part of technical factors but will nevertheless greatly affect the adoption and success of the software systems. In the following sections, we briefly discuss these criteria and related subcriteria.

Table 1: Categories of criteria introduced by author(s) in the major literature reviewed

Author(s)	Software system				
Beck & Lin (1981)	Automated office system	■	■		■
Seidmann & Arbel (1983)	Office automation software	■	■		
Seidmann & Arbel (1984)	Accounting information system	■	■		
Zahedi (1985)	Database management system	■		■	
Roper-Lowe & Sharp (1990)	Computer operating system	■	■		
Zahedi (1990)	Expert system	■			
Kim & Yoon (1992)	Expert system shell	■			
Min (1992)	Logistics software	■		■	■
Mohanty & Venkataraman (1993)	Automated manufacturing system	■	■	■	
Lesley & Glyn (1994)	Manufacturing simulation software	■		■	■
Kim & Moon (1997)	Workflow management system	■	■		
Lai et al. (1999)	Multimedia authoring system	■	■	■	■
Ossadnik & Lange (1999)	AHP software	■		■	
Teltumbde (2000)	ERP system	■	■	■	■
Lai et al. (2002)	Multimedia authoring system	■	■	■	■

Note: T: Technical, M: Managerial, C: Cost, V: Vendor.
The shadowed boxes denote that the authors have introduced the criteria in the related categories.

3.1 Technical Features

Technical features determine how well the software system can satisfy the company's requirements and how effectively it can fit in with the existing information systems and infrastructure. The technical aspects for data warehouse system selection include front-end utilities and back-end utilities [12, 36].

(1) Front-end Utilities

The front-end utilities are the part responsible for presenting and accessing data to the user community.

The front-end services should provide users with diverse needs that are commonly required of browsing, querying and reporting warehouse data. The front-end utilities include display interface [8, 23, 84], analysis tools [85] and query functionality [50, 58, 85].

- Display interface: Display interfaces are usually supported by two types of software, namely, spreadsheet programs such as Microsoft Excel or Internet browsers.
- Analysis tools: Analysis tools provide interfaces for end users to analyze data stored in the data warehouse system. The analysis tools consist of periodic access tools, query and reporting tools, and advanced analysis tools.
- Query functionality: Due to the characteristics of queries performed on data warehouses, the systems should at least support five types of functionality, namely, slice and dice, drill down and roll up, drill across, ranking, and rotating.

(2) Back-end Utilities

The back-end utilities are part of the warehouses responsible for gathering, preparing, and storing the data, and managing the data warehouse system. It also stresses the compatibility and integration capability of software systems. Therefore, the back-end utilities consist of compatibility [5, 47], integration [8, 23, 25, 51, 56], database [8, 12, 56], ETL functionality [8, 13, 37, 55], data quality checks [4, 80, 88], metadata management [13, 31, 85] and DW administration [12, 85].

- Compatibility: The fundamental technique of data warehouse software should be compatible with the existing IT infrastructure of the companies.
- Integration: The integration issue examines if the data warehouse system can be integrated with heterogeneous source systems, other decision support systems and third party tools.
- Database: The physical design of data warehouse converts logical data design into physical database. Data warehouse might be implemented on standard or extended relational database system (ROLAP), or multidimensional database (MOLAP).
- ETL functionality: The data staging process collects operational source data and integrates the data into data warehouse. It consists of three major steps: extraction, transformation and load (ETL). The ETL tools can help the extraction, transformation and load processes automatically.
- Data quality checks: Since data quality will impact on the credibility of data warehouse. When implementing a data warehouse system, maintaining data quality is a major concern. The quality factors in data warehouse design include data currency, data consistency and data completeness.
- Metadata management: Metadata maintenance is an important issue, because it has influence on the entire warehouse from initial model through data extraction and load processes to the exploration and access of users.
- DW administration: Data warehouse administrating tools can help system administrators to manage the operations of data warehouse throughout its operational life cycle.

For more detail descriptions and related references for technical features, please refer to Appendix B.

3.2 Managerial Decision Criteria

The managerial criteria are concerned with the administration features of software systems which satisfy the goals of decision makers. For the managerial factors, cost and vendor characteristics are two important elements [39, 40, 74].

The cost factors have also been considered for a diversity of software system decision problems [39, 40, 42, 47, 48, 54, 78, 92]. Data warehouse systems have differential expenditures, some are considered more expensive than others. The concept of total cost of ownership (TCO) not only includes the price of purchase but also many other purchase-related costs [6]. The TCO consists of all costs associated with the acquisition, use and maintenance of products or services [15, 18].

One important IT management function of supply side factor is the procurement of IT products to satisfy the requirements of a company [76]. Vendors play a key role in the acquisition of IT products and computerization of an organization [2, 24]. Hence, selection of suitable vendor should be taken into account when implemented data warehouse system. Vendor can provide related products, technological capability and knowledge and experiences to help implement data warehouse system [35]. The vendor criteria have been applied to many software selection problems [5, 39, 40, 42, 47, 78].

(1) Total Cost of Ownership

From the TCO viewpoint, the costs of software system should include costs associated with the software acquisition, maintenance and use. The TCO comprises many items, including direct cost and indirect cost [53]. Love and Irani [46] also identified IT costs as direct cost and indirect cost. The direct cost consists of the purchase of software packages that including license fee, the hardware cost for installing and running software systems, and the external consultant fee to assist implement the systems. The indirect cost comprises users in learning the hardware and software systems - training cost, the maintenance cost for systems operate normally, system upgrade cost for system scalability and advanced functionality in the future, along with the labor cost of support personnel.

(2) Vendor Characteristics

Some researches discussed the vendor selection problems by using the AHP [57, 60, 77]. The AHP approach was suggested due to its inherent capability to operate qualitative and quantitative criteria used in vendor selection. It is important for vendor to provide ongoing supports for system installation and maintenance after purchasing software. Therefore, enterprises desire to purchase the software packages from more credible and stable vendors. The issues that needed to be addressed in evaluating software vendors include vendor reputation [9, 38, 47, 77, 78], vendor stability [47, 78], vendor support [5, 9, 39, 40, 77, 78] and vendor experience [30, 59, 77].

- Vendor reputation: The commitments of vendors to the products and continuous improvement affect the longevity of data warehouse products. The vendor's reputation is a good benchmark for evaluating the credibility, goodwill and reliability of vendor.
- Vendor stability: The data warehouse implementation and ongoing operations will continue with many years. The vendor stability may affect the service supports from vendor afterward.
- Vendor support: In view of the operations of data warehouse system after implementation, the ongoing supports from vendor constitute

crucial factor. The value of system would increase with vendor supporting long-term technical assistance and sustained services.

- Vendor experience: The external support can contribute to the data warehouse implementation process. The vendors can provide experiences with all aspects during system implementation.

For more detail descriptions and related references for vendor characteristics, please refer to Appendix B.

4. Applying the AHP

The AHP modeling process involves four steps as described in previous literature review, namely, structuring the decision problem, creating pairwise comparison matrix, determining normalized weights and synthesize the priorities.

4.1 Structuring the Data Warehouse System Selection Problem

The survey was pre-tested with four consultants from three data warehousing vendors to ensure that all the criteria were well formulated and properly understood. These respondents have an average of 5.3 years experiences in data warehousing projects. The respondents in the pre-test were interviewed to discuss the selection criteria in more detail and reformulate the AHP hierarchy. The first respondent is the Taiwan sales director of the world's second biggest e-business software vendor. She suggested moving the data quality checks feature one level higher from DW administration, due to her practical experiences showed that data quality affects the accuracy of analytic data. The second respondent is a vice general manager of the world largest e-business software vendor. He agreed with the opinion of first respondent, and clarified some wording of elements at bottom level. The third respondent is the director of a DW department, and fourth respondent is a project manager of a DW vendor. The third and fourth respondents did not suggest any revision of the AHP model and wording of criteria and subcriteria, hence the pre-test process was concluded.

This first step involves formulating an appropriate hierarchy of the AHP model consisting of the goal, criteria and subcriteria according to the results of pre-test. Figure 1 shows the structuring of the data warehouse system selection decision into a hierarchy of four levels. The top level of hierarchy presents the overall goal or focus of the problem. The general criteria are usually considered important in determining the appropriateness of data warehouse software which forms the second level of the hierarchy. The two major criteria are technical features and managerial factors [39, 40]. At the third and fourth levels, these criteria are decomposed into more detailed elements that may affect the system selection. The third level of the hierarchy places the subcriteria defining the four subcriteria for the second level criteria. The technical capabilities can be divided into two major areas: front-end and back-end utilities [12, 36]. For the managerial factors, cost and vendor characteristics are two important elements [39, 40, 74]. There are three fourth level subcriteria related to front-end utilities, namely, display interface, analysis tools and query functionality. The back-end utilities include seven subcriteria: compatibility, integration, ETL functionality, database, data quality checks, metadata management, and DW administration. On the other hand, the subcriteria associated with total cost of ownership are direct cost and indirect cost. The vendor characteristics consist of vendor reputation, vendor stability, vendor support and vendor experience.

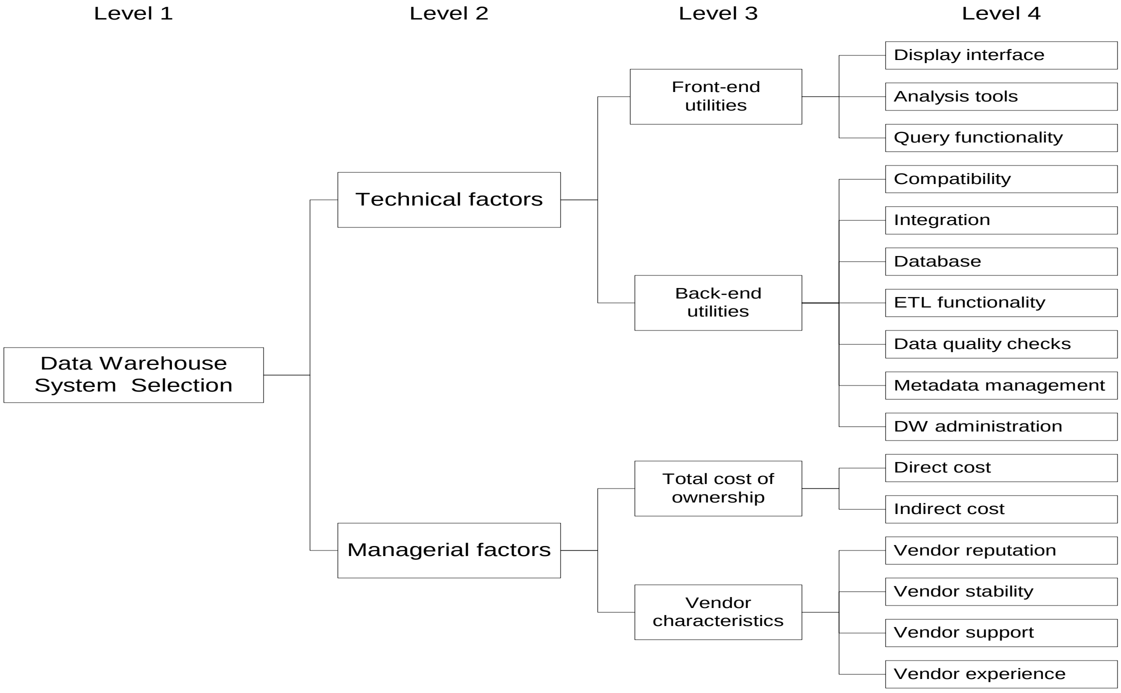

Figure 1: AHP model for data warehouse system selection

4.2 Creating Pairwise Comparison Matrix

Owing to a shortage of professional IT experts, it is not easy to find SMEs that could respond to our questions in an interview. Therefore, we chose experienced consultants from leading DW vendors which including international and local companies. Using market research of Market Intelligence Center (MIC), Information Industry Institute (III) in Taiwan, we found that there are only six international vendors active in Taiwan's DW market; only three leading companies in the global DW market were willing to participate on this project. Also, all three e-business software companies listed on the Taiwan Stock Market participated. In total, both international and local vendors had roughly two hundred and sixty customers in Taiwan; more than one hundred of which are SMEs.

A questionnaire including all criteria and subcriteria of the four levels AHP hierarchy was designed to collect the pairwise comparison matrices. The questionnaire was composed of three sections. The first section gathered experts' background information, which included factors such as respondent's position, years of data warehouse experiences, and contact information. The second section included seven pairwise AHP comparison matrices to identify the importance of criteria. A supplementary which described the hierarchy, detail explanation of each criterion and a sample questionnaire was also provided. Each evaluator is requested to fill in two sets of pairwise comparison matrices, one for SMEs and another for LEs. Before filling out the matrix, all experts were given a briefing in how to create pairwise comparison matrices. The collected data were then analyzed and normalized.

4.3 Determining Normalized Weights

The pairwise comparison matrices obtained from six experts are combined using the geometric mean approach. Table 2 and Table 3 present the normalized matrices of the result for SMEs and LEs separately. The consistency ratio (CR) of each pairwise comparison matrix is also shown. It can be found that the CR values are far less than 0.1, the value suggested by Saaty [66]. This indicates that the experts' opinions are consistent in measuring the pairwise comparison judgments. Besides, the CR values between matrices filled out by the same experts are also less than 0.1. This implies that the data in each questionnaire are consistent.

Table 2: Normalized matrices of pairwise comparison judgment for SMEs

Software Package Selection	A	B	Priority
A Technical factors	1	0.47	0.321
B Managerial factors	2.12	1	0.679
			CR=0.0

A Technical factors	A1	A2	Priority
A1 Front-end utilities	1	0.87	0.465
A2 Back-end utilities	1.15	1	0.535
			CR=0.0

B Managerial factors	B1	B2	Priority
B1 Total Cost of ownership	1	1.31	0.567
B2 Vendor characteristics	0.76	1	0.433
			CR=0.0

A1 Front-end utilities	A11	A12	A13	Priority
A11 Display interface	1	1.06	1.14	0.354
A12 Analysis tools	0.94	1	1.28	0.354
A13 Query functionality	0.88	0.78	1	0.293
				CR=0.003

A2 Back-end utilities	A2	A22	A23	A24	A25	A26	A27	Priority
A21 Compatibility	1	1.41	2.881.8	1.59	1.62	1.99	0.96	0.212
A22 Integration	0.7	1	1.31	0.81	0.79	0.66	0.76	0.116
A23 Database	0.3	0.76	1	0.47	0.64	0.55	0.5	0.078
A24 ETL functionality	0.6	1.23	2.14	1	1.67	1.67	1.28	0.177
A25 Data quality checks	0.6	1.27	1.56	0.6	1	0.89	0.82	0.124
A26 Metadata management	0.5	1.52	1.82	0.6	1.12	1	0.92	0.134
A27 DW administration	1.0	1.32	2.0	0.78	1.22	1.09	1	0.159
								CR=0.01

B1 Total cost of ownership	B11	B12	Priority
B11 Direct cost	1	3.47	0.776
B12 Indirect cost	0.29	1	0.224
			CR=0.0

B2 Vendor characteristics	B21	B22	B23	B24	Priority
B21 Vendor reputation	1	0.89	0.49	0.37	0.145
B22 Vendor stability	1.12	1	0.46	0.42	0.156
B23 Vendor support	2.04	2.17	1	1.28	0.355
B24 Vendor experience	2.7	2.38	0.78	1	0.344
					CR=0.01

Table 3: Normalized matrices of pairwise comparison judgment for LEs

Software Package Selection	A	B	Priority
A Technical factors	1	3.22	0.763
B Managerial factors	0.31	1	0.237
			CR=0.0

A Technical factors	A1	A2	Priority
A1 Front-end utilities	1	0.74	0.426
A2 Back-end utilities	1.35	1	0.574
			CR=0.0

B Managerial factors	B1	B2	Priority
B1 Total Cost of ownership	1	0.76	0.433
B2 Vendor characteristics	1.31	1	0.567
			CR=0.0

A1 Front-end utilities	A11	A12	A13	Priority
A11 Display interface	1	1.06	1.26	0.362
A12 Analysis tools	0.94	1	1.62	0.379
A13 Query functionality	0.79	0.62	1	0.259
				CR=0.01

A2 Back-end utilities	A21	A22	A23	A24	A25	A26	A27	Priority
A21 Compatibility	1	0.72	1.16	0.64	0.89	0.88	0.58	0.113
A22 Integration	1.39	1	1.47	1.66	1.07	0.76	0.6	0.153
A23 Database	0.86	0.68	1	0.88	1.05	0.74	0.55	0.112
A24 ETL functionality	1.56	0.6	1.14	1	1.51	1.17	0.85	0.151
A25 Data quality checks	1.12	0.94	0.95	0.66	1	0.68	0.62	0.116
A26 Metadata management	1.14	1.32	1.35	0.86	1.47	1	0.68	0.151
A27 DW administration	1.72	1.67	1.82	1.18	1.61	1.47	1	0.204
								CR=0.01

B1 Total cost of ownership	B11	B12	Priority
B11 Direct cost	1	0.6	0.373
B12 Indirect cost	1.68	1	0.627
			CR=0.0

B2 Vendor characteristics	B21	B22	B23	B24	Priority
B21 Vendor reputation	1	2.12	0.42	0.38	0.168
B22 Vendor stability	0.47	1	0.29	0.37	0.104
B23 Vendor support	2.38	3.44	1	1.16	0.382
B24 Vendor experience	2.63	2.7	0.86	1	0.346
					CR=0.02

4.4 Synthesize the Priorities

After calculating the normalized priority weights for each pairwise comparison matrix of the AHP hierarchy, the next step is to synthesize the local priority weights of criteria and subcriteria for obtaining the set of global composite priorities. Table 4 and Table 5 show the local and global priority weights of AHP model for SMEs and LEs separately. After computing the global priority weights of each subcriterion of level four, Table 6 shows the importance of sixteen subcriteria in influencing data warehouse system selection between SMEs and LEs. The direct cost factor is the most important subcriterion in influencing data warehouse system selection following with vendor support and vendor experience for SMEs. For LEs, the front-end utilities play critical factor. Two of the front-end utilities subcriteria, namely, analysis tools and display interface are in the top rankings. From viewpoint of back-end utilities, DW administration and integration are two significant factors for LEs. Among four vendor characteristics, vendor support and vendor experience are more important than vendor reputation and vendor stability for both SMEs and LEs.

Table 4: Composite priority weights of DW system selection for SMEs

Second level	Local weights	Third level	Local weights	Fourth level	Local weights	Global weights
Technical	0.321	Front-end utilities	0.465	Display interface	0.354	0.053
				Analysis tools	0.354	0.053
				Query functionality	0.293	0.044
		Back-end utilities	0.535	Compatibility	0.212	0.036
				Integration	0.116	0.020
				Database	0.078	0.013
				ETL functionality	0.177	0.031
				Data quality checks	0.124	0.021
				Metadata management	0.134	0.023
				DW administration	0.159	0.027
Managerial	0.679	TCO	0.567	Direct cost	0.776	0.299
				Indirect cost	0.224	0.086

		Vendor	0.433	Vendor reputation	0.145	0.043
				Vendor stability	0.156	0.046
				Vendor support	0.355	0.104
				Vendor experience	0.344	0.101
					Total	1.000

Table 5: Composite priority weights of DW system selection for LEs

Second level	Local weights	Third level	Local weights	Fourth level	Local weights	Global weights
Technical	0.763	Front-end utilities	0.426	Display interface	0.362	0.118
				Analysis tools	0.379	0.123
				Query functionality	0.259	0.084
		Back-end utilities	0.574	Compatibility	0.113	0.049
				Integration	0.153	0.067
				Database	0.112	0.049
				ETL functionality	0.151	0.066
				Data quality checks	0.116	0.051
				Metadata management	0.151	0.066
				DW administration	0.204	0.089
Managerial	0.237	TCO	0.433	Direct cost	0.373	0.038
				Indirect cost	0.627	0.064
		Vendor	0.567	Vendor reputation	0.168	0.023
				Vendor stability	0.104	0.014
				Vendor support	0.382	0.051
				Vendor experience	0.346	0.046
					Total	1.000

Table 6: Importance of subcriteria in influencing DW system selection between SMEs and LEs.

Subcriteria (Level 4)	Global weights (SMEs)	Rank (SMEs)	Global weights (LEs)	Rank (LEs)
Display interface	0.053†	5	0.118	2
Analysis tools	0.053†	5	0.123	1
Query functionality	0.044	8	0.084	4
Compatibility	0.036	10	0.049‡	11
Integration	0.020	15	0.067	5
Database	0.013	16	0.049‡	12
ETL functionality	0.030	11	0.066†	6
Data quality checks	0.021	14	0.051‡	10
Metadata management	0.023	13	0.066†	6

DW administration	0.027	12	0.089	3
Direct cost	0.299	1	0.038	14
Indirect cost	0.086	4	0.064	8
Vendor reputation	0.043	9	0.023	15
Vendor stability	0.046	7	0.014	16
Vendor support	0.104	2	0.051‡	9
Vendor experience	0.101	3	0.046	13

† The values are exact equal.
‡ The values are rounded.

4.5 Discussion of Results

Generally, a shortage of necessary resources and professional expertise of SMEs have been identified which corresponds to the findings of Welsh and White [90], and Blili and Raymond [7]. For SMEs, the limited financial resources should be considered for developing information systems strategies [43]. The limited access to capital resources leads to weaknesses in planning, control and training of information systems for SMEs [7], thus results in a lack of feedback on information system investments. As the importance of external IT expertise for information systems implementation within SMEs has been emphasized in the literature [3, 10, 19, 82, 83, 91], this implicates that SMEs are largely dependent on external sources including consultant assist and vendor support for advices on information systems implementation.

The main concerns anticipated by SMEs are cost and technical expertise. These obstacles also presumably explain why the cost and vendor characteristics are the most important criteria for data warehouse system selection in SMEs. This research supports what other studies on information technology in small and medium-sized enterprises: the lack of capital resources and IT expertise. However, the reasons for the focus on cost and vendor may be hard to overcome, especially as SMEs are likely to be due to a lack of financial, IT personnel and time resources.

In contrast with SMEs, LEs have sufficient resources on financial and IT expertise. This is why large enterprises do not consider the cost and vendor criteria as significant factors for DW systems selection. There are diversity kinds of information systems implemented in large enterprises. These enterprises use a diversity of information systems such as legacy systems, e-business solutions and ERP to automate and integrate business processes [79]. Usually, these information systems have diverse data formats, heterogeneous computing platforms and installed in different regions. The integration of different data sources into DW and management of the system are difficult and complicated. Large enterprises have more users spread enterprise wide utilized DW systems to assist reliable decision-making than SMEs. The DW system should provide ease to use and flexible interfaces for users accessing and analyzing mass of data. These tools are also needed to satisfy different requirements for diversity of users [32]. Hence, LEs tend to focus on technical factors when selecting DW systems. LEs pay more attention on indirect cost rather than direct cost which SMEs focused. This corresponds to the survey, the typical support cost (indirect cost) are about four times of the original purchase price (direct cost) for IT investments [62].

The Market Intelligence Center (MIC) of Information Industry Institute (III) conducted a data warehouse adoption survey in 2003. The survey reveals that 29% of responded enterprises already implemented DW systems, 22% planed to adopt DW systems within three years, and 49% did not have plan to install DW systems yet. The report also estimated that the sale of DW systems would grow from a NT$ 1.92 billion market in 2001 to a NT$ 6.3 billion market in 2005 with 34% compound annual growth rate (CAGR). The report also indicated that the market has moved from large enterprises to SMEs gradually.

The proposed model and criteria can help enterprises to improve the decision-making processes and reduce the time in evaluating and selecting a data warehouse system effectively. For an enterprise wants to make decision on DW system selection based on the proposed AHP model, it can take the following steps: (1) Establish a committee of decision makers (3-7 persons) which includes members with business and IT backgrounds. (2) Choosing three DW vendors to demonstrate their products. (3) Applying the AHP method (four stages as described in Section 4) for DW system selection according to vendors' presentation. The product with highest score or priority is the final choice to satisfy the overall decision goal of company.

5. Conclusions and Further Research

It is important to recognize the AHP model's limitations. It is possible that the focus on vendor side for pre-test is a source of bias. The pairwise comparison judgments may have been influenced by evaluator's subjectivity. The AHP model and pairwise comparison matrices were evaluated based on experiences and practices of experts. Therefore, new empirical studies are undoubtedly needed to refine the AHP model and related criteria. As this study was conducted on enterprises in Taiwan, the results may not be generalized to businesses in countries with very differing institutional and cultural contexts.

The AHP model developed in this study has provided substantially to the understanding of the decisions differences between SMEs and LEs for selecting data warehouse systems. The findings indicate that SMEs selecting data warehouse systems which mainly concentrate on cost and vendor criteria, and LEs focus on technical criteria. The decision-making of data warehouse system selection takes time and it seems likely that the proposed AHP model could greatly assist this complex process for companies. As data warehousing is still new for many companies, they should seek for external consulting advice. This would help them to better understand the benefits of implementing data warehouse systems and to improve the decision making quality and process.

Although the evidence shows that the information systems are beneficial to enterprises, it is not usually easy to make decision which software system to procure. The choice of a suitable software system can lead to productivity improved and costs reduced; the selection of an unsatisfactory software product can incur the loss of acquisition cost and time waste in short-term. Hence, the evaluation and selection of such software systems play an important role before real implementation. The increasing demand for timely business information and the need to improve the quality of decision making are motivating companies to consider implementing data warehouse system. The proliferation of data warehouse software packages has created a difficult, complex decision problem of evaluation and selection for companies.

The software selection process requires knowledge of the application area and understanding of the requirements of users or organizations. The work of software selection needs expertise in both the areas of software system and the specific application area. The methodology used for software selection should be practical, flexible, easy to understand and use, and inexpensive to implement [72]. The AHP satisfies these features and it provides as an excellent alternative to existing software selection and evaluation methodologies.

In this paper we present the appropriateness of the analytic hierarchy process to support data warehouse system evaluation and selection decision-making. The AHP can be applied if the decision problem includes multiple criteria and immeasurable factors. The AHP hierarchy is clearly defined to facilitate evaluation and reduce the conflicting viewpoints of evaluators. The hierarchy provides information about software system from two major perspectives: technical and managerial as shown in Figure 1. The presented taxonomy of data warehouse system evaluation criteria will be useful guides to those responsible for selecting data warehouse software. These criteria can be used to determine the relative importance of the various capabilities of products and vendors. The final global priority weights of subcriteria occupying fourth level of the hierarchy can be determined as shown in Table 6.

The most important direction of further research is to verify the derived AHP hierarchy and related criteria in practice. Some particular LEs and SMEs which planning to evaluate and select data warehouse system from a set of alternatives should provide an opportunity to test this AHP model. For other possible application, the AHP approach can combine with multiple and conflicting goals programming method under resource limitations situation [41].

With the increasing complexity of software selection, this makes AHP a decision support approach, which deserves the attention of many software selection applications. From the previous review, the AHP methodology is an excellent techniques as it provides a structure and hierarchy method of synthesizing software selection problems. The evidence of diversity software system selections shows that the AHP can be applied to the selection of software product consistent with the maximization of the underlying criteria and subcriteria expectations of the decision makers. In conclusion, we believe that the AHP is a useful technique for decision-makers addressing software selection problems.

References

[1] Ahire, S.L., and Golhar, D.Y. (1996). “Quality management in large vs. small firms”, *Journal of Small Business Management*, 34, 2, 1-13.

[2] Attewell, P. (1992). “Technology diffusion and organizational learning: the case of business computing”, *Organizational Science*, 3, 1, 1-19.

[3] Ballantine, J., Levy, M., and Powell, P. (1998). “Evaluating information systems in small and medium-sized enterprises: issues and evidence”, *European Journal of Information Systems*, 7, 241-251.

[4] Ballou, D.P., and Tayi, G.K. (1999). “Enhancing data quality in data warehouse environments”, *Communications of the ACM*, 42, 1, 73-78.

[5] Beck, M.P., and Lin, B.W. (1981). “Selection of automated office systems: a case study”, *OMEGA*, 9, 2, 169-176.

[6] Bhutta, K.S., and Huq F. (2002). “Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches”, *Supply Chain Management*, 7, 3/4, 126-135.

[7] Blili, S., and Raymond, L. (1993). “Information technology: threats and opportunities for small and medium-sized enterprises”,

International Journal of Information Management, 13, 6, 439-448.

[8] Bontempo, C., and Zagelow, G. (1998). "The IBM data warehouse architecture", *Communications of the ACM*, 41, 9, 38-48.

[9] Brown, L.A., and Forsyth, J.H. (1999). "The evolving approval plan: how academic librarians evaluate services for vendor selection and performance", *Library Collections, Acquisitions, & Technical Services*, 23, 3, 231–277.

[10] Caldeira, M.M., and Ward, J.M. (2003). "Using resource-based theory to interpret the successful adoption and use of information systems and technology in manufacturing small and medium-sized enterprises", *European Journal of Information Systems*, 12, 127-141.

[11] Chau, P.Y.K. (1995). "Factors used in the selection of packaged software in small businesses: views of owners and managers", *Information and Management*, 29, 2, 71–78.

[12] Chaudhuri, S., and Dayal, U. (1997). "An overview of data warehousing and OLAP technology", *SIGMOD Record*, 26, 1, 65-74.

[13] Chaudhuri, S., Dayal, U., and Ganti, V. (2001). "Database technology for decision support systems", *Computer*, 34, 12, 48-55.

[14] Dandridge, T.C. (1979). "Children are not little `grown-ups': small business needs its own organizational theory", *Journal of Small Business Management*, 7, 2, 53-57.

[15] Degraeve, Z., and Roodhooft, F. (1999). "Improving the efficiency of the purchasing process using total cost of ownership information- the case of heating electrodes at Cockerill Sambre S.A.", *European Journal of Operational Research*, 112, 42-53.

[16] Doukidis, G.I., Smithson, S., and Lybereas, T. (1994). "Trends in information technology in small businesses", *Journal of End User Computing*, 6, 4, 15-25.

[17] Dyer, R.F., and Forman, E.H. (1992). "Group decision support with the analytic hierarchy process", *Decision Support Systems*, 8, 99-124.

[18] Ellram, L.M., and Siferd, S.P. (1993). "Purchasing: the cornerstone of the total cost of ownership concept", *Journal of Business Logistics*, 14, 1, 163-184.

[19] Fink, D. (1998). "Guidelines for the successful adoption of information technology in small and medium enterprises", *International Journal of Information Management*, 18, 4, 243-253.

[20] Forman, E.H., and Gass, S.I. (2001). "The analytic hierarchy process – an exposition", *INFORMS*, 49, 4, 469-486.

[21] Gary, A.K. (2001) "Entrepreneurship and strategy in the international SME", *Journal of International Management*, 7, 155-171.

[22] Gorla, N. (2003). "Features to consider in a data warehousing system", *Communications of the ACM*, 46, 11, 111-115.

[23] Gray, P., and Watson, H.J. (1998). "Present and future directions in data warehousing", *ACM SIGMIS Database*, 29, 3, 83-90.

[24] Griese, J., and Kurpicz, R. (1982). "Investigating the buying process for the introduction of data processing in small and medium-sized firms", *Information & Management*, 8, 1, 41-51.

[25] Han, J., Lakshmanan, L.V.S., and Ng, R.T. (1999). "Constraint-based, multidimensional data mining", *Computer*, 32, 8, 46 -50.

[26] Heikkila, J., Saarinen, T., and Saaksjarvi, M. (1991). "Success of software packages in small businesses: an exploratory study", *European*

Journal of Information Systems, 1, 3, 159-170.

[27] Hsueh, L.M., Lin, A.L., and Okrasa, G. (2003). White paper on small and medium enterprises in Taiwan, 2003, Small and Medium Enterprise Administration, Ministry of Economic Affairs, Taipei, Taiwan.

[28] Hwang, H.G., Ku, C.Y., Yen, D.D., and Cheng, C.C. (2004). "Critical factors influencing the adoption of data warehouse technology: a case study of the banking industry in Taiwan", *Decision Support Systems*, 37, 1-21.

[29] Iacovou, C.L., Benbasat, I., and Dexter, A.S. (1995). "Electronic data interchange and small organizations: adoption and impact of technology", *MIS Quarterly*, 19, 4, 465-485.

[30] Illa, X.B., Franch, X., and Pastor, J.A. (2000). "Formalising ERP selection criteria", Proceedings of the Tenth International Workshop on Software Specification and Design, San Diego, California, 115-122.

[31] Inmon, W.H. (2002). *Building the data warehouse* (3rd ed.), John Wiley & Sons, New York.

[32] Inmon, W.H., Rudin, K., Buss, C.K., and Sousa, R. (1999). *Data warehouse performance*, John Wiley & Sons, New York.

[33] Kim, J., and Moon, J.Y. (1997). "An AHP & survey for selecting workflow management systems", *Intelligent Systems in Accounting, Finance and Management*, 6, 141-161.

[34] Kim, C.S., and Yoon, Y. (1992). "Selection of a good expert system shell for instructional purposes in business", *Information & Management*, 23, 249-262.

[35] Kimball, R. (1996). *The data warehouse toolkits*, John Wiley & Sons, New York.

[36] Kimball, R., Reeves, L., Ross, M., and Thornthwaite, W. (1998). *The data warehouse lifecycle toolkit - expert methods for designing, developing, and deploying data warehouses*, John Wiley & Sons, New York.

[37] Kimball, R., and Ross, M. (2002). *The data warehouse toolkit: the complete guide to dimensional modeling* (2nd ed.), John Wiley & Sons, New York.

[38] Kumar, V., Maheshwari, B., and Kumar, U. (2002). "ERP systems implementation: best practices in Canadian government organizations", *Government Information Quarterly*, 19, 147-172.

[39] Lai, V.S., Trueblood, R.P., and Wong, B.K. (1999). "Software selection: a case study of the application of the analytic hierarchical process to the selection of a multimedia authoring system", *Information & Management*, 36, 221-232.

[40] Lai, V.S., Wong, B.K., and Cheung, W. (2002). "Group decision making in a multiple criteria environment: a case using the AHP in software selection", *European Journal of Operational Research*, 137, 134-144.

[41] Lee, C.W., and Kwak, N.K. (1999). "Information resource planning for a health-care system using an AHP-based goal programming method", *Journal of the Operational Research Society*, 50, 12, 1191-1198.

[42] Lesley, D., and Glyn, W. (1994). "Evaluating and selecting simulation software using the analytic hierarchy process", *Integrated Manufacturing Systems*, 5, 1, 23-32.

[43] Levy, M., and Powell, P. (2000). "Information systems strategy for small and medium sized enterprise: an organizational perspective", *Journal of Strategic Information Systems*, 9, 63-84.

[44] Lin, Z.C., and Yang, C.B. (1996). "Evaluation of machine selection by the AHP method", *Journal of Materials*

Processing Technology, 57, 253-258.

[45] Little, R.G.J., and Gibson M.L. (2003). "Perceived influences on implementing data warehousing", *IEEE Transactions on Software Engineering*, 29, 4, 290 -296.

[46] Love, P.E.D., and Irani, Z. (2004). "An exploratory study of information technology evaluation and benefits management practices of SMEs in the construction industry", *Information & Management*, 42, 227–242.

[47] Min, H. (1992). "Selection of software: the analytic hierarchy process", *International Journal of Physical Distribution & Logistics Management*, 22, 1, 42-52.

[48] Mohanty, R.P., and Venkataraman, S. (1993). "Use of the analytic hierarchy process for selecting automated manufacturing systems", *International Journal of Operations & Production Management*, 13, 8, 45-57.

[49] Mukherjee, D., and D'souza, D. (2003). "Think phased implementation for successful data warehousing", *Information Systems Management*, 20, 2, 82-90.

[50] Murtaza, A.H. (1998). "A framework for developing enterprise data warehouses", *Information Systems Management*, 15, 4, 21-26.

[51] Nemati, H.R., Steiger, D.M., Iyer, L.S., and Herschel, R.T. (2002). "Knowledge warehouse: an architectural integration of knowledge management, decision support, artificial intelligence and data warehousing", *Decision Support Systems*, 33, 2, 143-161.

[52] Olhager, J., and Selldin, E. (2003). "Enterprise resource planning survey of Swedish manufacturing firms", *European Journal of Operational Research*, 146, 2, 365-373.

[53] Opfer, N.D. (2001). "Total cost ownership for information technology", *AACE International Transactions*, IT71-IT76.

[54] Ossadnik, W., and Lange, O. (1999). "AHP-based evaluation of AHP software", *European Journal of Operational Research*, 118 578-588.

[55] Palopoli, L., Terracina, G., and Ursino, D. (2003). "Experiences using DIKE, a system for supporting cooperative information system and data warehouse design", *Information Systems*, 28, 7, 835-865.

[56] Palpanas, T. (2000). "Knowledge discovery in data warehouses", *SIGMOD Record*, 29, 3, 88-100.

[57] Partovi, F.Y., Burton, J., and Banerjee, A. (1989). "Application of analytic hierarchy process in operations management", *International Journal of Operations and Production Management*, 10, 3, 5-19.

[58] Pedersen, T.B., and Jensen, C.S. (2001). "Multidimensional database technology", *Computer*, 34, 12, 40-46.

[59] Rao, S.S. (2000). "Enterprise resource planning: business needs and technologies", *Industrial Management & Data Systems*, 100, 2, 81-88.

[60] Raydel, T., and Lee, U.R. (1994). "A decision support system for integration of vendor selection task", *Journal of Applied Business Research*, 10, 1, 132-143.

[61] Raymond, L. (1990). "Organizational context and information systems success: a contingency approach", *Journal of Management Information Systems*, 6, 4, 5-20.

[62] Remenyi, D., Money, A., Sherwood-Smith, M., and Irani, Z. (2000). *The effective measurement and management of IT costs and benefits* (2nd ed.), Butterworth-Heinemann, Oxford.

[63] Roper-Lowe, G.C., and Sharp, J.A. (1990). "The analytic hierarchy process and its application to an information technology decision", *The Journal of*

the Operational Research Society, 41, 1, 49-59.

[64] Saaty, T.L. (1980). *The Analytic Hierarchy Process*, McGraw-Hill, New York.

[65] Saaty, T.L. (1986). "Axiomatic foundations of the analytic hierarchy process", *Management Science*, 32, 7, 841-855.

[66] Saaty, T.L. (1990). *Decision making for leaders - the analytic hierarchy process for decisions in a complex world*, RWS Publications, Pittsburgh.

[67] Saaty, T.L., and Vargas, L.G. (1994). *Decision making in economic, political, social, and technological environments with the analytic hierarchy process*, RWS Publications, Pittsburgh.

[68] Saaty, T.L. (1995). *Decision making for leaders - the analytic hierarchy process for decisions in a complex world* (1995/1996 ed.), RWS Publications, Pittsburgh.

[69] Seidmann, A., and Arbel, A. (1983). "An analytic approach for planning computerized office systems", *OMEGA*, 11, 6, 607-617.

[70] Seidmann, A., and Arbel, A. (1984). "Microcomputer selection process for organizational information management", *Information & Management*, 7, 317-329.

[71] Shin, B. (2002). "A case of data warehousing project management", *Information and Management*, 39, 7, 581-592.

[72] Sowder, W.E. (1972). "A scoring methodology for assessing the suitability of management science models", *Management Science*, 18, 10, 526-543.

[73] Stamelos, I., Vlahavas, I., Refanidis, I., and Tsoukiàs, A. (2000). "Knowledge based evaluation of software systems: a case study", *Information and Software Technology*, 42, 5, 333-345.

[74] Stylianou, A.C., Madey, G.R., and Smith, R.D. (1992). "Selection criteria for expert system shells: a socio-technical framework", *Communications of the ACM*, 35, 10, 30-48.

[75] Tagliavini, M., Faverio, P., Ravarini, A., Pigni, F., and Buonanno, G. (2002). "Exploring the use of ERP systems by SMEs", Proceedings of 6th World Multi Conference on Systemics Cybernetics and Informatics, Orlando, Florida, 14-18.

[76] Tam, K.Y., and Hui, K.L. (2001). "A choice model for the selection of computer vendors and its empirical estimation", *Journal of Management Information Systems*, 17, 4, 97-124.

[77] Tam, M.C.Y., and Tummala, V.M.R. (2001). "An application of the AHP in vendor selection of a telecommunications system", *OMEGA*, 29, 171-182.

[78] Teltumbde, A. (2000). "A framework for evaluating ERP projects", *International Journal of Production Research*, 38, 17, 4507-4520.

[79] Themistocleous, M., and Irani, Z. (2002). "Evaluating and adopting application integration: the case of a multinational petroleum company", Proceedings of the 35th Hawaii International Conference on System Science, Hawaii, 3715- 3723.

[80] Theodoratos, D., and Bouzeghoub, M. (2001). "Data currency quality satisfaction in the design of a data warehouse", *International Journal of Cooperative Information Systems*, 10, 3, 299-326.

[81] Thong, J.Y.L. (1999). "An integrated model of information systems adoption in small businesses", *Journal of Management Information Systems*, 15, 4, 187-214.

[82] Thong, J.Y.L. (2001). "Resource constraints and information systems implementation in Singaporean small

businesses", *OMEGA*, 29, 143-156.

[83] Thong, J.Y.L., Yap, C.S., and Raman, K.S. (1996). "Top management support, external expertise and information systems implementation in small businesses", *Information Systems Research*, 7, 2, 248-267.

[84] Tolkin, S. (1999). "Aggregation everywhere: data reduction and transformation in the Phoenix data warehouse", Proceedings of the second ACM international workshop on Data warehousing and OLAP, Kansas, 79-86.

[85] Van den Hoven, J. (1998). "Data warehousing: bringing it all together", *Information Systems Management*, 15, 2, 92-95.

[86] Van Everdingen, Y., Van Hillegersberg, J., and Waarts, E. (2000). "ERP adoption by European midsize companies", *Communication of the ACM*, 43, 4, 27-31.

[87] Vargas, L.G. (1990). "An overview of the analytic hierarchy process and its applications", *European Journal of Operational Research*, 48, 2-8.

[88] Vassiliadis, P., Bouzeghoub, M., and Quix, C. (2000). "Towards quality-oriented data warehouse usage and evolution", *Information Systems*, 25, 2, 89-115.

[89] Watson, H.J., Goodhue, D.L., and Wixom, B.H. (2002). "The benefits of data warehousing: why some organizations realize exceptional payoffs", *Information and Management*, 39, 6, 491-502.

[90] Welsh, J.A., and White, J.F. (1981). "A small business is not a little big business", *Harvard Business Review*, 59, 4, 18-32.

[91] Yap, C.S., Soh, C.P.P., and Raman, K.S. (1992). "Information systems success factors in small business", *OMEGA*, 20, 5/6, 597-609.

[92] Zahedi, F. (1985). "Data-base management system evaluation and selection decisions", *Decision Sciences*, 16, 91-116.

[93] Zahedi, F. (1986). "The analytic hierarchy process - a survey of the method and its applications", *Interfaces*, 16, 4, 96-108.

[94] Zahedi, F. (1990). "A method for quantitative evaluation of expert systems", *European Journal of Operational Research*, 48, 136-147.