IDENTIFYING QUALITY FACTORS WITHIN DATA WAREHOUSE

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Abstract— The popularity of data warehouses for data analysis has grown tremendously. Data warehouse systems have emerged as the core of management information systems. Data warehouse is part of a larger infrastructure that includes legacy data sources, external data sources, data acquisition software, a repository, analytical tools, and user interface. The difficulties of data warehouse implementations have been widely cited in the literature but research on the factors for initial and ongoing data warehouse implementation success is rare and fragmented. Through a comprehensive review of the literature, 10 factors were found to be critical to DW implementation success — Organizational, Technical, Project, Environmental, Infrastructure, Information Quality, System Quality, Service Quality, Relationship Quality, and Net Benefits. A proposed research model is developed in this paper to determine the impact of quality and success factors on the implementation of data warehouse by adapting the updated (2003) DeLone and McLean Information System Success Model, new dimensions are proposed to the model.

Keywords- Data warehouse; success implementation; information system; knowledge management; decisions making; decisions support system.

I. INTRODUCTION

Today many organizations possess Information Technology (IT) infrastructures that provide limited data management, integration, and access. These organizations would be better served by IT infrastructures that offer appropriate data and tools to support decision makers. Data warehouse (DW) appeared in the early 90s as a decision support technology that could integrate data from multiple sources, and that had a subject orientation in the way data was organized and presented. Literature is rich with evidence that DW provides a unique opportunity to improve the IT infrastructure [1]. DW addresses data management, integration, and access issues by creating a repository of quality data that can be manipulated to meet changing business needs [2]. This repository allows enterprises to collect, organize, interpret and leverage the information they have for decision support [3, 4]. It provides the foundation for effective business intelligence solutions for companies seeking competitive advantage [1]. In addition, DW supports an On-Line Analytical Processing (OLAP), which has quite different functional and performance requirements from those of the On-Line Transaction Processing (OLTP) applications that are supported by the operational databases [5]. OLAP tools provide an intuitive way to view corporate data. These tools aggregate data along common business subjects or dimensions and let users navigate through attribute hierarchies. Users can drill down, across, or up level in each dimension [6].

However, the implementation of a DW is both very expensive and highly risky. One study reported an average cost of $2.2 million for a typical DW [7], while another study found that the DW tools market repeated its 2004 performance in 2005 with an 11.3% growth rate to reach $9.6 billion in revenue [8]. A more recent study placed the enterprise DW market will experience double-digit growth through 2008 [9]. Another study expected that the DW market size is likely to approach $7 billion in 2008 [10]. Organizations of any size should begin to assess their current level of investment in the analytic infrastructure [9].

On other side, the scale and complexity of DW systems have proved a challenge to both information system (IS) specialists in terms of implementation and to decision-makers in terms of managing business changes essential to gaining benefits from these very expensive investments. In fact, the use of DW has not always led to significant organizational improvements. In many cases, the implementation of DW projects has a high possibility of failure rates [1, 11-14]. There have many reports on DW failure rates. The reported percentages vary based on the reporting agency but average between 20%-50% failure rates [4, 15, 16].

Nevertheless, there is little research that has been done to guide the successful development and implementation of DW. According to Hayen et al. [11] there is little empirical research about implementation of DW projects. In addition, yet few studies have assessed DW implementation in general and Critical Success Factors (CSFs) in particular [17]. Mukherjee and D'Souza [18] pointed that, the precise nature of the success factors and their impact on the implementation of DW are still unclear. Moreover, Ramamurthy et al. [14], Bhansali [19], and Mukherjee [20] contend that more studies in factors that impact DW implementations need to be conducted. The purpose of this paper is to identify the factors affecting the successful implementation of DW systems. Specifically, the paper develops a generalized model for gauging DW success implementation by adapting the

II. LITERATURE REVIEW

A broad range of factors that can influence the success of DW implementation has been mentioned in the literature. For example, much has been stated about organizational support, organizational culture, and information quality as important considerations for its accomplishment. According to Hwang and Xu [17], DW success is an important issue for both practice and research. Relatively few studies have been conducted to assess DW practices in general and CSFs in particular [4, 17, 22]. Wixom and Watson [4] pointed out that DWs have unique characteristics that may shift the importance of factors that apply to it. The literature review provides discussion for a sample of eight DW success studies. The following is a brief overview of each of these studies.

A study to examine the key determinants of DW adoption, a technology that falls into the category of an infrastructure type innovation was carried out by Ramamurthy et al. [14]. Hayen et al. [11] investigated a model of the factors affecting DW success. Their work was built upon a case study of the financial service company in the South-Eastern United States. In addition, Hwang and Xu [17] conducted an exploratory study on DW success implementation by examining success variables individually, the factors that are important and the strength of their effects on different success variables. Moreover, Solomon [23] provided guidelines to help managers avoid common pitfalls and obstacles in enterprise-level DW projects based on reviewing previous related-studies and extensive field experience. Also, Hwang et al., [12] intended to explore the critical factors affecting the adoption of DW technology in the banking industry in Taiwan. Additionally, Mukherjee and D’Souza [18] presented a framework which might help the DW people to visualize how CSFs can be included in each phase of DW implementation process. Furthermore, Shin [22] conducted an exploratory study to assist in the understanding of DW problems from the perspective of IS success, using system quality, information quality and service quality as they impact user satisfaction. Wixom and Watson [4] held an empirical investigation of the factors influencing DW success among the American organizations. Watson and colleagues [24, 25] conducted a series of DW studies and developed taxonomy of DW benefits that classifies six benefits based on their ease of measurement and level of impact.

Table 1 summarizes some prior studies, which differ widely in the factors measured. However, these studies have addresses only some aspects of the important issues and its generally agreed that there is a scarcity of comprehensive models in DW success evaluation area. While there is a shortage of comprehensive models for DW success, a model in the area of IS success has been well established, which is the updated D&M IS Success Model [21]. The next section discusses the IS success model and its association to this study.

III. THEORETICAL FRAMEWORK

The theoretical framework selected for this study is the updated D&M IS Success Model [21]. The study of the IS has appealed to both scholars and practitioners for decades. Success factors of an IS has been measured by researchers in various ways. In (1992), D&M [26] presented taxonomy and interactive model, which was to conceptualize and operationalize IS success. They combined several empirical measures of system quality, information quality, information system use, user satisfaction, individual impact, and organizational impact. They used these measures to create their six dimension IS success model. All of the empirical measures that D&M used focused on the context of the organization. In the following ten years, the original D&M model was studied in hundreds of research articles. Many researchers have validated the dimensions and confirmed the interrelationship between the dimensions of the model [27, 28]; some researchers suggested modifications [29, 30]. Wixom and Watson [4] followed the work of D&M [26] and Seddon [30] and developed a three-dimensional model of system success with DW: data quality, system quality, and perceived net benefits.

In (2003), D&M [21] concluded the research findings of over 100 D&M model studies, and presented by the updated D&M [21] model (Fig. 1). The major revision is the addition of a new dimension “Service Quality”. In addition, D&M decided to replace the “Individual Impacts” and “Organizational Impacts” in their original 1993 IS success model with a new “Net Benefits” measure. According to D&M [21], several researchers have commented on the difficulty of applying their success model in order to define and operationalize IS success in specific research contexts. D&M [21] also suggested that their new model be future tested and validated, and encouraged others to join this effort. Testing the D&M [21] model in a context other than their original organizational context would be very beneficial. The next section discusses the proposed research model and its justifications.

![Updated IS Success Model](image)
TABLE 1: PRIOR DATA WAREHOUSE STUDIES

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Objective</th>
<th>Origin of Factors</th>
<th>Outcome</th>
<th>Future research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramamurthy et al. [14]</td>
<td>To examine the key factors determinates of DW adoption</td>
<td>Extant body of research in organizational theory and IT innovation adoption.</td>
<td>Five factors</td>
<td>Three factors “Flexibility”, “Responsiveness”, and “Absorbed Slack” could include in future research.</td>
</tr>
<tr>
<td>Hayen et al. [11]</td>
<td>To identify factors that potentially affect DW success</td>
<td>A research treated IS success as a multi-faceted constructs and selected several appropriate success.</td>
<td>General model</td>
<td>Suggested to apply IS implementation knowledge to DW.</td>
</tr>
<tr>
<td>Hwang &amp; Xu [17]</td>
<td>To identify a success factors effect on DW implementation</td>
<td>Exploratory study of 8 DW success variables and 11 implementation factors.</td>
<td>General model</td>
<td>“Easy to Manage” could become an additional factor.</td>
</tr>
<tr>
<td>Hwang et al. [12]</td>
<td>To investigate the factors influencing adoption of DW technology in the banking industry in Taiwan</td>
<td>Prior studies and the result of an opinion survey which included academic and industrial practitioners from the Taiwan banks.</td>
<td>Five factors</td>
<td>Future research can be focused on integrate the DW technology with other IT such as CRM and ERP.</td>
</tr>
<tr>
<td>fnighnShin [22]</td>
<td>To improve general understanding of DW issues from the perspective of IS success.</td>
<td>IS success model for D&amp;M (2002) was used.</td>
<td>System quality affects user satisfaction.</td>
<td></td>
</tr>
<tr>
<td>Wixom &amp; Watson [4]</td>
<td>To identify significant relationships between system quality and data quality factors and perceived net benefits.</td>
<td>Survey findings and IT implementation and DW literature.</td>
<td>Data quality and System quality affects Net benefits.</td>
<td>Future research is needed to understand the factors that affect data quality.</td>
</tr>
<tr>
<td>Chen et al. [31]</td>
<td>To identify the underlying factors and measures of end-user satisfactions with DW.</td>
<td>Literature review</td>
<td>List of factors</td>
<td></td>
</tr>
<tr>
<td>Haley [32]</td>
<td>To identify the key Success Factors in DW implementation.</td>
<td>DW, infrastructure, database, IS implementation, and IS success literature.</td>
<td>9 factors</td>
<td>There is a great need for academic research in the area of DW success.</td>
</tr>
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</table>

IV. PROPOSED RESEARCH MODEL

A broad review of relevant literature in IS success and DW success factors provide us with a foundation for developing the theoretical model. Researchers have investigated the success of IS in numerous ways [33], such as by measuring the system quality, information quality, service quality, and the perceived usefulness of specific applications. Moreover, researchers treat IS success as a multi-faceted construct and select several appropriate success measures based on the research objectives and the phenomena under investigation. These provide possible relationships among the success dimensions when constructing a research model. That model establishes a framework for metrics that can be used to manage a DW implementation project to help insure its success [11]. According to Shin[22], the IS success model introduced by D&M [21] can become a good framework in understanding the success of DW. However, some important issues such as relationship quality, infrastructure factor, and environmental factor are not included in the D&M model. Also, there is no much research done to test the D&M [21] model in DW context.

The research model developed for this study is shown in Fig. 2, which allows for conceptualization of DW success, implementation factors that contribute to DW success, and the relationship between them.

TABLE 2: VARIABLES AND MEASURES FOR THE RESEARCH MODEL

<table>
<thead>
<tr>
<th>Variables</th>
<th>Measures</th>
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<tbody>
<tr>
<td>Organizational factor</td>
<td>top management support, clear objectives and goals, organizational resistance, organizational cultural</td>
</tr>
<tr>
<td>Technical factor</td>
<td>architecture design, data model design, backup terabytes of data, ETL tools selection and design</td>
</tr>
<tr>
<td>Project factor</td>
<td>project planning, project team competence, project champion, assistance of external consultants</td>
</tr>
<tr>
<td>Environmental factor</td>
<td>business competition, selection of vendors, compatibility with industry standards, compatibility with partners</td>
</tr>
<tr>
<td>Infrastructure factor</td>
<td>quality of data sources, having the right development tools, having sufficient hardware</td>
</tr>
<tr>
<td>Information quality</td>
<td>content usefulness, content adequacy, data integrity</td>
</tr>
<tr>
<td>System quality</td>
<td>ease of use, ease to manage, ability to locate data, interactivity</td>
</tr>
<tr>
<td>Service quality</td>
<td>user training, reliability, responsiveness</td>
</tr>
<tr>
<td>Relationship quality</td>
<td>trust, commitment, user participation</td>
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</table>
The model identifies the appropriate factors and dimensions for DW. In this model, the DW success is represented by four dependent variables: system quality, information quality, service quality, and relationship quality. In addition, the success is affected by five independent variables or implementation factors: organizational, technical, project, environmental, and infrastructure. This model is general and useful for comparing all the variables that have been discussed in the DW and other related literature. The factors included in this model encompass all the benefits mentioned previously [4, 12, 22, 24, 25, 34, 35]. For example, the five success factors can be used to classify all DW benefits discussed in prior studies.

When we apply the IS success model [21] on DW, the original context can't fit nicely into the DW environment. Use is excluded from the original model because it's utility in general [30] and in DW studies in particular [4, 36] has been questioned. User satisfaction is similarly excluded because it is not considered a good indicator of success for multiple-user applications such as DW [4, 36]. In addition, it's unlikely that companies would spend millions of dollars on DW projects just to make their users happy. Table 3.1 lists the nine variables and the 32 measures developed for testing the research model. Justification of the factors, measures, and the relations are discussed next.

V. IMPLEMENTATION SUCCESS FACTORS

There has long been a keen interest in identifying the factors that contribute to the success or failure of DWs implementation. In an early review of the literature, Vatanasombut and Gray [34] identified 51 success factors that may be classified into 12 categories. Most of these 51 factors, however, apply not only to DW, but also to large systems development projects in general; only nine factors are specific to DW. Other researchers provided their own lists of critical success factors. For example, Watson and Haley [25] identified eight critical success factors, whereas Sammon and Finnegan [35] discussed their ten commandments of DW. In this study, five factors that affect DW success can be classified as organizational, technical, project, environmental, and infrastructure factors. Most factors discussed in the DW literature fall into either the organizational or technical categories. The next section discusses these five success factors.

A. Organizational Factor

The impact of the organizational factor on IS success has continued to be researched using multiple perspectives. Some of the researches have used different terminologies including contexts, variables, and factors when referring to organizational dimension. Lu and Wang [36] for example, used management style as a measure of organizational context. Ang et al. [37] identified organizational factors that influence IT usage as organizational structure, managerial IT knowledge, top management support, financial resources, goal alignment and budgeting method. In addition, Hussein et al. [38] identified organizational variables that influence IS success as decision-making structure, top management support, goal alignment, managerial IT knowledge, management style, and resources allocation. Hwang et al. [12] identified four factors (Size of organization, Champion, Top management support, Internal needs) to measure the organizational dimension for DW adoption in the banking industry. A recent study conducted by Ramamurthy et al.,
[14] proposed a research model that posited the direct impact of five organizational factors (organizational commitment, absorptive capacity, organizational size, relative advantage, and complexity) on DW adoption. Moreover, top management support is perhaps the factor that always cited as the most relevant success factor in DW implementation projects [1, 4, 17, 39]. Based on the above arguments, we believe that the organizational factor in any DW project will result in implementation success. Four measurements (top management support, clear objectives and goals, organizational resistance, and organizational cultural) are identified to be used in this study.

B. Technical Factor

The technical factor measures the technical problems and technical limitations that occurred during the implementation of DW projects. According to Hwang and Xu [40], the technical factor measures the availability of technical resources and expertise. In addition, technical issues dominate the list of critical factors in implementations. They include features such as data quality, data access, data availability, technical expertise, availability of skilled resources, availability of equipment, technology platforms, and training [20]. Almost all authors emphasize the technical aspects of the DW projects implementation, including cleansed data, meta data, standard methodology, data conversion, data model design, architecture design, and ETL tools [23]. Technical problems may emerge at various points during the DW project implementation, such as when many heterogeneous data sources must be combined. Consequently, the current research chose architecture design, data model design, ETL tools selection, and backup terabytes of data to measure technical factor.

C. Project Factor

Information system projects often include a complex array of tasks and roles that must be managed [41]. DW projects in particular require highly skilled, well-managed teams who can overcome issues that arise during the project implementation [42]. Project factor is associated with resolving all related problems or issues about project planning, analysis, development, management, and control in the process of the implementation [12]. It is critical to have a business plan that outlines proposed strategic and tangible benefits, resources, costs, risk and timeline [43]. Furthermore, DW projects are large and complex undertakings. Therefore, a good planning is critical to successful implementation of it [32, 44]. In addition, DW being an enterprise-wide IS, needs a proper business plan and scope to steer the direction of the implementation project [39]. There should be alignment for investment in the DW system based on a change in work processes that is aligned with the future direction of the organization involved [19]. As a result, this study assumes that project factor affects the DW success during the implementation process. Consequently, this study chose project planning, project team competence, project champion, and assistance of external consultants to measure project factor.

D. Environmental Factor

The enterprise incorporates in a dynamic environment with high possibilities of sudden and uncontrolled changes. The enterprise must measure and reduce the uncertainties in the surrounding environment and create competitive advantages by adopting newer information technology [12]. As a result, the environment itself has a great influence on the utilization of new information technology. Most enterprises will be affected by such competition as raising the operational productivity and efficiency by implementing new information technology. Also, the selection of a vendor can be a factor that affects the implementation of DW technology. As a result, we believe that environmental factor in any DW project implementation will result in implementation success. Consequently, this study chose business competition, selection of vendors, and compatibility with industry standards to measure environmental factor.

E. Infrastructure Factor

Information technology infrastructure has been generally defined as a set of shared, tangible information technology resources that provide a foundation for supporting current and enabling future business applications [45]. Managing information technology infrastructure entails making decisions on software and hardware platforms, network architectures, corporate standards for acquisition and deployment of resources, etc. [46]. The capabilities of information technology infrastructure are expected to influence business value by effectively supporting business processes [47]. Information technology infrastructure capabilities include the services it provides, its reach, and its range, with an emphasis on organizational flexibility afforded for the future [48]. In fact, information technology infrastructure can affect managerial and operational processes, and improvements can produce business benefits such as improved managerial information and enhanced coordination between interdependent parts of the organization [49]. In addition, many organizations possess information technology infrastructures that provide limited data management, integration, and access. These organizations would be better served by information technology infrastructures that offer appropriate data and tools to support decision makers [50]. As a result, this study suggests that infrastructure may have important impacts on DW success. Three measurements (quality of data sources, having the right development tools, and having sufficient hardware.) for infrastructure factor have been identified to be used in this study.
VI. DATA WAREHOUSE SUCCESS

In an early review of the literature, Sakaguchi and Frolick [42] categorized the advantages of DW cited in 456 articles into 16 types of benefits. In another review, Vatanasombut and Gray [34] listed 12 goals of DW that can be classified as financial, operational, or application. Watson and colleagues [24, 25] conducted a series of DW studies and developed taxonomy of DW benefits that classifies six benefits based on their ease of measurement and level of impact. Wixom and Watson [4] investigated the effects of several implementation factors on three success variables, their empirical work showed the particular importance of system quality and data quality in securing benefits from the DW. According to Shin [22], many of the concerns were related to system and service quality which could affect the DW success. Furthermore, Hwang and Xu [36] found that the information quality has a positive effect on the DW success. The following section discusses the DW success dimensions.

A. Information Quality

Information quality is an important asset for organizations [51]. It seems that a DW is expected to enable production of information of higher quality as well as new information that may be put to innovative use. In a study on the determinants of IS success, [26] highlighted the importance of relevance, timeliness, and accuracy of information. Sakaguchi and Frolick [42], for instance, discuss one of the advantages of a DW as its ability to provide quantitative values, or metrics that allow a company to benchmark performance in an effort to measure progress. In other words, both the quality and quantity of information are important. As described by Watson and Haley [25], more and better information is one of the purported benefits of DW. Wixom and Watson [4] provided an excellent source for further research into DW concepts with many examples of studies on information quality and success factors for IT projects. They divided the subject of DW quality into the study of information quality and system quality. Consequently, the current research chose content usefulness, content adequacy, and data integrity to measure information quality dimension.

B. System Quality

Research on IS has resulted in various instruments to measure system quality. Wixom and Watson [4] empirical work showed the particular importance of system quality in securing benefits from the DW. In the context of DW, Shin [22] has identified system quality factors such as system throughput, ease of use, ability to locate data, access authorization, and data quality, which were regarded as crucial for the success of the DW. Furthermore, the success of a DW is more than likely be judged by how easy and efficient it is for both end users and IS-professionals to generate information to support decision making [22, 25, 52]. Therefore, current research chose ease of use, ease to manage, ability to locate data, and interactivity to measure system quality dimension.

C. Service Quality

The concept of service quality has attracted increasing interest in the IS field along the emergence of the role of the IS unit in an organization with the advancement in personal computing in the last decade. The notion of IS services was not well-defined initially when IS departments were primarily regarded as system developers and operators. A wide range of services, including installation assistance and technical help was provided to meet the rising demands from the DW users. Pitt et al. [53] observed that “commonly used measures of IS effectiveness focus on the products rather than the services of the IS function. Thus, there is a danger that IS researchers will miss measure IS effectiveness if they do not include in their assessment package a measure of IS service quality”. According to D&M [21], the service quality properly measured, deserves to be added as components of IS success. Moreover, the service quality was part of the study that published by [22] to investigate the success factors for DW implementation. Consequently, the current research chose user training, reliability, and responsiveness to measure service quality dimension.

D. Relationship Quality

The concept of relationship quality has arisen from theory and research in the field of relationship marketing [54] in which the ultimate goal is to strengthen already strong relationships and to convert indifferent customers into loyal ones [55]. Although, previous research of relationship quality [56-60] has discussed and tested the concept of relationship quality in various research contexts, the definition of relationship quality differs from research project to research project. These authors also agree that the concept of relationship quality is a higher-order construct consisting of several distinct but related components or dimensions. An investigation of the extant literature indicates trust, commitment, communication, cultural, and user participation all positively impact the quality of the relationship [56-60]. Various factors or dimensions have been used to study relationship quality within IS research. A meta-analysis was thus performed in IS literatures to determine the most common dimensions used to measure relationship quality. Table 3 summarizes the results of the review.

The relationship between business objectives and technology has surfaced in the DW implementation. Relationship quality, to our best knowledge has not been studied in DW research. Therefore, this study suggests that relationship quality may have important impacts on DW success. Also, this research revises the traditional definition of relationship quality by including affective
trust, commitment, and user participation as components of measuring relationship quality in DW.

<table>
<thead>
<tr>
<th>Goles &amp; Chin, 2005</th>
<th>Carr, 2006</th>
<th>Sun et al., 2007</th>
<th>Chakraborty et al., 2007</th>
<th>Wu, 2007</th>
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<tbody>
<tr>
<td>Commitment</td>
<td>√</td>
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<td>Trust</td>
<td>√</td>
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<td>Satisfaction</td>
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<td>Participation</td>
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VII. CONCLUSION

A combination of quality and success factors for DW implementation has been identified, based on a review of the DW literature. Organizational, project, and technical are a key factors influencing DW implementation success. Environmental factor should also play a major role in the implementation to facilitate a compatibility with industry standards and partners. Moreover, literature found data accuracy the most important aspect of information quality. The importance of quality of data source is similarly stressed by prior studies, which cites poor data source quality as the main cause of high DW project failure rates. In addition, good coordination and communication between the implementation partners are essential. Since DW covers a wide range of functional areas, it is also important to have a cross functional DW core team. Also, literature found that the concept of relationship quality is a higher-order construct consisting of several distinct. It is extremely critical that partnership trust is present and the team members are working well together. Another very critical factor is an organizational culture where the employees share common values and goals and are receptive to change is most likely to succeed in DW implementation. Furthermore, user training and support should be available and highly encouraged. Other factors include organizational resistance, ease of use, project team competence, ETL tools selection, having sufficient hardware, content usefulness, responsiveness, and commitment was found to have a great influence on the success of DW implementation.

In the next stage of this research, we will send out survey questionnaires to The DW Institution (TDWI) members to evaluate the degree of criticality and importance of the factors identified in the DW literature. We are also interested in studying how the perceived importance of these factors may differ across implementation partners such as top executives, project team members, internal IT specialists, vendors, and consultants. With a better understanding of the issues involved in DW implementations, management will be able to make critical decisions and allocate resources that are required to make DW implementation a success.

REFERENCES


