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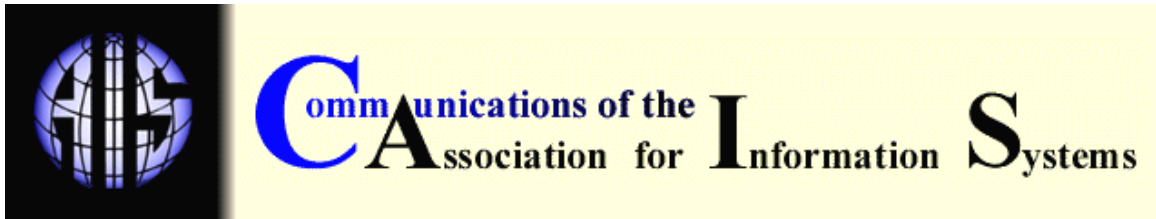
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DATA WAREHOUSING IMPLEMENTATION AND OUTSOURCING CHALLENGES: AN ACTION RESEARCH PROJECT WITH SOLECTRON

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ABSTRACT

Since the 1980s, Solectron evolved as a contract provider of manufacturing, distribution, product design, and full-service supply chain integration to many Fortune 500 companies in the telecommunications, electronics, and computer industries. In order to achieve this set of capabilities, Solectron established a tightly coupled set of collaborative relationships with supply chain participants— including both suppliers and customers. This action research study explores Solectron's data warehousing implementation and outsourcing experiences to support the organization's strategic direction. We uncover the absence of new set of critical pre-implementation performance metrics for managers and researchers to consider under conditions of outsourcing; multiple, simultaneous projects; and lack of IT internal expertise. Thus, our research offers hypotheses that can be further tested by future research.

Keywords: action research methodology, data warehousing, implementation, outsourcing, supply chain management, performance-based measures

I. INTRODUCTION

Organizations no longer must work simply within their internal barriers, but must compete as integrated entities across their suppliers and customers. Antiquated frameworks of data management within a single organization result in dysfunctional outcomes, such as failures to meet customer demands, lack of internal and interface integration, extreme cost overruns, and resistance to change [Wixom and Watson, 2001; Truman, 2000; Goodhue, et al., 1992a, 1992b]. Critical to the supply chain is the outsourcing/insourcing decision that organizations face; however, this decision is predicated on more than make versus buy alternatives [Handfield and Nichols, 2002].

Unfortunately, recent incidents of outsourcing of information systems often follow a pattern of limited a priori criteria evaluation. Given the large number of mergers and acquisitions among global businesses, data management across global supply chains continues to be a major barrier to strategic integration of organizations. Data sharing barriers become even greater when extending internal systems to an organization's supply chain that is composed of suppliers, business partners, and customers. These barriers are particularly the case when organizations make (in)outsourcing decisions without prior success measures.

To address these research issues, we advocate the use of action research because active learning from both research and practice is advantageous. To understand the organization in which we undertook action research, we used an iterative process of activities, interventions and reflective learning to address an immediate problem and invoke change within the organization [Avison, et al., 1999, 2001]. This article explores the experience of a major contract manufacturer in the electronic industry, Solectron Corporation, which went through a major outsourcing effort for its data warehouse. Using an action research team consisting of the authors and several Solectron supply chain and global data warehouse managers, we document the evolution of Solectron's data warehousing outsourcing implementation efforts. Our team suggests that outsourcing decisions of this scale warrant a priori performance metrics that enable organizations to measure implementation success, combined with on-going management of the outsourcing provider through a system of performance evaluation, communication of expectations, and continuous improvement.

ABOUT SOLECTRON

In 2001, Solectron's Profit Before Taxes exceeded 6%, with gross margins increasing to 12%. Compounded annual sales growth rates exceeded 60% over the last 5 years, and 66% over 18 years. Sales in 1996 exceeded \$2.8 billion. At the time of this research, the company employed more than 14,500 people worldwide.

In the next two years, while this project was underway the effects of the collapse in the telecom and high tech markets caused Solectron to experience significant challenges, and it closed a number of facilities and curtailed spending in IT. This change led to top management's reducing capital investments required to support IT requirements for the levels of growth sustained in earlier years.

Sections II and III discuss the IT outsourcing and implementation research. Section IV provides the research methodology. Next, we describe factors that our research showed affect implementation success under data warehousing outsourcing conditions (Section V). In Section VI, we discuss the action research from the company administrative view. Section VII deals with the outsourcing metrics that provide a means of continual assessment of technology and vendor performance. In Section VIII, we discuss lessons learned using our action research methodology. We present the need to augment the existing Wixom and Watson [2001] data warehousing implementation model to capture the outsourcing context encountered at Solectron and offer propositions for future research in Section IX.

II.IT OUTSOURCING LITERATURE

The literature surveys in this section and the next deal with outsourcing and data warehousing since Solectron was involved in outsourcing the design and implementation of a new data warehouse.

Prior IS research studies [Huxham and Vangen, 2000; Ho, Ang and Straub, 2003] document increases in IS/IT outsourcing trends. As more organizations move to offshore, functional and value chain sourcing [Handfield and Nichols, 2002], relationships and partnerships with outsourcing vendors will prove significant as outsourcing firms migrate to strategic sourcing. Vital

to the success of these strategic directions are complex, analytical information technologies, such as data warehouses.

In a survey of senior executives from 188 firms, Grover, et al. [1996] report that the outsourcing success is a multi-item construct consisting of core business, IT competence, control of IS expenses, access to IT players, economics of scale (human resources and technological), skilled personnel, and avoidance of obsolescence risk. While on average outsourcing benefits the recipient, the effect of service quality can lead to a direct effect on outsourcing success. Further, Grover et al. imply that outsourcing success is partially mediated by vendor partnerships; thus, while outsourcing can lead to a partnership that fosters success, early nurturing in pre-implementation phases should be established to identify service level agreement and performance expectations.

Others [Ang and Straub, 1998] suggest that performance expectations are characteristic of varies degrees of IS outsourcing – namely, operations, functional, and applications perspectives. In a survey of senior IT managers in 243 U.S. banks, Ang and Straub [1998] studied economic determinants (e.g., production cost, transaction cost and financial slack) of IS outsourcing. While economic factors can drive outsourcing decisions, financial slack failed to influence the degree to which banks outsourced. The opposite was determined when accounting for transaction and production costs. That is, banks sought cost reductions in production costs and potential cash injections into the organization due to decrease monetary resources needed to support an internal IS infrastructure. Subsequent work by Ho, et al. [2003] shows that persistence of these and other expectations impact the overall performance of the IT outsourcer. Furthermore, the lack of experience with outsourcing vendors tends to increase managerial expectations.

More important to our problem situation and based on an action research methodology, Lacity and Willcocks [1998] provide an extensive analysis of 61 outsourcing decisions involving 145 participants. When asked if their outsourcing decisions were successful, these participants tended to focus on financial expectations with 80% indicating IT cost reductions. This outcome was followed by improving technology service (59%), jumping on the outsourcing bandwagon trend (38%), migrating toward core competencies (31%) and restructuring IT budgets from capital to operating expenses (30%). Within these managerial expectations, fee-for-service, strategic alliances/partnerships, and buy-in vendor service models are described. Lacity and Willcocks offer prescriptives about flexible pricing, competitive bidding for services beyond the contract, performance-based contracts and building long-term relationships via short-term contacts; these prescriptives propose optimal mixes for IT sourcing.

In sum, the outsourcing literature is relevant to our research. Prior research

- provides a framework for success measures for which outsourcing initiatives can be based.
- point to the need for adequate organizational financial and human resources to enable outsourcing success.
- provide background on organizational expectations of outsourcing engagements.

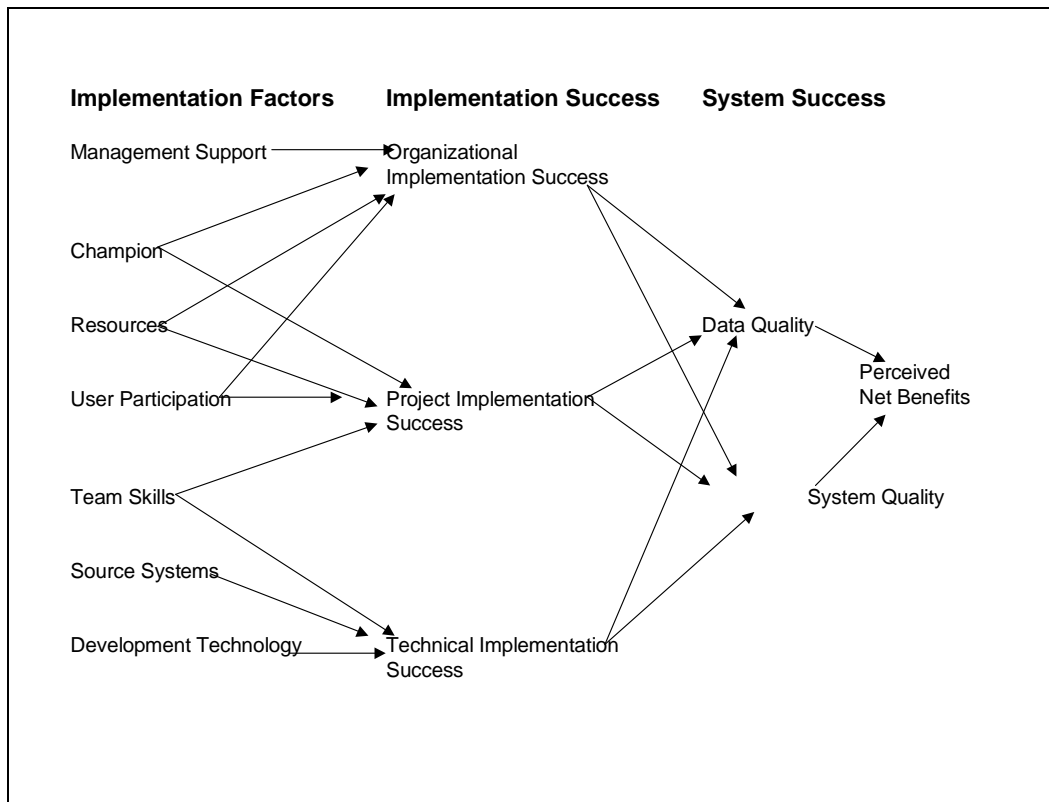
To address the deployment aspects of our research, we turn to the data warehousing implementation literature.

III. DATA WAREHOUSING IMPLEMENTATION LITERATURE

Current technologies, such as data warehouses, continues to be met with limited implementation success.. When organizations seek to implement these technologies and deploy an outsourcing strategy, implementation success can be further complicated.

In an investigation of 111 organizations that implemented data warehouses, Wixom and Watson [2001] conclude that perceived net benefits are associated with system quality and data quality. Management support and resources also contributed to organizational implementation success;

however, organizational, project and technical implementation did not impact data quality. The Wixom and Watson [2001] research model was used as the basis for the initial theoretical model of data warehousing success to drive action research investigations during our work with Solectron (Figure 1).



Adapted from Wixom and Watson [2001]

Figure 1. Research Model for Data Warehousing Success

The research model proposes three levels of implementation success:

- Organizational,
- Project, and
- Technical.

The Wixom and Watson [2001] model advances the current body of knowledge by identifying levels of success, including those most relevant to data warehousing environments. Moreover, the research model is inclusive of shared topologies attributes that define the infrastructure needed to deploy data warehousing applications [Payton and Ginzberg, 2001]. In Figure 1, these factors are team skills, source systems, and development technology. They point back to the sourcing literature discussed in Section II.

As shown in Wixom and Watson model in Figure 1, systems success is moderated by the three levels of success. Systems success is a combination of systems quality and data quality. Seddon [1997] defines systems quality as the consistency of the user interface, ease of use; and quality of documentation and maintainability of the program code. Data quality and information quality take on an analogous meaning of relevance, timeliness, action and accuracy of the data generated by the system in question.

The model implies that significant paths exist among the implementation factors, implementation success and system success that result in perceived net benefits. Similar to Wixom and Watson

[2001], the IS success research of Seddon [1997] defines net benefits as the sum of all anticipated benefits less any past and future costs credited to the use of the IS application.

Thus, the use of the Wixom and Watson [2001] model as a theoretical foundation is based on three factors.

1. The model synthesizes the data warehouse IS implementation literature. The model also captures details of the IS outsourcing research to incorporate factors, such as top management support, user participation, resources, and systems quality. Thus, it is comprehensive and cumulative.
2. The model was tested in part using qualitative and quantitative research methods [Cooper, et al., 2000].
3. The model explicitly addresses the issue of data warehouse implementation – which aligns with our problem situation.

The Wixom and Watson [2001] framework offers a precursor to the elements that do and do not impact the three levels of implementation success (organizational, project, and technical) listed earlier in this Section. Namely, their model enabled us to establish a set of pre-implementation factors impacting data warehousing deployments while linking measurement of each variable to each of the implementation levels. This is particularly the case at the technical stage which we later call the ongoing measures at a post deployment phase.

IV. RESEARCH METHODOLOGY

Our research uses action research to refine the data warehousing implementation framework as set forth by Wixom and Watson [2001]. In addition, we sought to develop solutions (which proved to be novel) to the specific challenges confronting the Solectron management team.

Our action research team consisted of the authors of this article, and members of the Solectron global supply chain and data warehousing deployment teams. The five practitioners (Global Data Warehouse, IT Manager, Chief Materials Officer, and two Supply Base Managers) added extensive internal and external experience in supply chain applications and supplier relationship management to the team. The global data warehousing manager's prior industry experience included deploying ERP. Our team, however, did not include a Solectron IT member because Solectron's IT organization outsourced the IT functions to IT, data warehousing and ERP vendors and consultants.

HISTORY OF ACTION RESEARCH

Baskerville and Wood-Harper [1998] provide an historical background of IS action research dating back to the 1940s. Disciplines, such as operations research and psychology, use action research to examine problem situations in social disorders among prisoner of war camps, post-war experimentations, and organizational consulting. While the 1975-1990 timeframe ushered in action research addressing organizational learning, systems learning and soft systems methodologies, IS researchers [Lau, 1997; Baskerville and Wood-Harper, 1996; Lacity and Willcocks, 1998; Baskerville, 1999] provide procedures to improve the field's acceptance and use of this methodology.

While the specifics of action research [Baskerville and Wood-Harper, 1998] vary in form, we ascribe to participant observation, action learning, unstructured interviews and archival information. For an 18-month period, we interacted with the five Solectron managers on a bi-weekly basis. During the following, concluding eight months of the project, these interactions occurred weekly. Our participant observation enabled us to be directly involved in Solectron's daily activities, including departmental and corporate meetings, global conference calls, plant tours and vendor assessment sessions. During these sessions, we served as experts of the action research team, yet our primary goal was scientific knowledge about our data warehousing implementation questions.

Using action learning, we adhered to a reflective process of documenting all interactions with Solectron. To this end, we transcribed all interactions (e.g., unstructured interviews, focus groups) within 24 hours. We could therefore quickly analyze our data and determine which of our perceptions and tentative conclusions were inappropriate relative to our research model and for the organization. For archival information, we gained access to internal Solectron documents about its data warehouse implementation and data quality assessments. These data enabled us to track key performance indicators (KPIs) over time and to introduce new approaches to assess outsourcing success. For this research, we present our newly developed and tested performance metrics (Section VII) without revealing Solectron confidential data.

Lastly, we drew from Baskerville and Wood-Harper [1998] for evaluation criteria for our research. Adhering to internal and external validity assessments, respectively:

- We sought to resolve the immediate problem in question through our research initiatives. That is, action research lends itself to goal achievement through the validity of actions directed toward our objective.
- We sought to refine or augment an existing framework to demonstrate how our actions resulted in beneficial outcomes. Here, we highlighted the criticality of condition-seeking [Greenwald, et al., 1986] to aid practitioners with analogous characteristics and researchers for future action studies.
- Other validity criteria in our research included:
 - a. multivariate social settings,
 - b. recorded and analyzed observations in an interpretative frame,
 - c. researcher action and intervention and
 - d. participatory observation.

V. RESULTS – FACTORS THAT AFFECT SUCCESS

Our initial findings based on a second set of field experiences¹ are presented based on three conditions that we found:

- Multiple, concurrent project implementations
- Outsourcing strategic IT function combined with lack of internal IT expertise
- Lack of a priori success measures

We provide details about the data warehousing outsourced by Solectron.

MULTIPLE CONCURRENT, LARGE SCALE PROJECT IMPLEMENTATIONS

To support its phenomenal growth (Section I), Solectron engaged in multiple IT initiatives, including implementation of an enterprise resource planning (ERP) system, a reporting application, a World Wide Material Planning System, and a global data warehouse. This level of IT growth and the number of concurrent projects proved to be unmanageable. Outsourcing the strategic data warehouse was seen as a means to reduce IT costs, staff, and maintenance.

OUTSOURCING STRATEGIC IT FUNCTIONS COMBINED WITH LACK OF INTERNAL IT EXPERTISE

Given its growth (Section I) and its need to integrate data from diverse internal and external sources along the supply chain, Solectron deployed numerous technologies to consolidate its

¹ Figure 2 in Section IV presents the timeline.

corporate data into one source system. Solectron's success had been linked to its ability to establish long-term partnerships with customers and suppliers, supported by consistent quality, responsiveness, continuous improvement, and technology leadership. In deploying this strategy, Solectron essentially created a new market, and thereby developed a new way of managing its customer and supply base, through an evolving total business strategy of supply chain management. To build this capability, it required vendors that could provide IT support, since the organization lacked the human resources internally to deploy an integrated system across its customer and supplier bases.

Despite past successes, the organization continued to be challenged by its technology implementations. In particular, Solectron was concerned about what determines data warehousing implementation success particularly in cases of an outsourced IT function. Using several action research categories [Bryman, 1987; Baskerville and Wood-Harper, 1998], our initial participant observation, action learning, unstructured interviews and archival information we found many issues involving source systems, system and data quality, resources, team skills and management support.

Given the vast number of acquisitions among global businesses, internal data integration was another ongoing-challenge. When extending data integration across multiple tiers of suppliers and customers in integrated supply chains, the challenge to organizations, such as Solectron, appear insurmountable. The hurdle of internal data sharing among intra-organizational departments becomes huge when attempting to integrate across external supply chain customers and suppliers. At Solectron, these challenges increased as the company acquired new divisions from key customers such as IBM, Hewlett Packard, Nortel Networks, and Cisco. Solectron's outsourcing of its internal IT operations, likewise, added to the complexity associated with its supply chain data integration initiatives.

LACK OF A PRIORI SUCCESS MEASURES

Building from a position as a simple contract manufacturer, its services were integrated to the point where the firm was responsible for all supply chain processes associated with sourcing parts, building, and distribution of electronics and systems for almost every major OEM customer in the computer industry. While the diversity of major customers was said to contribute to the organization's financial success, prior diversity in the levels of IT maturity in Solectron's customer base acquired through its high growth strategy proved to be difficult. Solectron's high growth meant that a lack of a priori measures of success existed within this entrepreneurial model of growth at any cost. The company grew its business in response to opportunities, and often overlooked the implications for building a solid IT infrastructure behind this growth.

For the data warehouse implementation, top management decided to outsource the IT function in the midst of multiple IT supply chain application development projects. However, Solectron was unsuccessful in establishing pre-outsourcing implementation success metrics to engage effectively in long-term vendor partnerships, short-term contracts, or performance-based contracting.

VI. RESULTS - FIELD EXPERIENCES AND TO PRACTICE

Figure 2 illustrates our progress and field experiences over time with Solectron. During 1999, our interactions with Solectron involved data gathering from various supply chain, HR and material management managers. This was followed by a long series of interactions from 2000-2001 as indicated in Figure 2. In 1999, our initial field experiences began by collecting internal Solectron documentation and meeting notes. Our second set of interactions occurred between 2000 and 2001; these activities on-site observations, manufacturing tours and weekly reviews of the data warehousing performance, just to name a few. Our third set of field experiences involved working directly with the Global Data Warehousing Manager. In an effort to implement what Solectron called a "single source system" or its data warehouse, management recognized early in the deployment process the need for internal data integration. To this end, data from internally

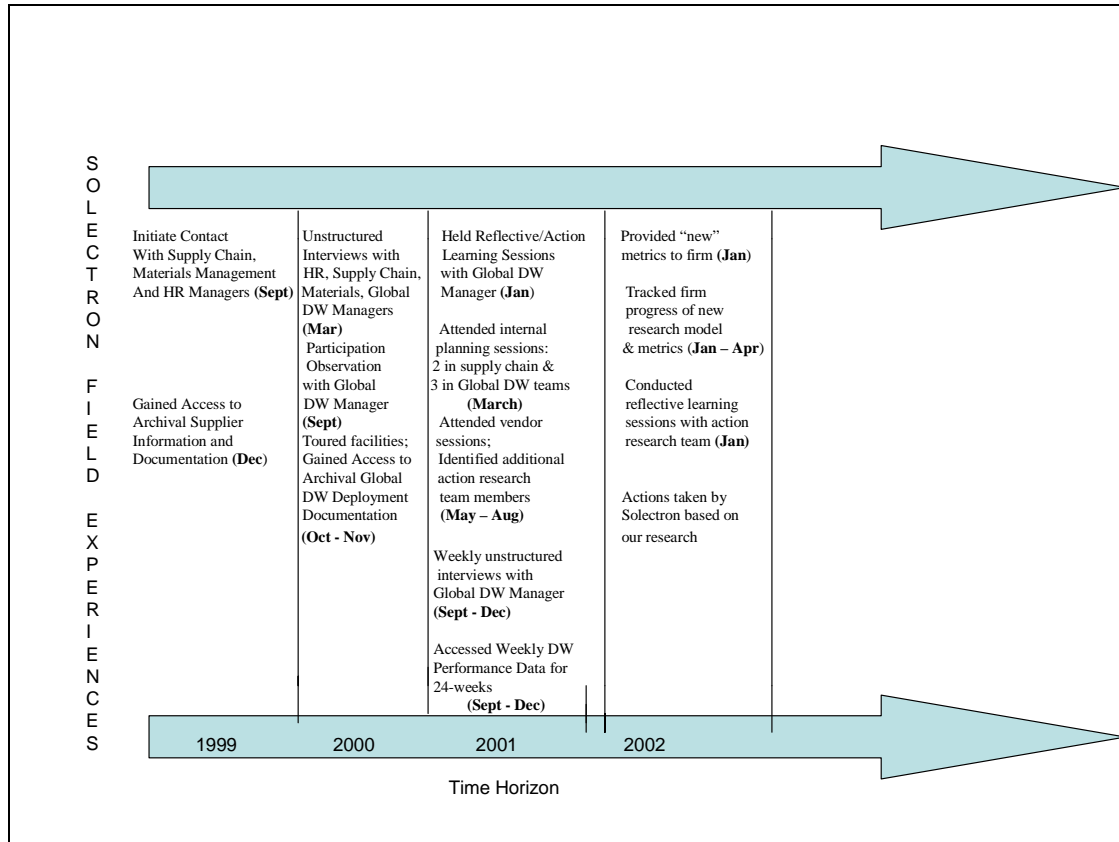


Figure 2. Action Research Timeline

developed systems, the ERP application, and disparate user tools (Access databases, Excel files) compromised the quality of the data in the warehouse.

"One other person along with myself manually scrubbed the data from legacy systems over the course of 4 to 5 months. It was a laborious, tedious job and human error was bound to happen".(Global Data Warehousing Manager)

Further, Solectron used an internal corporate steering committee to determine its data integration needs – given the corporation's strategic direction to migrate to supply chain solutions with its ERP application and an internally developed material management system to enable collaborative forecasting. The steering committee consisted of finance, human resources and material management representatives. A member of our action research team described how poor data quality in source systems impacts data quality to and from the warehouse:

"Data integration and the data warehouse are vital to maintaining our competitive edge. For years, we have experienced remarkable financial returns. We have sustained the highest of quality standards. To share data across all of our plant sites and with our business partners, we must talk apples to apples. This is part of our total business strategy. We want to become and remain the highest quality, low cost supplier of components to our suppliers and customers."(Global Data Warehousing Manager)

Our Solectron team members suggested that data quality from the data warehouse is a function of data accuracy, standard formats and common definitions. We believe that common definitions are the most difficult issues to resolve and require the most labor-intensive activity. This problem

proved to be the case with Solectron. A standardized language is a prerequisite because supply chain partners and internal business units must adhere to a common jargon. Admittedly, Solectron did not employ standard supplier codes prior to its data warehouse implementation. To date, smaller less strategic suppliers, the organization continues to lack standard codes. While common definitions would foster universal standards, language, and understanding, Solectron faced the challenge of data accuracy of its data warehouse's content. Several members of the Global Data Warehousing team lack confidence in "what's in the data warehouse". One manager described a recent instance involving upper management and explained that the data warehouse vendor failed to meet his expectations.

"Much of this problem is that [the ERP] treats data elements differently than our internal processes. Standard supplier codes are not standard, so we use cross-reference tables for validation...if this did not happen; we had VPs yelling at the plants because data in the reports were not accurate. (They....know from experience that the data are wrong)."

VII. DATA WAREHOUSE OUTSOURCING METRICS

As discussed in section V, we found that outsourcing metrics were badly needed. The outsourcing team, therefore, created the metrics described in this section for the data warehousing initiative.

To develop the needed metrics, our action research team analyzed the systems and data quality dimensions in the research model (Figure 1). Solectron was clearly concerned about improving its understanding of the data warehouse along these dimensions and thus wanted to refine what it called key performance-based indicators (KPIs) or metrics to measure success. Eight metrics were developed to measure Solectron's data warehouse performance. Each was refined and defined over a period of 30 days during the action research process. They are :

1. Completeness

$$\text{Total Complete} = \left(\frac{\text{\#Records}}{\text{Total \#Records Expected}} \right) \times \left(\frac{\text{\#Records Expected}}{\text{Total \#Records in all tables}} \right) \times 100. \quad (1)$$

We suggested that this metric would serve Solectron better than a simple binary yes/no in measuring the weighted average of each table in the data warehouse. It also measures the percentage completion during an Extract –Transfer- Load (ETL) and/or refresh process. This metric also, and helps identify any possible SQL problems within a particular table. The metric allows troubleshooting individual tables and methods of and for users connecting to these tables.

2. Connectivity

$$\text{Response Time} = \text{\#Users} \times (\text{RTD}\% + \text{TR}\%) \quad (2)$$

Where² Run Time Duration (RTD) in minutes = Hardware/DW size

$$\text{Transfer Rate (TR)} = \text{Actual Transfer Rate/Optimal Transfer Rate}$$

This metric measures connectivity by enabling Solectron to identify and isolate underlying issues including ISP transfer rates, data sources, and hardware issues. Software packages, such as Tivoli/Netview 6.0, Spotlight, or I/Watch, can be used to automate and tap further into the database structural architecture to pinpoint performance problems.

3. Data Integrity

² "Hardware" is defined as the capability of the company's hardware as it relates to Run Time Duration. This definition is based on the assumption that it includes such factors as processor speed, amount of RAM, and drive speed.

$$\text{Data Quality Tool Rate/Manual} = \% \text{ Accuracy} \quad (3)$$

Our action research team strongly recommended that Solectron pursue a software program that will perform scrubbing so that the tedious, resource intensive method done in the past is not repeated. Commercial applications, such as SAS DataFlux and Trillium, can be used to calculate the data quality rate. These statistics can further be compared to a prior manual rate to report a data integrity metric.

4. Usage Data from the Data Warehouse

$$\text{Usage Rate on Data} = \text{Most frequently used/Total} \quad (4)$$

Our team proposed that Solectron track the usage rate of tables, reports, and the overall data warehouse to identify any trends and/or problems that may occur, particularly during peak operating times. This metric also enables the organization to visualize those reports, tables, and other outputs used most frequently, thereby enabling refresh times to be staggered according to the organization's needs.

5. On-Time delivery

This current metric is defined as: tables are on time if they are delivered by 7:00AM local time at the sites to which they apply. Ideally, this metric is multi-level.

- Level one asks: were all required tables delivered by 7:00AM - yes or no?
- Level two is, how late were the tables? The difference between one minute late and four hours late is big.
- Level asks how many of the required tables were late? 1 out of 40, or 40 out of 40?

6. Ticket Cycle Time

Average of the number of days a ticket stayed open; that is how long was an issue unresolved by the IT/data warehouse vendor before completion?

7. User Hits on the Databases

The number of times per day (broken out by hour, and averaged for a week) that users "hit" the data warehouse databases. Our focus here is on "real" users rather than system administrators – thereby representing the utilization rates and reducing over (under)estimations.

8. Run-Time

The number of minutes required to produce all extracted tables, by site.

Based on performance data from the warehouse, our team plotted these eight metrics over 24 weeks. While the precise results are confidential, several warehousing sites reported an upward trend of run time (duration to produce all extracted tables) which in several instances peaked slightly over 150 minutes.

During the third series of field experiences, we analyzed the issue of performance-based success and data quality because organizations must achieve an acceptable level of quality to roll out the warehouse to their users. Initial phases of Solectron's outsourced data warehouse implementation failed primarily because the organization lacked adequate financial and human resources.³ The absence of upper management support, adequate resources and necessary team skills largely explained the lack of organization, technical and project success. Therefore, our research team sought to use the above metrics as a communication tool among the senior Solectron officers and the vendor.

³ Management was cutting back on resources in 2001 due to a sudden slowdown in the electronics and telecom sectors.

While Solectron did not attain an acceptable level of data quality, the organization did proceed with its data warehouse phased implementation approach while outsourcing this entire process and function to a data warehousing vendor. With more integrated and comprehensive data, Solectron anticipated that it would capture, transform, and share data along its supply chain which includes work-in-process, customer orders, and collaborative forecasting.

“The ability to include business partner data adds strategic advantage; then, the warehouse moves from an operational, tactical function to gaining value on a global supply chain scale”. Global Data Warehouse Manager

A Ninth Measure

Along the System Success dimension of data warehouse implementation success in Figure 1, the absence of management support, resources and team skills hindered the organization from reaching the net benefits it hoped for.

Our performance-based metrics were used to communicate areas of concern to the data warehousing vendor. During interaction three, Solectron practitioners segregated our metrics that they deemed most critical to correcting the issues of its contractual relationship with its vendor. Consequently, our action research team developed a weighted average measure using four of the eight metrics to determine how the vendor stacked up relative to data quality and systems quality. Based on input from Solectron and using four of the eight KPIs, we developed the following data warehouse performance measure (on a scale of 0 to 1.0) analogous to the following:

$$\text{Data Warehouse Performance} = (0.40 \times \text{Data Integrity}) + (0.10 \times \text{Completeness}) + (0.30 \times \text{Connectivity}) + (0.20 \times \text{Run Time}) \quad (5)$$

These weights are based on Solectron’s managers’ input. The four metrics used were deemed the most critical to the organization assessing data warehouse performance. Solectron endorsed this single measure as a means of isolating problem areas among data quality versus system quality issues. Given our graphic tools of the eight measures using 6-month data plots, our research team was able to use quantifiable data to support the following:

1. Increased management support and resources would improve organizational implementation success.
2. Inefficient team skills hampered project implementation success. Thus, Solectron management used our quantitative data to renegotiate contract terms with the vendor and communicate deficit areas associated with the data warehouse.
3. Solectron’s data warehouse implementation was supported by an internal team limited in size, available resources, and technical skills needed to sustain the technology. While there were no apparent issues with the development technology, the many source systems feeding the data warehouse proved to be a challenge to data and system quality.

VIII. REFLECTIONS: LESSONS LEARNED

After tracking the warehouse data, our research team continued to communicate via email and bi-annual supply chain meetings. This communication enabled us to assess progression of the data warehouse project. During the last months (January-April 2002), the authors conducted interviews with members of the Solectron management team to determine how our research had caused change to result in the organization – as we sought to resolve the problems noted from our initial interactions and field experiments.

Based on our interactions with Solectron, we offer lessons learned to the field as action researchers and to practice.

LESSON #1: CREATE PERFORMANCE-BASED MEASURES PRIOR TO DATA WAREHOUSE VENDOR SELECTION

Performance-based measures are needed prior to data warehouse vendor selection. This is particularly the case in outsourcing where the outsourcing organization lacks an internal, skilled IT staff. These metrics should be tightly linked to the users' pre-implementation requirements associated with business processes. The performance metrics our team provided helped Solectron with monitoring its data warehousing vendor. Solectron personnel, indicated that in general it would be valuable to generate these metrics earlier in its vendor selection process, that is, prior to deployment. In particular, the organization could engage in managed contract negotiations and assess vendor selection using more quantitative criteria.

"We hope to use these metrics to communicate with the [warehousing] vendor on how they can improve the services provided to us, and we can, in turn, pass improvements in productivity and efficiency to our business partners and customers." (A Solectron manager)

Though metrics abound, they should be limited to a few key performance indicators to enable the organization to track and monitor its technology investment and perceived benefits.

LESSON #2: ON-GOING METRICS TRACKING IS REQUIRED FOR SUCCESS

On-going post-implementation metrics are also required to ensure success. During the second quarter of 2002, the Global Data Warehouse Manager continued to advocate the performance-based measures and graphical tools to evaluate performance. While graphical tools assisted the practitioners to visualize key problem areas both internally and with the vendor, challenges remained with the data warehouse's success measures. Problems pointed to the inability to improve performance associated with runtime in Solectron's global operations centers and with management of the ETL process.

LESSON #3: OUTSOURCING ORGANIZATIONS SHOULD CONTINUE TO STAFF INTERNAL EXPERTS AND PERSONNEL TO SUPPORT THE OUTSOURCED FUNCTION.

Outsourcing critical, strategic applications can create large implementation challenges, particularly when a dedicated internal IT staff does not exist. The quality of the outsourcing partnership, in Solectron's case, was largely affected because the degree of trust was challenged and conflict arose [Lee and Kim, 1999]. As shown in this action research, outsourcing to a data warehouse vendor without keeping some internal technical skills as a building block can be a miscalculation.

To increase the IT skills of the development team, Solectron hired two data warehouse architects, one of whom was responsible for performance tracking using the measures and graphical tools described in section VII. Further, upper management allocated additional money to support the data warehouse implementation, which was described as a

"blessing in these economic times and a signal that the project is now mission critical for the entire organization". (Global Supply Chain Manager)

More organizational communications endorsing the data warehouse occurred through a written directive from upper management. These efforts targeted upper management (CEO, CFO and Supply Chain Director) and communicated that the project was global for Solectron and its supply chain.

Sourcing and order fulfillment capabilities are vital to the strategic application of the data warehouse. The sourcing function includes

- supply base management,
- controlling total cost,
- creating and exchanging long-term value, and

- creation of value partnerships with suppliers.

The order fulfillment function focused on

- plant management,
- OEM relationships,
- distribution,
- configuration of products to customer orders, and
- tying in to the OEM's customer order systems to identify configurations, and post-manufacturing support.

Optimization of these capabilities was expected to enhance systems and data quality – thereby yielding net benefits associated with the data warehouse implementation.

LESSON #4. PAY CLOSE ATTENTION TO DATA QUALITY AND INTEGRATION

Solectron was deploying a global data warehouse, ERP applications, and many internally developed source systems at multiple international locations, all at the same time. This combination of technology platforms further complicated Solectron's strategic vision and sustainability of its core competencies. The politics of resource allocation (money, time and human) among these projects tended to impact organizational, project, and system implementation success and ultimately systems and data quality.

"...the robustness of EDI remains and it (is) a low cost option. Implementations of ERPs and data warehouses are costly and have tons of implicit consequences to the organization....such as process reengineering and cost overruns.... Understanding how the ERP views data verses how Solectron views data is a challenge. Often, we (the organization) have had to rethink our processes to (fit) the ERP rather than pay for additional customization from [ERP vendor]". (An interviewee)

One of the most important but overlooked elements of implementation success is data quality and integration. The task of data integration requires that organizations begin data requirements and definitions processes early in the process. If the data warehouse is implemented without well-defined data elements, organizational resources can become depleted, thereby distracting from the strategic vision and core competencies of the firm.

"we had to make sure what the data elements were first, and to some degree, we are still looking at data elements. The warehouse hosts a large number of tables, and this was time consuming." (A Solectron manager)

LESSON #5. USE A COMMITTEE TO DRIVE CRITICAL PROCESSES

Ideally, joint application development, steering committees, and/or cross-functional teams should define performance metrics, implementation success measures, and perceived benefits in such a way that they are aligned with those of users. Ideally, the supply chain systems team collaborates with the IT group (or vendor) to determine the types of information and reports needed, leading to the information requirements for the data warehouse. Note that supply chain users and IT staff should be on an equal footing in making decisions about the structure of the warehouse. Each group should be able to make a solid economic business case to a neutral team leader to ensure a structured approach to decision-making.

As illustrated by our research, this approach is the exception rather than the rule. Political issues inevitably creep in, and personal agendas may define the requirements of the system that ultimately are unrelated to user requirements. To avoid such scope creep, we emphasize again the importance of tapping into user satisfaction requirements, and establishing solid pre- and post-implementation metrics for success.

IX. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

CONCLUSIONS

We found that action research facilitated our ability to capture the outsourced data warehousing implementation experiences of Solectron. Moreover, action research enabled us to define and refine a set of pre-implementation metrics. While the organization appreciated our evaluation tools, Solectron learned lessons that were, otherwise, overlooked by its upper management team. Though the Wixom and Watson model provided a foundation for several of our findings, the model does not capture the outsourcing conditions as experienced by Solectron or numerous other organizations that are increasing moving to off-shore and/or outsourcing strategies. Finally, our research resulted in three propositions that warrant further testing:

- P1: a) Outsourcing pre-implementation metrics and
b) post-implementation metrics
are associated with data warehousing implementation success.
- P2: Defining organizational barriers and team skill requirements prior to implementation is associated with data warehouse implementation success.
- P3: Data quality and system quality metrics are associated with perceived net benefits.

FUTURE RESEARCH

The following are important future research topics based on what we found at Solectron:

1. Determine if common data warehousing implementation metrics can be adopted by organizations by industry sector and under what conditions.
2. The metrics offered for Solectron can be examined to determine their generalizability and robustness.
3. Determine, through quantitative analyses, whether the Propositions presented in the Conclusions are correct. While a common set of implementation factors is often cited in the literature, our research suggests that pre-established key performance indicators lead to implementation success.
4. Extend the Wixom-Watson [2001] model so that it explicitly takes outsourcing into account.

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