Understanding Postadoptive Behaviors in Information Systems Use: A Longitudinal Analysis of System Use Problems in the Business Intelligence Context

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Abstract: For an organization to gain maximum benefits from a new information system (IS), individual users in the organization must use it effectively and extensively. To do so, users need to overcome many problems associated with their system use in order to integrate the new IS into their work routines. Much remains to be learned about the types of problems that users encounter in using the new system, in particular, the root causes of system use problems and how they relate to and co-evolve with the problems over time. In this study, we seek to develop a comprehensive and dynamic view of system use problems in organizations. Using a combined method of revealed causal mapping and in-depth network analysis, we analyze nine-month archival data on user-reported problems with a new business intelligence application in a large organization. Our data analysis revealed seven emergent constructs of system use problems and causes, including reporting, data, workflow, role authorization, users' lack of knowledge, system error, and user–system interaction. The seven constructs were found to interact differentially across two usage phases (initial versus continued) and between two types of users (regular versus power user). This study contributes to advancing our theoretical understanding of postadoptive IS use by focusing on its problematic aspect. This study also suggests useful methods for organizations to effectively monitor users' system use problems over time and thus guides organizations to effectively target mechanisms to promote the use of new technologies.

Key words and phrases: business intelligence, IS use, postadoptive behavior, revealed causal mapping, social network analysis, system use problem.

Organizations face challenges in achieving effective use of an information system (IS), such as the underutilization of system features [14, 39]. IS use has been commonly conceptualized and operationalized as the frequency, duration, or variety of system features used, based on users' self-assessment of frequency in using a system [15] or the duration of their usage via system logs [51]. These conceptualizations are limited as they largely focus on the successful incidents of individuals' system use while overlooking the unsuccessful ones. The difficulties users experience undoubtedly can influence their willingness and ability to use a new IS.

For an organization to gain maximum benefits from a new system, the system must be used effectively and extensively. To do so, users need to overcome many problems associated with their system use in order to integrate the new technology into their work routines. Unresolved problems related to users' difficulties in employing a specific technical feature to fulfill a business task can limit the continued and extended use of the technology application [12]. When system use problems are understood and resolved in a timely manner, organizations will be able to reap greater benefits from their new systems [20], while lack of timely response may negatively impact the task performance of both the individual users and organizations [12].

Despite their importance, users' problems with IS and particularly the evolution of types of problems over time are understudied. A few studies have examined system use problems with personal office applications, such as e-mail systems, word processing, and spreadsheet software [12, 23, 26]. In this study, we seek to develop a comprehensive and dynamic view of *system use problems* in organizations. Specifically, we aim to address the following questions: (1) What types of system use problems emerge during the postadoptive use of a new IS? (2) What are the causes of the system use problems? and (3) How do system use problems and their causes co-evolve over time?

We investigated these questions in the context of postadoptive use of business intelligence (BI) systems. BI systems are data-centric, fact-based software applications [49], which require users' understanding of data and data sources. Moreover, BI systems enforce strict user access to different reporting functions and data sets, which presents users with significant structural barriers to system access as well as discretion in how to make use of system features. The BI application context thus offered us an ideal opportunity to examine a variety of system use problems in postadoptive IS use.

We collected secondary data on user-reported problem incidents during the first nine months of users' employment of a new BI system in a large organization. We used a combined method of revealed causal mapping (RCM) [32, 33] and social network analysis (SNA) [17, 54] to analyze the data. We identified seven emergent constructs of system use problems and causes and the associations between these constructs and their evolving dynamics over time. These constructs interacted differentially across two usage phases and between two types of users. This study provides a systematic and dynamic theoretical view of the problems and barriers that hinder the successful use of new IS. Further, this study introduces a combined RCM/SNA approach based on secondary data as a valuable method for identifying emergent constructs and linkages and visualizing their evolving patterns.

The remainder of this paper is organized in six sections. In the Theoretical Background section, we review prior research and discuss our motivations for focusing on the problematic aspect of system use. In the Research Design and Method section, we describe our combined approach of RCM and network analysis to identify emergent constructs and linkages. In the Results and Discussion sections, we derive a comprehensive and dynamic view of BI use problems. Finally, we discuss the theoretical contributions and practical implications, and suggest directions for future research.

Theoretical Background

System use problems are important to understanding postadoptive behaviors in IS use. Prior research has noted the negative effects on individual or organizational performance. For example, Ceaparu et al. [12] found that organizational employees with computer use problems struggled with frustration and lost work time, resulting in a 38 percent loss in individual productivity. Users' problems with a new technology not only delay the completion of their work tasks but also impede the utilization of their domain expertise. For example, Mackay and Elam [26] found that a lack of expertise in spreadsheet software inhibited users' application of domain knowledge in health-care planning. However, research on postadoptive system use problems has focused on the context of personal office applications [12, 23, 26]. Ceaparu et al. [12] identified common system use problems, including confusing error messages, dropped network connections, and hard-to-find system features. Leung and Lau [23] differentiated routine IS use problems (i.e., simple problems associated with information technology [IT] administrative issues) and complex IS use problems (i.e., problems involving corrupted or missing files and slow performance of servers and Web sites). These studies have identified some common categories of system use problems in the context of personal computer applications.

However, this view is less sensitive to *IS use problems* in an organizational context, in which integration of technical features, work processes, and user roles is critical for achieving extensive, effective system use. We posit that postadoptive *system use problem* is a complex construct with different characteristics based on types of users and phases of system use. Thus, to fully understand postadoptive use, it is important to understand the causes and dynamics of system use problems during an individual user's enactment of ITs in an organization.

Our study extends existing literature by examining the problematic aspect of postadoptive behavior in IS use from two perspectives. First, we take a *multi-user* perspective to examine the barriers to effective use of new technologies. Second, we take a *dynamic* perspective to examine the associations between system use problems and causes and their evolving patterns.

A Multi-User View of System Use Problems

Individual users' technology use behavior is critical to understanding postadoptive use of IS and to maximizing organizational use of the technology [20, 21, 43]. For example, users' underutilization of system features may prevent organizations from obtaining fully the promised benefits of the installed technologies (e.g., [14, 39]). Rice and Cooper [39] found that user-enacted workarounds and undesired work routines resulted in delays in work schedules and negatively affected organizational performance. Hsieh et al. [20] observed that organizations were able to extract more business value from IS by engaging users in using more system features, when user problems with technical systems were understood and resolved in a timely manner.

Characteristics of individual users, such as their prior experiences and skills, influence their experience with IS. For example, research has found that users' lack of skills and expertise were major causes of problems with new computer technologies [6, 38, 41]. More importantly, users with different levels of expertise (experienced versus inexperienced) had different perceptions about their system use [49] and adopted different coping strategies in their interaction with ITs [2].

Prior studies categorize users into two types based on functional expertise and familiarity with ITs: power user and regular user (e.g., [6, 52]). The two types of users also tend to differ in their job functions. Power users are often key players in their business areas (e.g., in processing financial transactions) and are expected to interact with the system frequently and to attend formal trainings [6]. In the context of enterprise system implementations, power users have been described as "an individual from the users' community of practice sent to work with the implementation project team and to bring back practice-based knowledge" [52, p. 283].

In this study, we follow the conceptualization of power users by Boudreau and Robey [6] and examine system use problems in relation to power users and regular users. We posit that power users are likely to reveal different patterns of problems and causes in their postadoptive behaviors, given their differences in work context and expertise level.

A Dynamic View of System Use Problems

IS use is also dynamic, as individuals have demonstrated different adaptation patterns in their actual employment of technical features to perform work tasks over time. For example, during the early phases of postadoptive system use, employees engage in their initial learning of both new technologies and new work practices. Later, they engage in more exploration of system features and accomplish different kinds of tasks [43]. Some prior studies have suggested that organizations should focus on initial learning and use of technologies, highlighting the critical "window of opportunities" for users' exploration and adaptation [50]. Others have focused on extended use of technologies, emphasizing the use of more functions to complete a sophisticated array of tasks [20]. Regardless of the focus, these studies suggested that system use behavior varies over time. A longitudinal study of individuals' system use enables us to better understand why and how different patterns of system use emerge over time so as to extract differential values from a technology application [7, 21]. Likewise, examining system use problems over time generates additional insights regarding problem causes and effective resolution strategies.

In summary, our understanding of the problems and barriers that inhibit effective system use is still at an early stage despite the increasing attention to postadoptive IS use. Identifying the major areas of users' difficulties with an implemented technology and tracing the underlying causes will enable organizations to recognize and resolve system use barriers promptly and to prevent similar problems. Therefore, this important, yet underexplored, aspect of postadoptive behavior is the focus of our study.

Research Design and Method

To achieve the research objective of this study, we collected secondary data on user-reported system use problem incidents (problem records) in a large organization over a nine-month period after the implementation of SAP Business Warehouse (BW), the business intelligence and warehousing application produced by SAP AG. We analyzed the data with a combined approach of RCM [32, 33] and SNA [17, 54]. RCM provides qualitative insights into the constructs of IS use problems and causes, while SNA offers quantitative insights into the linkages among the constructs and a visualization of the changes in the causal–effect linkages over time. This combined approach enables us to identify the dimensions and evolution of system use problems, thus adding value to studying postadoptive use of IS, especially those technologies that are emerging and rapidly evolving.

Business Intelligence System as the Research Context

The term "business intelligence" describes a set of concepts and methods based on fact-based decision support systems (DSS) for improving business decision making [37]. BI applications extract, transform, analyze, and report large volumes of data to aid strategic and managerial decision making in organizations. BI technologies have been increasingly adopted by organizational users ranging from senior executives to business analysts [16]. In the past two decades, BI technologies have been rapidly evolving toward real-time and powerful data analysis and visualization [49]. Effective use of those capabilities requires users' discretion in employing BI system features and data sources. Individuals face challenges of not only getting familiar with technical functionalities (e.g., data reporting) but also understanding the integration of disparate data sources. BI systems are further characterized by role orientations regarding different system functions and data sources [16]. Therefore, individuals in different roles may experience different problems and challenges when using the system, necessitating an examination of the system use problem construct by user type.

Research Site and Data Collection

We collected data in a large organization (the Organization) located in the northeastern region of the United States. In January 2007, the Organization implemented a BI application (i.e., SAP/BW) with four modules: Human Resources (HR)/Payroll, Supply Chain, Sponsored Projects (e.g., Grants Management), and Finance. Prior to the SAP/BW system, employees accessed disparate systems and databases for their information and reporting needs. Starting in April 2007, all users who relied on legacy reporting applications had to switch to the new BI system for their data analysis and reporting. At that time, the Organization set up a centralized SAP/BW support center, which became the major resource of systems use knowledge. The problems reported by the SAP/BW users offered a comprehensive perspective on the system use problems in the Organization.

To manage its operation, the support center used a ticketing database to record all the user-reported problems as well as details of the diagnosis and resolutions. We extracted the problem records during the first nine-month period of SAP/BW use, from April 2007 to December 2007. Each record of a problem incident, identified by a unique ticket number, included a brief description of the problem, the assigned and closing support personnel, the opening and closing time, and problem resolution details. Users elaborated on the details of their problematic interactions with the BI application, thus facilitating the support center's accurate and objective recording of each problem incident in the ticketing database.

To improve the internal validity of our analysis results, we used two additional data sources: field observations and interviews. First, we conducted field observations of user training in March 2007 (prior to the formal use of SAP/BW), including one full-day SAP/BW training session and one two-hour private demonstration of SAP/BW reporting functionalities. Second, we interviewed the lead SAP/BW specialist and the support center manager at two different points in time, in March 2008 and August 2008 to discuss our initial analysis results with the informants. Insights from these two sources supplemented our data analysis and facilitated the interpretations of the research findings.

Data Analysis Using Revealed Causal Mapping and Network Analysis

Data analysis was performed by using the combined approach of RCM and SNA. RCM is a qualitative methodology commonly used in studies of managerial cognition and strategy. Revealed causal maps show the networks of causal relations revealed in a person's statements or assertions in causal mapping [33]. Although not widely used in IS research, RCM has proven to be a useful approach in building midrange theories where generalized frameworks and theories exist, but the domain-specific nature of an important phenomena calls for an in-depth understanding [32, 33]. We first constructed revealed causal maps, following the guidelines provided by prior research [32, 33, 34], to identify the recurring problems that individual users experienced with the SAP/BW system and to reveal the underlying causes. In the network analysis, we created network matrices to analyze the causal linkages. We then calculated various measures to examine the interactions among constructs and to assess the relative importance of various constructs over time. This combined approach allowed us to derive new insights into the association between system use problems and their causes.

Similar to the early sociotechnical systems approach (e.g., [4, 5]) and organizational linkage analysis or interpretive structural modeling [19, 44, 53], our approach views system use as a joint coupling of the technical aspects (e.g., processes, tasks, and technology) of IS and social aspects (e.g., attitude, values, knowledge, and skills) of the users (e.g., [4, 5]), and examines the interdependencies and connections among causes and consequences at the individual level of use within an organization. However, unlike those approaches, which focus on the sources and consequences of variances, our approach integrates more in-depth network analysis with RCM. This emphasis allows us to identify emergent constructs and linkages, to quantify their importance, and to visualize their evolving patterns.

We view the system use problem construct as a collective construct at the organizational level because of interdependence in use among BI users [7, 8]. The interdependence was evidenced when all the SAP/BW users accessed the SAP/BW support center for assistance and when the support center coordinated and managed all the resolution and diagnosis that individual users received.

Our analysis includes three parts: (1) causal maps for all data over nine months, (2) temporal analysis in four-week increments and two usage phases, and (3) in-depth analysis of causal maps for two nominated informants, who represented power users and regular users. The interview analysis was supplemented by these users' problem reports generated by the ticket system. We used a four-step process to identify system use problems and evolving patterns in the context of the SAP/BW system: (1) data elicitation, (2) construction of revealed causal maps, (3) validation, and (4) network analysis.

Step 1: Data Elicitation. We retrieved the archival data from the research site's ticketing database in March 2008. Overall, approximately 2,000 users, typically managers and business analysts across the Organization, had access to the new SAP/BW system. To maximize the sample variation, the lead SAP/BW specialist and the support center manager recommended a representative group of 13 business units, including two business offices, one controller office, one HR/payroll office, one research division, one nursing administration, and seven academic departments. In total, we extracted 329 problem incidents during the nine-month period (April 2007–December 2007) for data analysis. The number of problem incidents per business unit ranged from 13 to 37, with an average of 25.

Step 2: Construction of Revealed Causal Maps. Following Nelson et al. [33], we derived revealed causal maps of BI system use problems in five steps. We started the construction of initial causal maps by coding problem descriptions into causes and effects. Two researchers independently constructed the initial causal maps of 20 randomly selected incidents and compared the coded constructs and linkages. The Cohen's kappa index of 0.778 exceeded the sufficient level of 0.70 for intercoder reliability [25, 42]. In the case of disagreement between coders, a third judge, the lead SAP/BW specialist at the site, helped to resolve discrepancies. Two coding examples—one with coding agreement and the other with an initial disagreement—are illustrated in Appendix A.

Based on the initial causal maps constructed, we identified a total of 429 relevant concepts via two approaches. We highlighted and grouped repeating words or phrases, such as "role," "reporting," and "tell me how." Further, we drew upon the IS support studies for guidance on high-level categories of technical issues, such as "missing functionality" and "erroneous operation" [13], to facilitate categorization of the concepts we identified. We then replaced the "cause" and "effect" statements with the coded concepts and linked "cause" and "effect" with an arrowed line to obtain a causal map at the concept level. Finally, we aggregated all the concept-level maps across all the incidents to obtain a causal map at the construct level. In addition, we developed causal maps for two usage phases and for the power user and regular user. Each number shown on a causal map reflects the percentage of that particular linkage over all the concepts identified at that level of analysis.

Step 3: Validation. Expert checks were used to validate the concepts and constructs identified in the revealed causal maps [33]. We interviewed the lead support specialist for the SAP/BW application during the first 12 months after the system went live. We visited the site in August 2008 and held a half-day (four hours) meeting with the lead support SAP/BW specialist, in which the informant provided useful feedback regarding the identified constructs. For example, we classified "reporting availability" and "reporting navigation" under the category of "reporting problem," based on the feedback that these two problems often emerged in one incident. Finally, we confirmed the analysis results with the SAP/BW support expert, which helped verify the validity of our revealed constructs.

Step 4: Network Analysis. To capture the direct and indirect causal linkages, we created two network matrices: the adjacency matrix and the reachability matrix. Although a similar procedure was suggested in prior research using RCM (e.g., [33]), we conducted a more detailed network analysis based on Freeman [17] and Wasserman and Faust [54]. When using the adjacency matrix to analyze a causal linkage between two concepts, we were interested not only in the relationship's *existence* (its presence or absence) and *direction* but also in its *strength.* We calculated the strength as the frequency of the linkages between two concepts. We further calculated three centrality scores—out-degree centrality, in-degree centrality, and betweenness centrality—to examine the interactions among constructs. In particular, we were interested in the number of constructs that a focal construct was influencing, the number of constructs that influenced a focal construct, and the construct(s) that was more critical in bridging the causal chain linking two other constructs. These measures were obtained using UCINET v6.278 [3].

To identify the cumulative influence of a construct on a revealed causal map, we created the reachability matrix to take into consideration all the direct and indirect linkages between two constructs. Reachability is the total probability of one construct resulting in another construct through direct and indirect paths. We calculated reachability scores by summing up the total strength of all the direct and indirect paths going from one construct to the other. The strength of the direct path is the probability of one construct directly causing another construct. The strength of the indirect path is the probability of one construct indirectly causing another construct and is calculated by multiplying the strengths of all the linkages involved in the indirect path linking the two constructs. As the reachability score is a weighted value, the row sum of the reachability matrix represents the total cumulative effect of one construct on all the other constructs, while the column sum indicates the total cumulative influence that a construct receives from all the other constructs. Appendix B provides detailed definitions and calculations for the reachability and betweenness centrality of a construct.

Results

Our data analysis revealed that system use problems were related to seven major constructs: role authorization problem, reporting problem, data problem, workflow problem, users' lack of knowledge, system errors, and user–system interaction. Four identified constructs (i.e., reporting, data, users' lack of knowledge, and system errors) are consistent with those found in prior studies on IS usage (e.g., [7, 9, 21]). However, three other constructs (i.e., role authorization, workflow, and user–system interaction) have not been systematically examined in prior studies. Moreover, our data analysis demonstrated explicitly the causal linkages between the constructs and the changes in these linkages over time. Table 1 presents all the constructs and concepts identified in the study.

We next present the results of the study in three steps. First, we present the constructs revealed in the aggregate-level causal map and highlight the major characteristics of the linkages between constructs. Second, we compare and contrast the revealed causal

Table 1. Concepts and Constructs of BI System Use Problems and Causes

Construct	Concept	Definition
Role authorization problem	Role assignment Role request Role update Role failure Role conflict	Role-related problems that occur when users' attempt to access SAP/BW application is denied.
Reporting problem	Report availability Report navigation Report bookmarking Report export Report customization Reporting errors	Reporting-related problems that occur when users fail to use the reporting features to perform their tasks, especially with regard to report availability and navigation.
Data problem	Data inquiry Data retrieval Data interpretation Missing data Incomplete data Incorrect data Duplicate data Inaccessible data Nonapplicable data	Data-related problems that occur during users' actual employment of a SAP/BW report, such as missing data, inaccessible data, or nonapplicable data.
Workflow problem	Process integration Data discrepancy Data loading error	Workflow-related problems that occur when process integration or data integration does not work as designed, such as delayed data loading, data discrepancy across reports, data mismatching between data sources.
Users' lack of knowledge	Lack of know-what Lack of know-how Lack of know-why Lack of know-who	Users' lacking knowledge of the system access, functionality, and reported data that led to an unsuccessful system usage incidents.
System errors	Missing system feature System malfunctioning System set-up System nonresponse System proxy issue	A system-related factor, such as missing a report variable or outdated value in a configuration table, which led to unsuccessful system usage incidents.
User–system interaction	User–system interaction	A problem cause that required diagnosis when both users and the system seem to function as expected, such as unexpected data update. The error occurs when the user believes that the system is in one state (mode), but when it is actually in another state [34].

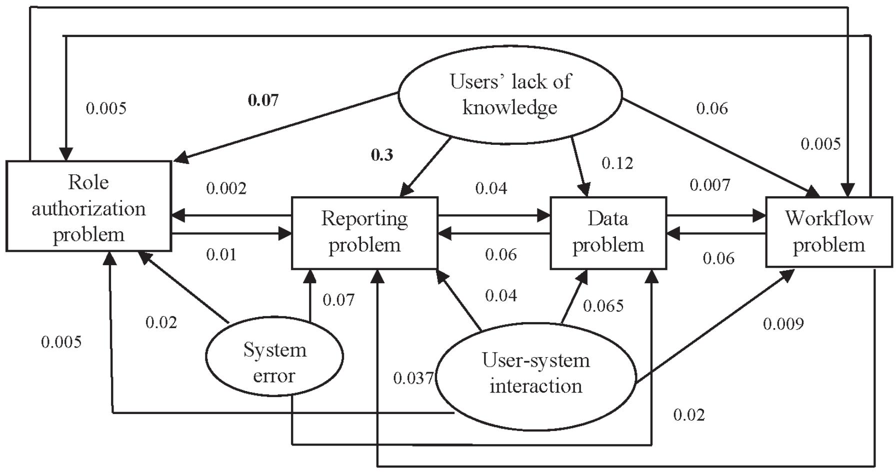


Figure 1. Aggregated Construct Level Revealed Causal Map of System Use Problems (based on 429 linkages identified in 329 problem incidents)

maps over time. Third, we compare and contrast the revealed causal maps for the regular versus power user and highlight the differences in their system use problems.

Constructs of System Use Problems

The aggregate-level revealed causal map (Figure 1) presents both the major constructs and their causal links. The constructs of role authorization, reporting, data, and workflow emerged as the main problem domains in the SAP/BW system usage, based on the distribution of "in-arrows." Users' lack of knowledge, system errors, and user–system interaction were identified as the main causes, as they only had arrows going out to other constructs. Details of the four problem domains are provided below.

Role Authorization Problem

The role authorization problem was a common and recurring problem in the use of the SAP/BW system in the Organization. To view SAP/BW reports, employees needed to acquire four different access roles in the following order: for (1) the portal, (2) the SAP/BW application, (3) the reporting modules, and (4) the specific report. As employees initially attempted to use the system, they were overwhelmed by the restrictions imposed on accessing the system. In particular, problems occurred when employees tried to access a reporting module or view a specific report.

To a great extent, access problems revealed users' lack of understanding of the role hierarchy embedded in the SAP/BW application. Access roles could differ from roles reflected in the organizational chart. For example, a frustrated budget analyst reported:

> I have not been able to find the SAP role for this "Overpayment Report." This is very important since I have several employees who have been overpaid. Until yesterday, I was under the impression that Payroll handled this—but was told "no." I really need this access ASAP.

Sometimes, access problems were caused by outdated or updated roles in the SAP/BW system, which were caused in part by automatic, inaccurate input from another system at the Organization, such as the Human Resource Application of SAP/R3 (the third version of the main enterprise resource planning [ERP] software). The SAP/BW specialist at the research site considered those as "system-related" problems because problem resolution required fixing the role configuration table or updating users' organization IDs.

Lastly, we created the category of "user–system interactions" for problems that were not user related or system related. For example, one analyst believed that she was authorized to access the "Labor Distribution Report" under the HR/Payroll module, despite the "No Authorization" message, but her access role was actually associated with the "Payroll Administration Report." The gap between the analyst's knowledge of her access role for the BI reports and the role designation in the technical system caused the system use problem. While the SAP/BW application improved data security via enforcing different access roles for a hierarchy, SAP/BW users had to endure the restrictions and complexity associated with the added layers of security.

Reporting Problem

Reporting problem was identified as a main construct of system use problems, which was essential to enhancing effective use of the SAP/BW system. A typical reporting problem was related to locating a report ("report availability") and creating a report ("reporting navigation"). Similar to the role authorization problems, reporting problems were often caused by users' unfamiliarity with system features. There were more than 300 reports in the SAP/BW system, whose industry standard format was largely new to the budget analysts and business managers at the Organization. Not surprisingly, they frequently contacted support specialists for assistance with locating a report (e.g., purchase order details) or with viewing a report for a specific time period (e.g., "Revenue-Expense Report" for last fiscal year). Those incidents suggested users' lack of conceptual knowledge ("know-what") and procedural knowledge ("know-how") about BI reporting functionality, as well as lack of understanding of the associations with their legacy reporting systems. According to the lead SAP/BW specialist, users kept asking for a "cross-walk" between old (paper) reports and new (SAP/BW) reports, even though a complete list of all the SAP/BW reports was available on the intranet site of the support center.

Reporting problems could be caused by system-related factors, such as system time-out and being slow or no responses. For example, one analyst described a "frozen" system when running a detailed financial report. Sometimes, the specialist could identify and resolve technical errors by using workarounds, such as creating a smaller-sized version of the report to avoid bookmarking failure.

Reporting problems could also arise during user–system interactions when users entered correct inputs, but did not see the desired report results, because a reporting function did not work as it was designed to. For example, a user described that she was "trying to view a report in SAP/BW under nonsponsored financial summary for October, putting 4 for October, 8 for the year, but the report came up as July." This description of errors is consistent with that of "mode errors" in human–computer interactions; the error occurs when the user believes that the system is in one state (mode), but when it is actually in another state [35].

Data Problem

Data problems refer to problematic incidents with regard to data input and output in BI reports. For example, a user questioned a transaction amount she did not recognize, while another user doubted "the total grant and total obligated amounts" in a report. This is problematic, as data accuracy is considered as the dominant determinant for information quality in the successful use of BI tools [34].

Similar to role authorization and reporting problems, data problems could be caused by users' lack of knowledge, system errors, or user–system interactions. When users doubted reported data, they were seeking "know-what" knowledge regarding those data. In other cases, users lacked "know-how" knowledge on locating a piece of data, such as vendor name or department code. While guidelines or documentation could prevent similar problems [23], they were insufficient to resolve data problems when users lacked context-dependent and consequence-specific knowledge about reported data. For example, users were not able to interpret different accounting consequences in the "Revenue-Expense Report" due to different visualization of the data in their legacy reports. As the specialist explained in the interview:

> At first when a shopping cart of $100 is created, the $100 appears under "Commitment." Once the shopping card is approved, a negative $100 was added under "Commitment," and a positive $100 under "Purchase." When goods are received, a negative $100 appears under "Purchase" and a positive $100 under "Expense." To the grant management, the $100 becomes revenue for the institution. When the posting dates are different for each of the actions mentioned above, there may be five different separate entries [rows] of the same dollar amount in the report.

As such, the data interpretation problem was caused by users' lacking knowledge of the reporting design and data processing logic embedded in the packaged software, which were different from those in their legacy reports. In this case, the specialist relied on context-specific examples to illustrate the meaning and consequences of those different entries for the users.

The second cause to data problems was system related, such as delayed data loading for payroll data or missing numeric fields. Data problems caused by system-related errors required SAP/BW specialists to perform further diagnosing, to check into configuration details, and to request developers' assistance in modifying programming codes.

Lastly, data problems occurred even when users provided input as expected and the system seemed to run normally. One common data issue was represented by "No Applicable Data." One SAP/BW specialist investigated such an issue regarding a personnel report on hospital employees and explained to users:

> The reason that you get "No Applicable Data" is that there are no data types xx or xx entered into Infotype 0041 for any hospital employees. The report is looking exclusively for these two data types. So while the SAP/BW report is working properly (other Personnel Areas do display data) there may have been either some problem during conversion or simply a business decision at the hospital not to enter this information.

Workflow Problem

Workflow problems occurred when data discrepancies existed between reports due to the integration issues of business processes and data sources in the SAP/BW system. When the problems occurred, users were responsible for tracing the data source (i.e., the transactional ERP system SAP/R3) and ensuring the correction of a data error at its source. Thus, users' knowledge about the workflows was essential for consolidation of data from multiple sources, as the SAP/BW specialist explained in the interview:

> Users are responsible for tracing and correcting data discrepancy on their transactions, e.g., purchase orders. If it is a non-payroll transaction, they need to do "transfer" transaction to remove the discrepancies. If it is payroll transactions, they need to process "E-forms."

Workflow problems, which occurred even after users had acquired sufficient knowledge about data integration, were categorized in "user–system interaction." For example, when a business analyst reported that data of four employees were missing in an employee directory report, an SAP/BW specialist discovered that "those employees do not have a value entered in subtype 4 (work-physical location) on Infotype 000x in SAP/R3." In another case, an employee moved from one department to another, but her payroll record was not updated accordingly. The data inconsistency problem was thus caused by conflicting schedules in data updates.

The Longitudinal Analysis of System Use Problems

System use problems and causes varied over time. According to the lead SAP/BW specialist and the support center manager at the research site, two distinct usage phases existed during the first nine-month postimplementation period: the initial usage phase and the continued usage phase. The former refers to the time period when users were familiarizing themselves with the new system, and the latter refers to the time period when users were employing system features to perform business tasks. This distinction between the initial and continued phase was also noted in prior studies of system usage (e.g., [15, 51]).

System Use Problems at the Two Usage Phases

Our analysis revealed the same seven constructs of system use problems at the initial and the continued usage phases. Reporting appeared to be the number one problem in both phases, followed by data problems. This pattern suggests that getting familiar with BI system functionality is essential for the adoption and use of a new system. However, the causal linkages between the constructs were different across the two phases, as shown by the revealed causal maps in Figure 2.

During the initial usage phase, users encountered more reporting problems than other types, as they started to explore the reporting features and navigation in SAP/BW. While half-day training sessions on the new SAP/BW system were provided to employees, users appeared to be lost when they actually employed the reporting functions of the SAP/BW system. The lead SAP/BW specialist considered the user training sessions inadequate:

> Training did not click with people. There was no frame of reference for them. It's like you dropped them on the moon. They did not know where they were. They did not know the alphabetical language for that environment.

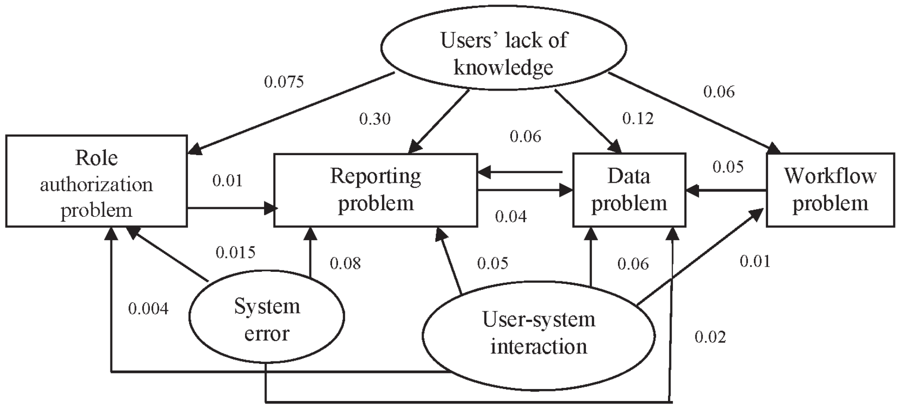
The "frame of reference" in the above example echoes the notion of "mental models," the knowledge on the task procedures, strategies, likely scenarios, and contingencies [9]. When individuals are working in the same team or engaging in similar tasks, they are likely to develop a mental model shared by all the members, which help them describe and predict problems in their environment, and coordinate and adapt their actions [9, 29]. While users would benefit from context-specific knowledge of "how that technical module and function relate to a user's tasks on hand," it often takes time for users to establish such a mental model.

At the continued phase, the two constructs started to show a decreasing trend despite their dominance. This trend is reasonable as users gained more knowledge in general and about the reporting functions in particular.

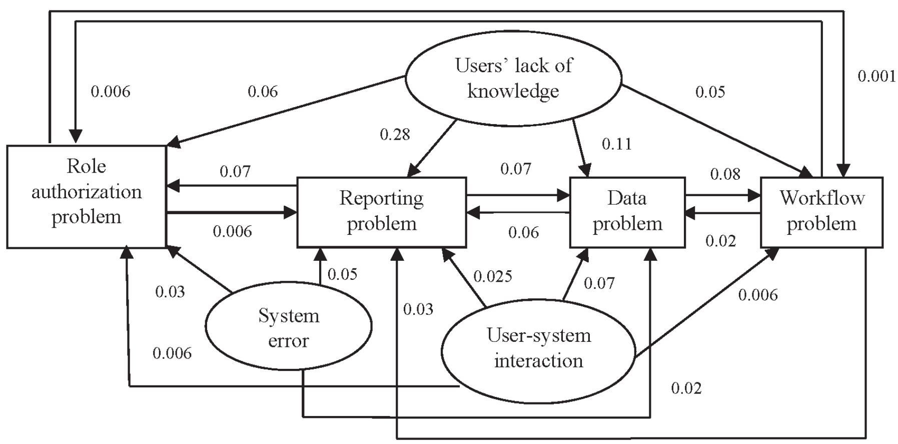
System Use Problems at Four-Week Intervals

We created a valued matrix for every four-week period and calculated out-degree and in-degree centralities of each construct to reflect influence patterns. The valued matrix accounted for the strength of the linkage among constructs, where the strength of each link is reflected by the frequency of problem occurrence. Out-degree centrality was calculated by summing up the frequencies across the row. In-degree centrality was calculated by summing up the frequencies across the column.

Figure 3 depicts the evolving patterns of causes for a four-week moving window during the first nine-month period. The y-axis represents the out-degree centrality of the problem cause, reflecting the significance or dominance of the cause. Greater out-degree centrality represented stronger significance of a factor in causing user-reported problems. As Figure 3 shows, users' lack of knowledge was the dominant cause to SAP/BW usage problems (i.e., more than half of all the usage problems). Over time,



(a) The Initial Usage Phase
(based on 267 linkages identified in 214 problem incidents)



(b) The Continued Usage Phase
(based on 162 linkages identified in 115 problem incidents)

Figure 2. Aggregated Construct Level Revealed Causal Maps of System Use Problems

the impact of system errors on usage problems seemed to decline, but the impact of user–system interaction (usinteract) seemed to grow more significant.

Similarly, an evolving pattern of the problems emerged during a four-week moving window (Figure 4). The *y*-axis shows the in-degree centrality of the problems, which reflects their significance or dominance. The greater the in-degree centrality, the more dominant the problem was among SAP/BW users. As shown in Figure 4, reporting type was consistently the dominant factor, followed by data problems. Over time, reporting problems declined, while data problems seemed to show a growing trend.

Combining RCM and SNA enables us to visualize direct or indirect links (or influences) between problems. System use problems not only were associated with the three identified causes but also could be triggered by other types of problems (i.e., a

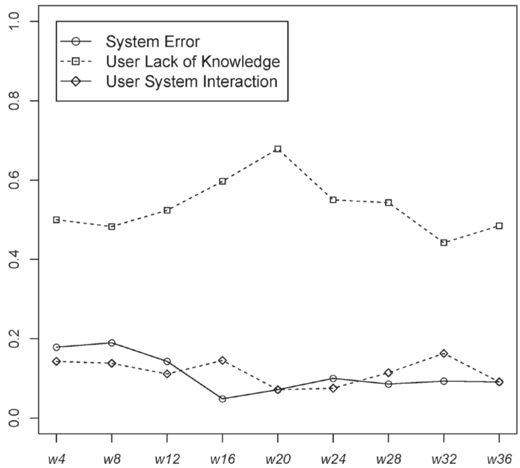


Figure 3. Evolving Patterns of Causes in SAP/BW Use

reporting problem could be caused by a data problem). In one incident, a purchasing manager encountered problems in generating purchasing order reports because a vendor was dropped from the authorized supplier list. In this case, an update of vendor master data was necessary to allow users to complete their reporting tasks.

We further calculated the betweenness centrality of problem domains to reflect the evolving importance of a problem type over time. A higher betweenness centrality indicated a greater importance of a problem type in comparison to others. Figure 5 depicts the evolutionary trajectory over the nine-month period.

As shown in Figure 5, reporting problems were a critical construct for SAP/BW system usage. The importance of data problems appeared to increase rapidly, which indicated that data problems tend to be a central construct in achieving and sustaining effective SAP/BW usage. Overall, the number of problems by categories decreased over time. However, the relative importance of workflow problems (as reflected by their percentage of all problems) increased in the continued phase. In other words, workflow issues assumed greater importance in the continued phase than in the initial phase, directly and indirectly affecting other types of system use problems.

The Revealed Causal Maps by User Types

Users of the SAP/BW system can be generally classified into two categories: *regular* users and *power* users. According to the lead specialist and the support center manager, regular users of the SAP/BW system in the Organization consisted of 1,000 budget analysts, whose job responsibilities included assisting primary investigators with managing grant packages and handling procurement requests. Performing reporting tasks and data analysis duties on the SAP/BW system accounted for a small portion (e.g., 10 percent) of their work. By contrast, power users consisted of financial reporting managers, who relied heavily on the SAP/BW system to carry out their job

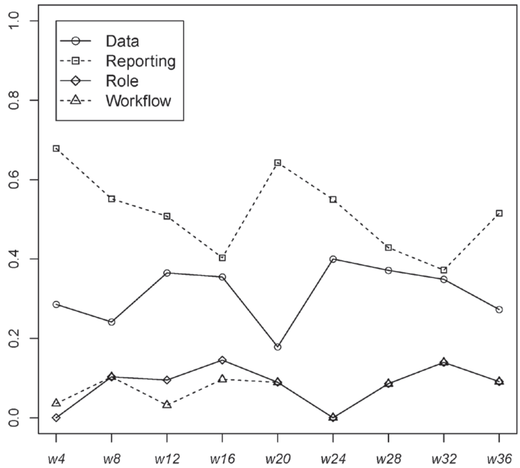


Figure 4. Evolving Patterns of Problems in SAP/BW Use

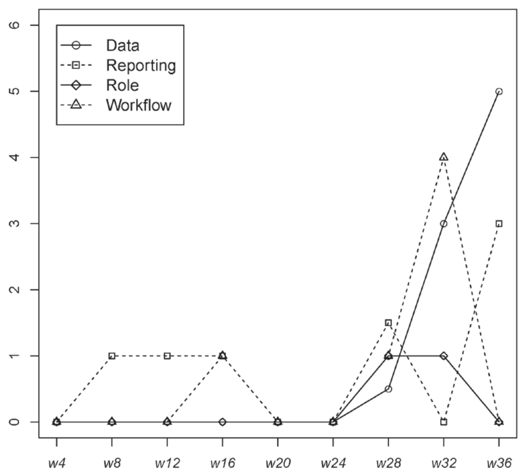


Figure 5. Evolving Importance of Problems in SAP/BW Use

responsibilities focusing on reporting and data analysis. Generally, power users were more technically savvy and familiar with the new BI system than regular users; they also participated in the user testing phase of the BI implementation. This distinction between regular and power users is consistent with that described in prior IS studies (e.g., [7, 27]).

To explore potential differences in the system use patterns and to develop the respective causal maps, we analyzed the problem incidents reported by the two types of users by identifying a representative user of each type. Our confidence in the representativeness of the nominated power user and regular user is based on the specialist's expertise in supporting the BI system and familiarity with the BI user community. The analysis of system use problems reported by the representative users revealed most of the constructs identified in the aggregated maps. However, we found differences in the linkages (e.g., in terms of number and strength) between the constructs as well as in the evolution of those linkages.

Regular User

Regular users (i.e., budget analysts) were concerned primarily because they no longer received paper copies of the "Revenue and Expense" report ("Green Statement") when the SAP/BW system went live. During the initial phase, they frequently asked questions such as "What are the Green Statements called in SAP/BW?" and "How did I get my green statements?" The lead specialist explained in the interview:

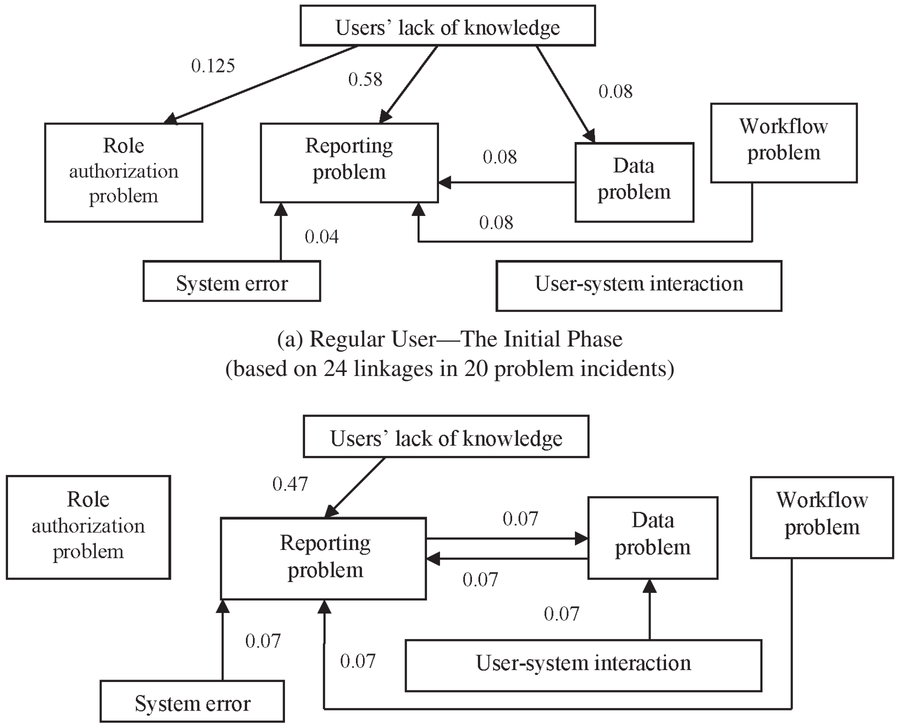
> For the last twenty years prior to SAP/R3 and SAP/BW, 100-plus budget analysts at departments and divisions were used to receiving a paper copy of *green* statement, the "Revenue and Expense Report." They were supposed to check line by line, and to collect back-up documents to support each transaction. Then they filed all those paper documents in big file cabinets. These budget analysts were used to the old way of accounting, and they wanted *paper*.

As shown in the revealed causal map for a representative regular user (Figure 6), reporting problems were dominant in the initial phase, followed by problems associated with role authorization. Users' lack of knowledge appeared to be the greatest cause of user problems. In the continued phase, no linkage was associated with role authorization problems, suggesting that the regular user had overcome the barriers of role access. Although reporting was still the dominant problem, users' lack of knowledge had a smaller impact on reporting problems compared to the initial phase.

We used network analysis to observe changes in the magnitude of the total cumulative effects and consequences of constructs (i.e., total influence a construct receives from others) (Figure 7). The regular user's problem patterns changed across the two phases. While reporting appeared to be the number one problem in both phases, workflow problems arose as another major problem domain in the continued phase. This pattern is of particular interest to us, as it suggests that organizations need to pay attention to educating their end users on the integration of data and processes embedded in the decision-making technologies, which are designed to draw data from multiple sources and to aid organizations in decision making [55]. Furthermore, the magnitudes of total cumulative effects and total cumulative consequences also changed. For example, the strength of the impact exerted by users' lack of knowledge appeared to decline across the two phases, suggesting that the regular user benefited from accumulated experience in interacting with the system.

Power User

The revealed causal maps of the representative power user (Figure 8) demonstrate a pattern different from that of the regular user (Figure 6). While reporting problems accounted for the largest portion of system use problems in the initial phase, the power user was much more familiar with reporting and therefore encountered fewer problems with different reasons, such as system errors as opposed to lack of knowledge.



(a) Regular User—The Initial Phase
(based on 24 linkages in 20 problem incidents)

(b) Regular User—The Continued Phase
(based on 15 linkages in 12 problem incidents)

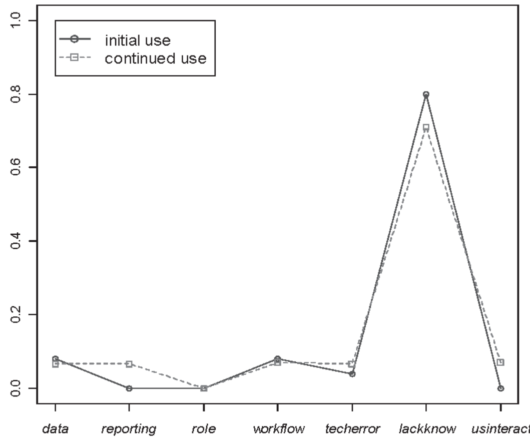
Figure 6. The Regular User's Revealed Causal Maps of System Use Problems

Moreover, the power user experienced other problems, such as access role problems for a variety of modules and reports during the continued phase.

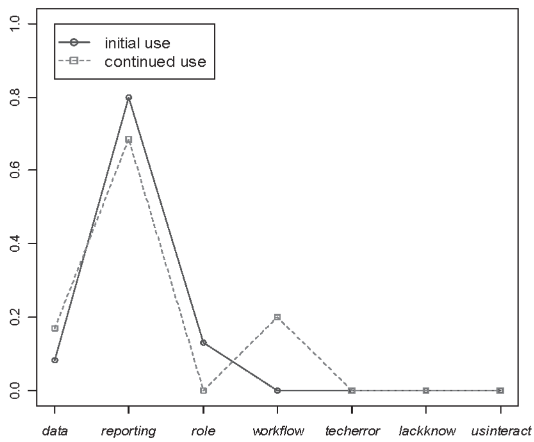
Furthermore, system use problems demonstrated changing patterns (Figure 9) between the initial and continued phase. During both phases, system-related errors appeared to be the dominant cause, and reporting problems appeared to be the number one problem. However, the magnitude of reporting problems appeared to decline significantly in the continued phase, while role authorization problems increased significantly. This finding is interesting, as this problem type is particularly associated with the inherent complexity of the role-based structure in a data-driven and decision-oriented system, and with the job nature of the power user (i.e., the need to access to multiple data sources and reports from different system modules). Overall, the results are valuable in directing organization's attention and resources to address power users' needs and issues differentially from those of regular users.

Discussion

In this study, we investigated system use problems and their evolving patterns in the organizational context. In particular, we took a bottom-up approach and examined



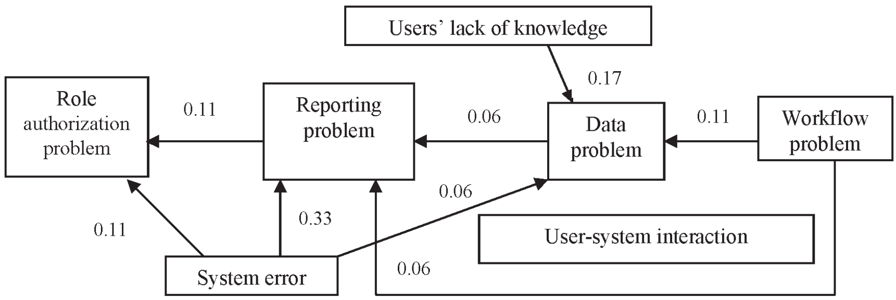
(a) Cumulative Effect of One Construct on All Other Constructs



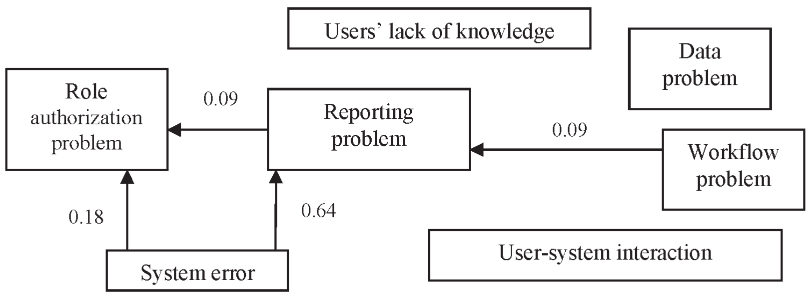
(b) Total Cumulative Influence (Consequence) That a Construct Received from All Other Constructs

Figure 7. Cumulative Effect and Influence at a Regular User Level

problem incidents that occurred as a result of individual user's interactions with specific features, that is, incidents of individual technology-in-use at specific points in time. We intended to achieve two research objectives by examining the postadoptive use of a highly integrated and data-driven IT SAP/BW in a large enterprise. First, we sought to identify the type of problems and causes that emerged during postadoptive system use. Second, we examined the change in system use problems and their causes over time, focusing on the multi-user and temporal nature of postadoptive behavior. Based on the analysis of secondary data of user-reported problem incidents with RCM and SNA, this study developed a conceptualization of system use problems, and offered a comprehensive, systematic, and dynamic view of users' problems with technology use.



(a) Power User—The Initial Phase
(based on 18 linkages in 15 problem incidents)



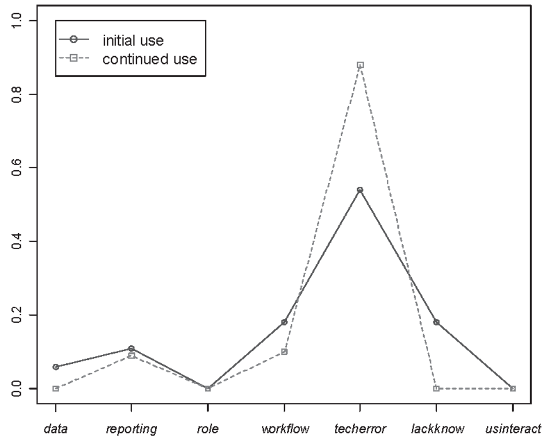
(b) Power User—The Continued Phase
(based on 11 linkages in 9 problem incidents)

Figure 8. The Power User's Revealed Causal Map of System Use Problems

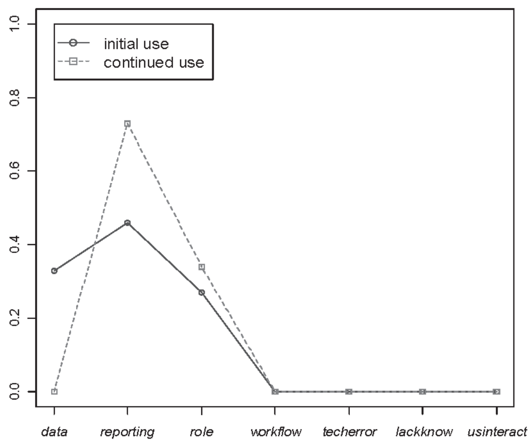
This study has limitations that should be acknowledged before we consider in detail its theoretical and practical implications. First, our analysis draws from one organization and its members' experiences using a particular enterprise-level BI system. Although this organization is similar to many large firms pursuing BI strategies, following Lee and Baskerville's [22] framework, we do not attempt to generalize the empirical findings of this case to other settings; we do, however, consider how these empirical findings may be generalized analytically and thus might guide empirical study in other organizations with other IS. An important analytic boundary for our study is its focus on BI systems, rather than transactional or communication IS. Such a system may require a higher level of user knowledge for effective use, and the types of system use problems and causes identified here are likely most applicable to this context. With these qualifications, we now consider the patterns of system use problems and causes.

Revealed System Use Problems

Seven major dimensions of system use problems and causes were identified in the study, including four problem domains of reporting, data, role authorization and workflow, and three problem causes of users' lack of knowledge, system errors, and user–system



(a) Cumulative Effect of One Construct on All Other Constructs



(b) Total Cumulative Influence (Consequence) That a Construct Received from All Other Constructs

Figure 9. Cumulative Effect and Influence at a Power User Level

interaction. The most dominant associations among these seven dimensions were the links between users' lack of knowledge and reporting problems as well as data problems. These results demonstrated that knowledge of both technical features and output of the BI system was critical for users in accomplishing their data-centric work tasks, such as budget comparisons or financial analyses. BI systems are designed to help individual employees derive meaningful information and useful knowledge from vast quantities of data to aid their decision making [55]. As such, effective use of BI requires users to learn about the technical features and comprehend the information generated from the system. While our results are consistent with the general conclusion from prior studies that users' knowledge and skills play a critical role in influencing system usage [7, 26, 38], we offer additional insights into the multifaceted nature of users' knowledge. Simply learning about the features and functionalities of a new BI system is not sufficient for users; they also need to understand the source of data, the reported data, and the integration of data across business units. Therefore, users' IT competence should be evaluated not only in the context of the system (e.g., BI system, transaction processing system [28]) but also in the underlying domains of knowledge in system use, such as in the domains of role authorization, functionality, data, and workflow, as identified in our study.

Our data analysis also revealed that system use problems and causes differed between regular users and power users. The regular user was more frequently frustrated by reporting problems and role authorization problems, which were mostly associated with users' lack of knowledge. The power user encountered more reporting problems and data problems, which were often associated with system-related errors. These findings suggest that users' expertise in technology use was partially affected by the work context and by the technology-enabled tasks.

Moreover, our study found that even when the power user and the regular user experienced the same type of problems, the causes may differ (e.g., lack of knowledge versus system-related errors). The regular user and the power user experienced different patterns in the problem–cause linkages, which may be explained by two distinct feedback loops (reflective and nonreflective) in individual cognition of postadoptive behavior [21]. The reflective feedback loop includes reflecting on the user's previous technology experience, making sense of a new application, and adjusting the individual's cognition about technology features or initiating a work system intervention. This reflective feedback loop was evidenced in our study when users were exploring a new technical feature, whether generating a summary report or running a detailed analysis of data. As a result, a variety of problems and causes would likely emerge during the process of reflective feedback. By contrast, a nonreflective feedback loop entails repeated system use behavior, which becomes habitual and hinders the substantive use of technology. The regular user in our study demonstrated the habitual system use behavior, as this user repeatedly generated and analyzed the same reports (e.g., the "Green Statement").

Evolving Patterns of System Use Problems

To investigate changes in the problem–causal linkages underlying system use problems over time, we analyzed the nine-month data according to two usage phases and four-week intervals. Our data analysis revealed that reporting problems and users' lack of knowledge were the two dominant dimensions of initial BI system use problems. At the continued phase, data and workflow problems showed an increasing pattern. In summary, our data analysis depicts a comprehensive and evolving picture of users' learning behavior.

First, reporting problems declined over time in magnitude as the dominant system usage problem domain, while the magnitude of other problems increased. We found that users took some time during the initial phase to learn about their access roles and reporting functionalities in the SAP/BW, that is, "know-what" and "know-how" knowledge. Later users made inquiries about data issues and sought "know-why" knowledge from the SAP/BW specialists. This suggests a progressive learning process [10]. Santhanam et al. [45] have reported knowledge transfer activities between users and IS support professionals and found that users mostly acquired knowledge about the technical system from those professionals. Our study presented an in-depth understanding of users' knowledge-seeking behaviors from BI support specialists: users not only obtained technical knowledge (i.e., reporting functions) and business knowledge (i.e., data flows and process integration) from those SAP/BW specialists but they also benefited from the context-specific knowledge that the specialists had accumulated, such as the knowledge on the "cross-walk" between old reports from the legacy system and their counterparts in the new SAP/BW system. Hence, the longitudinal study of users' difficulties with the BI system reflects a process of experiential learning by users [25]. In contrast to learning motivated by others (project leaders, power users, and peers) as described in Boudreau and Robey [6], users' learning resulted from their seeking help and engaging in the problem solving with support specialists in our study. This supports the general theoretical argument that individual motivation is a significant determinant in facilitating postadoptive technology use and learning [21].

Second, the increasing occurrence of data and workflow problems in the continued phase indicates the importance in attending to system-generated information and its interdependence between different data sources in the BI context. This emphasis on system-generated information has been echoed by researchers studying data-centric applications such as warehousing applications [34]. The findings of our study suggest that when users became familiar with system features, they became more comfortable and committed to using the BI application. Conversely, when system use problems were caused by system-related errors, the frustrated users employed workarounds as short-term solutions, which may be routinized as "unusual routines" in organizations, which lead to undesirable outcomes [39]. Prior studies have highlighted the importance of ongoing adaptations of organizations [21] in the shift from paper-based office work to computer-based office work [7, 40]. The in-depth investigation of system use problems in our study revealed possible root causes for unusual routines in postadoptive IS use, allowing the Organization to make proactive and effective adaptation strategies.

Our data analysis has shown that individual users experienced different barriers and adapted their postadoptive use behaviors over time in their interaction with the new BI technology. The findings are consistent with the view of human enactment of technology and adaptive technology use [2, 6, 21, 46], in which human agents (i.e., individual users) play an important role in employing technical systems for their business tasks. Technology use difficulties and system-related errors triggered users' problem-solving and knowledge-seeking endeavors, which resembled an important factor triggering the adaptive system use [46]; the system use problems and causes revealed the discrepancies between what was expected and what was observed in postadoptive technology use. Moreover, our study considered technical factors (e.g., system failures), users' competence with technology use (e.g., users' lack of knowledge), and the integrated structure of processes and data embedded in a technology (e.g., workflow), extending the scope of the trigger category noted by Sun and Zhang [46]. In doing so, we suggest that *discrepancy,* the trigger to adaptive system use, is characterized by multiple dimensions, including system functionality, data, users' knowledge, and role authorization.

Our data analysis revealed the dominant evolving patterns of the system use problems discussed above, but there was an unexpected observation at one point during the nine-month period. At week 20 there was a dramatic change of data and reporting problems (Figure 4) as well as an increase of users' lack of knowledge (Figure 3). This unexpected observation could possibly be attributed to organization-specific characteristics and merits consideration in future research. Overall, an individual's postadoptive behavior is influenced by the organizational context and associated social influence [21, 39] as well as by the users' communities [6, 47]. Once the causes to system use problems are identified, the mechanisms to address the problems need to be explained. By analyzing user-reported problem incidents, our study focused on one important mechanism, that is, the support operation by IS professionals, and further provided an in-depth investigation of how users' problems with the BI application were supported. Moreover, the various problems and causes related to role authorization and data/process integration embedded in the new system indicated the importance of other organizational mechanisms, such as systematic and formal training programs and technical feature redesign, in improving postadoptive behavior and extending users' adoption of system features [21].

Contributions and Implications

Theoretical Contributions

This study makes several contributions to the IS literature on postadoptive system use. It represents an initial effort to develop a comprehensive and dynamic conceptualization of IS use problems with integrated IS such as BI. Prior studies have suggested that postadoptive IS use may diminish over time as installed technologies are treated with indifference or used in a limited fashion [21]. The results from our study extend this line of research by identifying the underlying causes to undesirable postadoptive use behavior and examining the dynamics of problem–cause associations over time. Our findings also provide an explanation for unintended use patterns or undesirable routines identified in prior studies [6, 39].

Furthermore, we offer a multi-user view of system use problems. Results from our study suggest the important role of work context and prior use in predicting system use problems associated with the two different types of users.

Methodological Contributions

This study demonstrates an approach to investigate system use problems with secondary data and the combined method of RCM and in-depth network analysis. First, problem records can be viewed as users' diaries, which record actual problem occurrences.

Hence, those problem incidents allow us to examine actual system usage problems in a realistic organizational setting [21] rather than studying the perceptions of usage problems or using students' surveys in experimental settings (e.g., [3, 12, 28, 47]). Prior research has noted that interviews or surveys provide insights into perceived system usage but less reliable views of users' problem-solving behavior [36]. Analyzing the secondary data allows us to mitigate the risks and biases of interview or survey data due to users' difficulties in recalling past experiences or bounded rationality in understanding system problems. Moreover, collecting the secondary data on user-reported problems offered us a cost-effective way to monitor and track users' system use problems and related problem resolutions.

Second, our method offers a useful way to study evolving patterns of system use problems and causes in the real organizational settings, which are difficult or costly to obtain with other approaches, such as surveys [12, 30, 48] or computer-based simulations [31]. As postadoptive use is adaptive over time, it is important to perform a longitudinal analysis for a comprehensive and systematic understanding of the phenomenon. In addition, the combined method allows us to identify various emergent constructs and linkages, to quantify their importance, and to visualize evolving patterns. For example, by calculating the weighted centrality scores, we were able to examine the interactions among constructs, and to assess the relative importance of each construct over time.

Practical Implications

The *system use problem* construct captures both the outcome and causes of those unsuccessful attempts users undertake in interacting with an IS to accomplish business tasks. Insights from the *system use problem* construct are likely to provide helpful explanations for IS underutilization and also to offer practical guidance for enhancing system usage. Findings from our study suggest that organizational use of IS can be enhanced in several ways. First, monitoring users' system usage problems over time enables an organization to deploy training strategies and enhance support services pertaining to users' differentiated and evolving needs. For example, during the initial phase, it is more effective to introduce users to basic functionalities and features as needed, such as the "Revenue and Expense" financial reporting functions for budget analysts. Offering those services and functionalities clearly added value to the users in terms of satisfaction and efficient use [38]. As users learn through their interactions with a technical system, they experience system use problems on cross-functional data flows and work processes during the continued phase. Thus, those system use problem patterns should be addressed by a training curriculum on an ongoing basis so as to develop training programs that "click" with the users. Organizations that determine the technical features associated with most user problems and their causes will be in a good position to proactively manage their postadoptive use of technology.

Moreover, our findings of the various problem–cause linkages suggest that the mechanisms to address system use problems should go beyond the focus on users themselves (e.g., the human agency view). Instead, organizations should consider facilitating mechanisms at the level of the organizational context and the technical system to promote technology use in the long term. The identification of the underlying causes to those problem incidents can become useful in motivating individual users to undertake the reflective feedback loop and to achieve extended use of an implemented technology. For example, we found that the regular user frequently experienced reporting and data problems, which were mainly caused by his or her lack of knowledge. This may be due to the user's limited exploration [24] in the new BI system. To motivate regular users to experiment with system functionality, organizations should consider work context changes, such as redesigning job categories or modifying job descriptions, to introduce new tasks or new task requirements. These changes may function as triggers to enact individuals' adaptation to the set of features they use [18, 46]. In contrast, the power user explored a wider range of system modules and functionalities, resulting in more problems associated with role authorization and system errors. This suggests that organizations should understand and consider users' work environment, goals, and motivations [1] when evaluating postadoptive IS use.

Our findings of the system use problems and causes also provide valuable guidelines to IS support operations on how to assist users more effectively. Studies on user frustration suggest that a good strategy in improving IS use is to "bridge the gap between what users know and what they need to know, thereby leading to more successful, less frustrating user experience" [12, p. 336]. By focusing on the problematic episodes of the system use, our study suggests that there is much to be learned from system use failures in order to design training courses and to improve users' interactions with a technical system. In other words, IS support departments can look at what users *do not know* and what they *need to know,* and assist users more effectively by bridging the gap between *do not know* and *need to know.* Mechanisms to bridge the gap include the creation of a shared knowledge resource (e.g., short videos on frequently problematic technical functionalities) and the designation of a user representative (such as a power user) to assist the support center with addressing frequently experienced problems. By tracking users' problems with technical systems and taking advantage of the knowledge on the underlying causes, organizations can design support services around the needs of users [11, 30].

Conclusion and Future Research

In this paper, we empirically investigated the complex and dynamic phenomenon of system use problems with an enterprise-wide SAP/BW system, answering the call for more and broader investigations of individual postadoptive use with regard to integrated work systems [2, 20]. Findings from this study not only advance our understanding of critical constructs that affect BI system usage but also provide a strong basis for large-scale empirical investigations of evolving integrated technologies such as customer relationship management and supply chain management systems.

Future research should extend our initial conceptualization of system use problems and examine the system use problem patterns of a larger number of power users and regular users across a variety of ITs to validate the results of this study and to derive additional insights. Further, our methodological approach of using secondary data might be extended by using observational studies. Our data set captures one major source of user adaptation behavior, that is, users seeking help from IS support professionals. However, users may improve their system use or solve their system use problems through other channels, such as searching for workaround solutions by themselves [6] or asking peers for help (e.g., [7, 47]). Thus, adopting observational studies will add additional insights into understanding the circumstances in which users seek help from one source versus another.

As organizations adopt and implement advanced IS at ever-increasing rates, underutilization of system features by organizational users continues to limit the full realization of organizational value and benefit from IS adoption [14, 39]. Improving our theoretical understanding of postadoption use behaviors in ways that highlight actionable solutions is an important contribution of IS research to knowledge and to practice. Our study advances this endeavor by providing a comprehensive and dynamic view of system use problems and enhancing the understanding of this important postadoptive use behavior in the IS community.

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Appendix A: Examples with Initial Coding Agreement and Disagreement

Problem incidents	Initial coding and resolution of coding discrepancies
Problem Description: "BW Reporting: Need help with A/P (Accounts Payable) Invoice Aging and Vendor Payment by Cost Center." *Problem Resolution:* "A/P Invoice Aging Report won't allow reporting by cost center. The lowest level of detail for this report is by Business Area (BA). A proposed alternative is to have user run Vendor Payment report by their cost center, create a "condition" that filters out all check amounts that are not equal to $0.00. This would essentially provide all open/unpaid items related to a specific cost center." (Division of Research and Evaluation, June 11, 2007)	Initial coding was *agreed* between two coders. Both coded the BI usage problem as a link between users' lack of knowledge (problem cause) and reporting (problem domain).
Problem Description: "Unable to get detail info. [I] want to get the reports from BW (sponsored projects). [I] received the following message 'No data was found.'" *Problem Resolution:* "Educated or trained the customer as to the correct procedure" (Department of Medicine—Infectious Disease, June 18, 2007)	The two coders *disagreed* on their coding of problem cause: user–system interaction by the first coder and users' lack of knowledge by the second coder. To resolve coding difference, the two coders first discussed their rationale for the coding. For example, the second coder explained that she relied on the statement "Educated or trained the customer as to the correct procedure" for her coding. Then the two coders consulted the lead SAP/BW support specialist at the research site. The SAP/BW specialist explained that even when information was provided to users, the root cause to that problem incident might be more complicated than users' lack of knowledge. According to the problem description in this example, the user followed the appropriate procedures in generating a sponsor project report, but encountered the error message of "Data Not Found." The specialist explained that the unavailable data problem was often resulted from delayed data loading schedule. Based on the discussion and consultation, the two coders reconciled the cause of problem to be "user–system interaction," which occurred during data flows.

Appendix B: Betweenness Centrality and Reachability in the Revealed Causal Maps

Betweenness Centrality

We extended Freeman's [17] betweenness centrality measure into our analysis of system usage problems. *Betweenness centrality* in our revealed causal maps measures the probability that a (system usage problem or cause) construct falls on the shortest path (geodesic) of pairs of other constructs. Based on Freeman [17], a *normalized betweenness centrality* scores $C'_B(p_k)$ is computed as the betweenness divided by the maximum possible betweenness expressed as a percentage:

$$C'_B\left(p_k\right) = \frac{2C_B\left(p_k\right)}{n^2 - 3n + 2},$$

where

$$C_B\left(p_k\right) = \frac{\sum_{i}^{n} \sum_{< j}^{n} b_{ij}\left(p_k\right)}{C_{\max}}$$

$b_j(p_k) = g_{ij}(p_k)/g_{ij}$, which is the probability that p_k falls on a randomly selected geodesic connecting two constructs p_i and $p_j = g_{ij}(p_k)/g_{ij}$; g_{ij} is the number of geodesics linking p_i and p_j; $g_{ij}(p_k)$ is the number of geodesics linking p_i and p_j that contains p_k; $C_{\max} = (n^2 - 3n + 2)/2$, which is the maximum value when p_k falls on the shortest path between any two pairs of other constructs, which is expressed as a percentage; p_i, p_j, p_k are the (system usage problem or cause) constructs i, j, k; $i \neq j \neq k$; $i = 1, 2, ..., n$; $j = 1, 2, ..., n$; $k = 1, 2, ..., n$.

A higher betweenness centrality indicates a greater proportion that a system usage problem construct appears on the shortest paths in the causal chains linking other constructs in the causal map, thus suggesting a greater importance of a problem type in comparison to others.

For example, to obtain the betweenness centrality of the *reporting* construct in the revealed causal maps of initial use phase (see Figure 2a) and continued use phase (see Figure 2b), we first constructed two adjacency matrices of these two phases, as illustrated in Tables B1 and B2.

The normalized betweenness centrality of the *reporting* construct can be obtained using the above formula as 3.333 in the causal map of initial use phase and as 9.667 in the causal map of the continued use phase. These scores suggest that *reporting* as a system usage problem increases its importance from the initial use phase to the continued use phase, suggesting that greater attention will be needed to address the *reporting* problem as the organization continues its use of the new SAP/BW system.

Table B1. Adjacency Matrix of Initial Use Phase (Based on Figure 2a)

	lackknow	role	reporting	data	workflow	techerror	usinteract
lackknow	0.000	0.075	0.300	0.120	0.060	0.000	0.000
role	0.000	0.000	0.010	0.000	0.000	0.000	0.000
reporting	0.000	0.000	0.000	0.040	0.000	0.000	0.000
data	0.000	0.000	0.060	0.000	0.000	0.000	0.000
workflow	0.000	0.000	0.000	0.050	0.000	0.000	0.000
techerror	0.000	0.150	0.080	0.020	0.000	0.000	0.000
usinteract	0.000	0.004	0.050	0.060	0.010	0.000	0.000

Table B2. Adjacency Matrix of Continued Use Phase (Based on Figure 2b)

	lackknow	role	reporting	data	workflow	techerror	usinteract
lackknow	0.000	0.060	0.280	0.110	0.050	0.000	0.000
role	0.000	0.000	0.006	0.000	0.001	0.000	0.000
reporting	0.000	0.070	0.000	0.070	0.000	0.000	0.000
data	0.000	0.000	0.060	0.000	0.080	0.000	0.000
workflow	0.000	0.006	0.030	0.020	0.000	0.000	0.000
techerror	0.000	0.030	0.050	0.020	0.000	0.000	0.000
usinteract	0.000	0.006	0.025	0.070	0.006	0.000	0.000

Reachability

Reachability is the total probability of one construct directly and indirectly resulting in other constructs. We calculated the reachability score of a construct by summing up the total strength of all direct and indirect paths going from one construct to all the other constructs. The strength of the direct path is the frequency (probability) of one construct directly causing another construct. The strength of the indirect path is probability of one construct indirectly causing another construct and is calculated as the multiplication of the strengths of all linkages involved in the indirect path linking the two constructs. So, the reachability score reflects the cumulative effect or influence of one construct on all the other constructs in the causal map.

For example, we detail the calculations below to illustrate how to obtain the reachability of the *reporting* construct in the revealed causal maps of the initial use phase and the continued use phase based on the adjacency matrices in Tables B1 and B2.

$$R_{reporting\_initial\ use\ phase} = \underbrace{0}_{\text{lackknow}} + \underbrace{0}_{\text{role}} + \underbrace{0.06}_{\text{data}} + \underbrace{0}_{\text{workflow}} + \underbrace{0}_{\text{techerror}} + \underbrace{0}_{\text{usinteract}} = 0.06$$

$$R_{reporting\_continued\ use\ phase} = \underbrace{0}_{\text{lackknow}} + \underbrace{0.07 + 0.07 \times 0.08 \times 0.06}_{\text{role}}$$

$$+ \underbrace{0.07 + 0.07 \times 0.001 \times 0.02}_{\text{data}} + \underbrace{0.07 \times 0.08 + 0.07 \times 0.001}_{\text{workflow}}$$

$$+ \underbrace{0}_{\text{techerror}} + \underbrace{0}_{\text{usintereact}} = 0.1457.$$

We aggregated the probabilities of *reporting* causing all other constructs through all direct and indirect paths. We thus obtained a reachability score of 0.06 for *reporting* in the initial use phase and a reachability score of 0.1457 for *reporting* in the continued use phase. These scores suggest that the *reporting* problem increases its influence on other system problems as the organization continued its use of the SAP/BW.

Although both the betweenness centrality and reachability of a construct calculates the probability, the former calculates the probability of a construct occurring on the shortest paths of pairs of other constructs and the latter calculates the probability of a construct causing other constructs. Thus, the two measures have different meanings—while betweenness centrality reflects the criticality of a construct in influencing others, reachability reflects the cumulative influence of a construct on others in the causal map.