

12-2011

Designing, Implementing, and Evaluating Information Systems for Law Enforcement—A Long-Term Design-Science Research Project

Siddharth Kaza

Department of Computer and Information Sciences, Towson University, skaza@towson.edu

Paul Jen-Hwa Hu

Department of Operations and Information Systems, University of Utah

Han-Fen Hu

Department of Operations and Information Systems, University of Utah

Hsinchun Chen

Department of Management Information Systems, University of Arizona

Follow this and additional works at: <https://aisel.aisnet.org/cais>

Recommended Citation

Kaza, Siddharth; Hu, Paul Jen-Hwa; Hu, Han-Fen; and Chen, Hsinchun (2011) "Designing, Implementing, and Evaluating Information Systems for Law Enforcement—A Long-Term Design-Science Research Project," *Communications of the Association for Information Systems*: Vol. 29 , Article 28.

DOI: 10.17705/1CAIS.02928

Available at: <https://aisel.aisnet.org/cais/vol29/iss1/28>

This material is brought to you by the AIS Journals at AIS Electronic Library (AISeL). It has been accepted for inclusion in Communications of the Association for Information Systems by an authorized administrator of AIS Electronic Library (AISeL). For more information, please contact elibrary@aisnet.org.

Communications of the Association for Information Systems



Designing, Implementing, and Evaluating Information Systems for Law Enforcement—A Long-Term Design-Science Research Project

Siddharth Kaza

Department of Computer and Information Sciences, Towson University
skaza@towson.edu

Paul Jen-Hwa Hu

Department of Operations and Information Systems, University of Utah

Han-Fen Hu

Department of Operations and Information Systems, University of Utah

Hsinchun Chen

Department of Management Information Systems, University of Arizona

Abstract:

The design science research (DSR) paradigm prescribes building and evaluating an Information Technology (IT) artifact to address organizational problems incorporating and enhancing relevant theories. In this article, we present a large-scale design science project that aims to address problems in the digital-government domain. The COPLINK project started at the University of Arizona with National Institute of Justice (NIJ) funding to integrate data from multiple law-enforcement databases and subsequently broadened in scope and funding to develop methodologies for capturing, searching, analyzing, and visualizing information for law-enforcement, intelligence, and national security applications. The project involves a complete spectrum of DSR activities including problem diagnosis, technology invention, technology evaluation, and theory building, while contributing to appropriate knowledge bases and making a significant impact on the real-world IT problems. Algorithms, methodologies, techniques, and the resulting Information Systems designed as part of the project are being successfully used in over 300 law-enforcement agencies, and have generated more than forty peer-reviewed publications. In this article, we describe these artifacts and the design process behind them, present summaries of evaluative studies, and discuss the factors that we believe were behind the success of this decade-long DSR project.

Keywords: design science research, digital government, law enforcement, COPLINK, knowledge management, data mining

Volume 29, Article 28, pp. 533-550, December 2011

The manuscript was received 11/20/2010 and was with the authors 4 months for 1 revision.

I. INTRODUCTION

The design science research (DSR) paradigm, in its broadest terms, prescribes building and evaluating an Information Technology (IT) artifact to address organizational problems while utilizing and expanding relevant theories [Hevner et al., 2004; Kuechler et al., 2008; Land et al., 2009; March et al., 1995; Nunamaker et al., 1991]. Innovative IT artifacts are constructed to aid individuals within an organization perform their task efficiently and effectively. In order to achieve this, information science (IS) researchers need to identify relevant problems, understand and contribute to appropriate theoretical bases, develop Information Technology (IT) artifacts, and perform rigorous evaluation to pinpoint problems, measure improvement, or pursue alternative solutions.

The thrust to introduce IT at all levels of government has provided an opportunity for IS researchers to develop and evaluate systems for various problems in the digital government domain. IT is being used in the government to provide citizens with access to information using the Web and other avenues, enable transactions with the government (e.g., using websites and kiosks), enable citizen participation (with e-voting and participatory rule-making), and facilitate information sharing and management within government agencies [Marchionini et al., 2003]. Application areas represent a cross-section of government mandates: healthcare and safety; law enforcement, security, and justice; education; land use; and many others [Chen et al., 2008]. The IS-oriented issues faced by government employees and citizens using government services are not unlike those common to businesses and their customers. Such problems provide IS researchers with the opportunity to design systems for knowledge management, information retrieval, information access, data analysis and data mining. The area also offers excellent scope for studies dealing with the evaluation, adaptation, use, and effectiveness of IT artifacts. Since government agencies, just like other organizations, face issues with cultural inertia and technology acceptance, behavioral research methodologies can be used to examine perceived usefulness, impact, valuation, and management of IT artifacts in diverse settings. While the digital government domain offers many opportunities, effective system implementation is a common and critical challenge. Inherently, many of the problems faced by government agencies may be categorized as “wicked problems” typically comprised of technical, economic, and political elements that operate together as a system [Hutchinson et al., 2002]. Solutions to such problems must be technically feasible and organizationally viable. According to Vreede and Vogel [2000], such systems need to be collaboratively designed in such a way that they are capable of addressing the human elements (members of the organization and their working methods), technical elements (hardware and software), and informational elements (data).

In this article, we present the COPLINK and associated digital government research projects at the University of Arizona’s Artificial Intelligence (AI) Lab within the context of DSR frameworks. We describe in detail the DSR activities carried out (problem diagnosis, technology invention, technology evaluation, and theory building) and the lessons we learned that might benefit similar DSR projects. The COPLINK project started with National Institute of Justice (NIJ) funding in 1997, with the goal of designing a system for law enforcement personnel to seamlessly share, and effectively analyze, data extracted from multiple sources. Since then, the project has expanded in scope to include information retrieval, identity resolution, social network and association analysis, and spatio-temporal analysis; it has received additional funding from agencies that include the National Science Foundation (NSF) and the Department of Homeland Security (DHS). Reflecting its broadened goals and impacts, the project has also acquired other titles, such as BorderSafe and Regional Information Sharing and Collaboration (RISC). In July 2009, the COPLINK system was acquired by the industry leading company ‘i2.’ The combined company has more than 450 employees and \$100 million in sales in 2009 and is a leading provider of security information sharing and crime analytics. Algorithms, methodologies, techniques, and the resulting Information Systems designed as part of the COPLINK project are being successfully used in over 1600 law-enforcement and intelligence agencies and have generated more than forty peer-reviewed publications. The research has also been featured in the *New York Times*, *Newsweek*, *Los Angeles Times*, *Washington Post*, and on ABC News, among others. The COPLINK project was selected as a finalist by the prestigious International Association of Chiefs of Police (IACP)/Motorola 2003 Weaver Seavey Award for Quality in Law Enforcement in 2003 and won the INFORMS Design Science Award in 2008.

Section II discusses the COPLINK research project by placing it within the DSR activity framework. Section II presents an overview of COPLINK research and systems developed at the University of Arizona along with a brief description and conclusions of some of the major DSR studies conducted. In the COPLINK project, we used design-science and behavioral-science research in a complementary way to further system development effectiveness. Section III presents a summary of the results of various technology acceptance studies of the COPLINK system. Section IV presents the conclusions and lessons learned from the project.

II. COPLINK RESEARCH PROJECT WITHIN THE DSR FRAMEWORKS

Figure 1 presents the primary research areas within the project and their interactions with knowledge bases in Information Systems (IS) and other reference disciplines within the context of the law enforcement problem domain. As shown, we engage in DSR activities (problem diagnosis, technology invention, technology evaluation, and theory building) presented in Venable [2006] and Nunamaker et al. [1991] in the context of the environment-knowledge base and rigor-relevance framework proposed by Hevner et al. [2004].

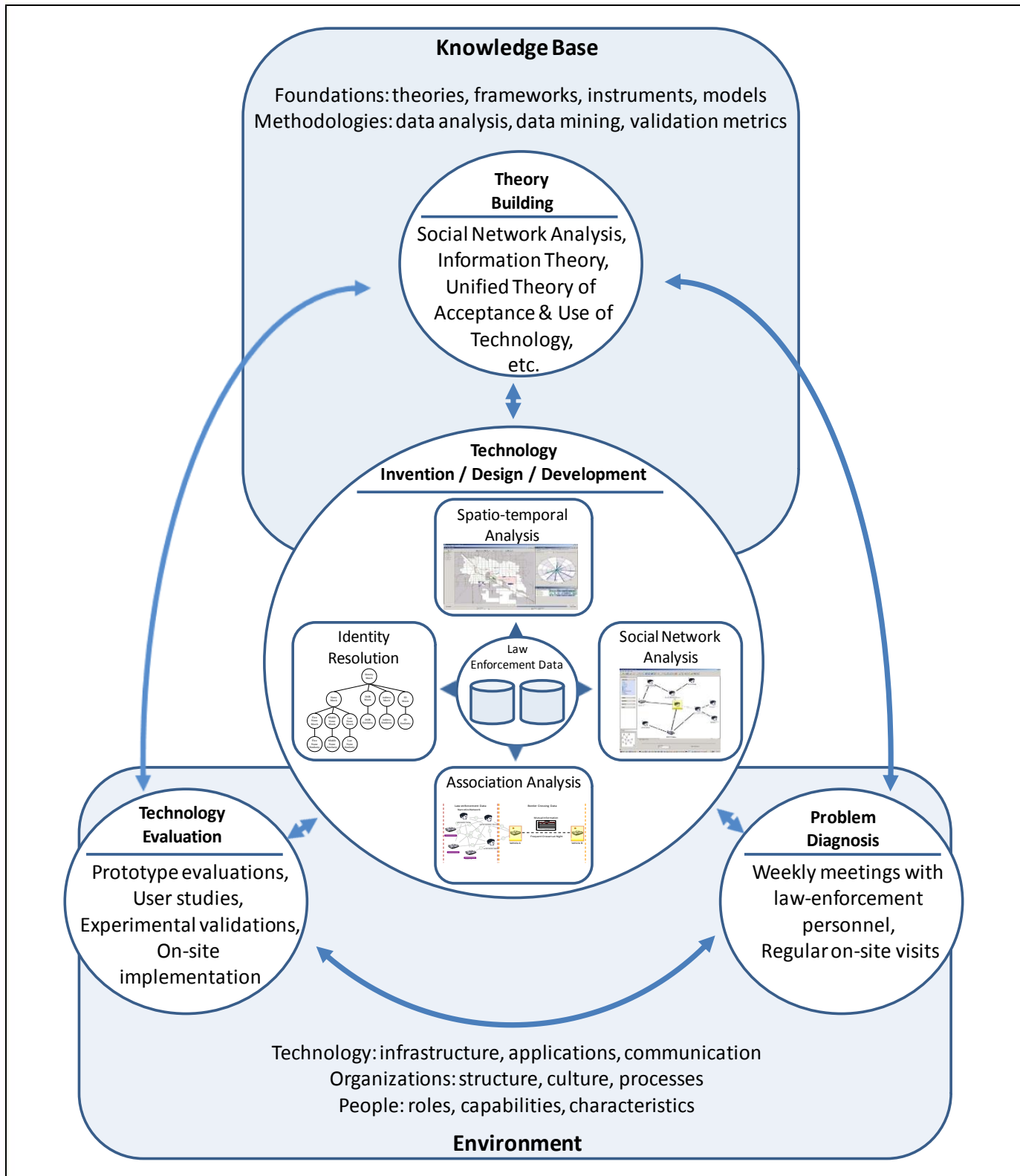


Figure 1. The COPLINK Project and Activities Within the Design Science Research Framework



Problem Diagnosis

The objective of DSR is to acquire knowledge and understanding that enables the design, development, and implementation of technology-based solutions to organizational problems [Hevner et al., 2004]. The COPLINK project was initiated by a collaborative effort between the Tucson Police Department (TPD) and the AI Lab to address the technical challenges of data compatibility, information accessibility, and knowledge sharing in law-enforcement agencies. TPD agreed to participate in investigations of state-of-the-art, near-term, and cost-effective database, Intranet, and multimedia technologies capable of making justice information integration, management, and access more efficient (implying that the task at hand could be achieved faster than comparative techniques) and effective (implying that the task at hand could be performed better than comparative techniques) [Chen et al., 2003b]. As the project expanded in scope, an officer was assigned as a liaison for the project to facilitate the interactions between AI Lab researchers and TPD officers, detectives, and crime analysts. The liaison officer visited the AI Lab for weekly meetings and provided specialized, in-depth domain expertise on ongoing research efforts. Furthermore, this officer was instrumental in our understanding of other IT-related problems faced by police and other law-enforcement agencies. When a problem was identified, the officer arranged meetings with appropriate parties in TPD that allowed us to better understand the problem scope, prior investigations and the methods employed, the current problem-solving strategy or process, and the existing technology solution (if any). We tackled each of the problems with a team-based approach. A team consisted of a research lead, several scientists and doctoral students, a domain expert from TPD, and a group of software developers. In many cases, a team was further decomposed into multiple subgroups, each concentrating on specific aspects of the problem. The team typically met on a weekly basis (usually face-to-face) to exchange ideas, review the progress, analyze and solve problems, define action items, recruit more members and adjust time tables, if necessary. This was in line with the suggestions by Hutchinson, English, and Mughal [2002] for addressing wicked problems. Our team structure and routine meetings provided the communications and collaborative mechanisms necessary for developing and validating a DSR based IT solution.

Technology Invention, Design, Development

DSR aims at the creation of an artifact to address organizational problems [Hevner et al., 2004]. In the COPLINK project, various challenging problems were addressed using innovative artifacts. These included data integration and identity resolution techniques and models [Chen et al., 2003a; Chen et al., 2003b; Kaza et al., 2008; Wang et al., 2004a, 2004b], social network analysis metrics [Kaza et al., 2009; Xu et al., 2005a, 2005b], spatio-temporal event detection models and algorithms [Chang et al., 2008; Chen et al., 2005], and association analysis techniques [Kaza et al., 2007]. Throughout the development of these artifacts, we approached design as a search process [Hevner et al., 2004]. That is, a prototype artifact was constructed in consultation with the liaison officer; alternatives were continually examined against the agency's requirements in the design process; algorithms, models, and systems were developed on the basis of real data and realistic assumptions, followed by rigorous evaluations and incremental improvements that lead to the final technology solutions.

Denning [1997] and Hevner [2004] suggest that the artifacts should be more than algorithms, prototypes, or Information Systems. Rather, they should be innovations, practices, and products through which the implementation and use of Information Systems can be effectively and efficiently accomplished. During the development of these IT artifacts, we learned about management's reluctance and administrative hurdles impeding effective technology implementation within agencies. To address these barriers, administrators at TPD and UA designed template documents for information sharing among government agencies and research institutions, critical to information sharing and implementation of Information Systems in law enforcement agencies [Atabakhsh et al., 2004].

Technology Evaluation

The artifacts produced during the research process were instantiated as prototypes necessary for feasibility demonstrations and system evaluations. We adopted evaluation techniques from data mining (e.g., n-fold cross validation, ROC curves [Han et al., 2006]), employed metrics from information retrieval (e.g., recall and precision), and used prevalent theoretical models including the technology acceptance model [Davis, 1989] and unified theory of acceptance and use of technology [Venkatesh et al., 2003]. Following DSR guidelines [Hevner et al., 2004; Nunamaker et al., 1991], we instantiated the novel algorithms and techniques into systems and tested them within the TPD's existing technical infrastructure. Our evaluations, embracing both functionality and usability, involved student participants [Chung et al., 2005; Xiang et al., 2005] as well as crime analysts and detectives from law enforcement agencies [Hu et al., 2005; Xu et al., 2004; Xu et al., 2005a], and comparison against appropriate gold standards and metrics [Kaza et al., 2007; Marshall et al., 2008; Wang et al., 2006].

Theory Building

We used appropriate theories in IS and reference disciplines to inform the research conducted in COPLINK project. We employed the social network analysis (SNA) theory [Granovetter, 1982; Wasserman et al., 1994] to examine the

structure, formation, growth, and destruction of different criminal networks based on narcotics, gang related, and other crimes. Record linkage [Fellegi et al., 1969] and other theories provided a basis for identity resolution and data integration methods developed for efficient access to data stored in multiple law enforcement jurisdictions. We used measures in the information theory [Fano, 1961] to conduct association analyses that identify suspect vehicles crossing the southern border. Kernel theories [Vapnik, 1999] were used for building innovative spatial scanning methods for spatio-temporal hotspot detection. All the above studies contributed to the appropriate knowledge bases by the application of theories to large-scale real-world datasets and developing new measures that were more appropriate and effective than existing measures in the problem domain. The studies developed and tested utility theories [Venable, 2006] that asserted that our systems or methods outperformed existing solutions. In addition, we anchored in salient behavioral theories to study target officers' acceptance of the resulting technology artifacts. For example, we developed a factor model premised in the theory of planned behavior [Ajzen 1991] and technology acceptance model [Davis, 1989] and empirically tested the model for explaining law enforcement officers' technology acceptance of a system developed as part of the project [Hu et al., 2005]. We also tested a model built upon unified theory of acceptance and use of technology [Venkatesh et al., 2003] to examine officers' acceptance of COPLINK mobile, a handheld device for accessing COPLINK applications remotely (details of this study are presented in Section IV).

III. SYSTEM OVERVIEW AND RESEARCH STUDIES

The COPLINK research project started with NIJ funding to integrate data from multiple law-enforcement databases and subsequently broadened in scope and funding to develop methodologies for capturing, accessing, analyzing, and visualizing for law-enforcement, intelligence, and national security applications. The first comprehensive version of the system consisted of two major components (the current version includes seven): COPLINK Connect and COPLINK Detect [Chen et al., 2003b]. COPLINK Connect is designed to allow police departments to share data seamlessly through an easy-to-use interface that integrates different data sources including legacy record management systems. The intended users of COPLINK Connect are police officers who have pressing, often mission critical, information needs. The design of this system was closely guided by user requirements acquired through multiphase brainstorming sessions, storyboards, mock system demonstrations, focus groups, and more formally structured questionnaires and interviews [Chen et al., 2003b].

COPLINK Detect uncovers various types of criminal associations that exist in law-enforcement databases. It uses a technique called concept space to identify such associations from existing crime data automatically [Chen et al., 2003b]. In general, a concept space is a network of terms and weighted associations that represent the concepts and their links within an underlying information space. COPLINK Detect uses statistical techniques such as co-occurrence analysis and clustering functions to weight relationships between all possible pairs of concepts.

COPLINK Connect and Detect formed the basis for further research projects to improve the efficacy and efficiency of individuals involved in law enforcement. The primary areas include (1) social network analysis and visualization, (2) spatio-temporal analysis and visualization, (3) identity resolution and data integration, and (4) association analysis. We summarize in the following subsections a few studies on these topics and refer the reader to the appropriate publications for details.

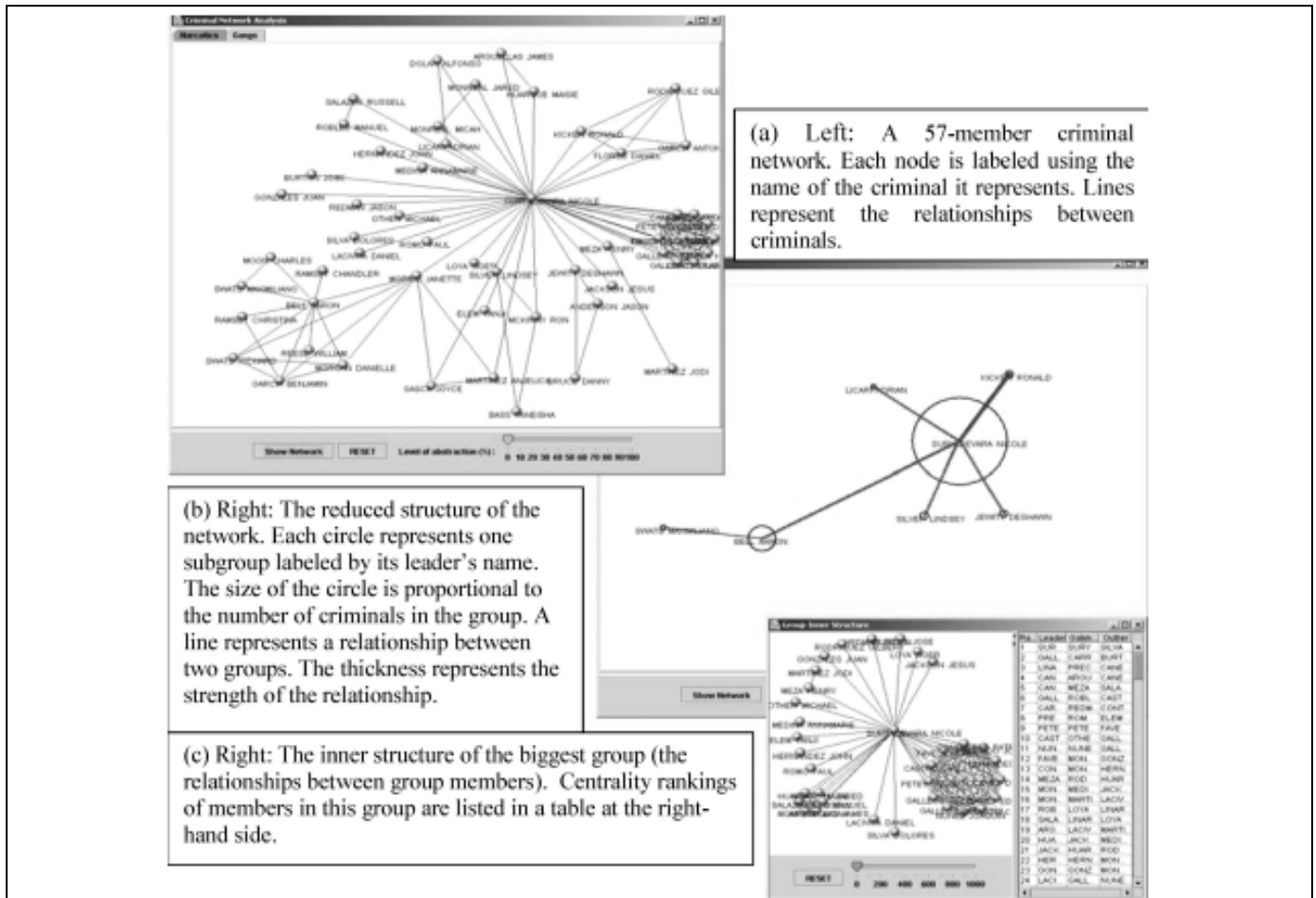
Social Network Analysis and Visualization

Knowledge about the structure and organization of criminal networks is important for both crime investigation and the development of effective strategies to prevent crimes. However, except for network visualization, criminal network analysis remains primarily a manual process. We found that existing tools did not provide advanced structural analysis techniques that allow extraction of network knowledge from large volumes of criminal-justice data. Several studies [Hu et al., 2009; Kaza et al., 2009; Marshall et al., 2008; Xu et al., 2004, 2005a, 2005b] were conducted that ranged from studying the structure of criminal networks using and defining metrics in the SNA theory to the development of systems for the analysis and visualization of networks by end-users. Most studies included the entire range of DSR activities from problem diagnosis to technology evaluation. Two of these studies are summarized below.

CrimeNet Explorer: A Framework for Criminal Network Knowledge Discovery

To aid law-enforcement and intelligence agencies in the efficient and effective use of criminal network knowledge, a framework was proposed for automated network analysis and visualization [Xu et al., 2005a]. Based on the framework, we developed a system called *CrimeNet Explorer* (Figure 2) that incorporated several advanced techniques: a concept space approach, hierarchical clustering, SNA methods, and multidimensional scaling. Results from controlled experiments involving student subjects demonstrated that our system could achieve higher clustering recall and precision than did untrained subjects when detecting subgroups from criminal networks. Thus, the system could perform effectively. Moreover, subjects identified central members and interaction patterns between groups

significantly faster with the help of structural analysis functionality than with only visualization functionality. Domain experts comprising of detectives and analysts also reported that CrimeNet Explorer could be very useful in crime investigations. Figure 2 shows snapshots of the CrimeNet Explorer system.



(The names of the actual nodes in the figure are intentionally blurred due to the sensitive nature of the data)

Figure 2. Snapshots from the Crimenet Explorer System Showing Interaction Patterns and Sub-Group Identification [Xu et al., 2005a]

Identifying Significant Facilitators of Dark Network Evolution

In this study [Hu et al., 2009], we used dynamic social-network analysis methods to examine several plausible facilitators of co-offending relationships in a large-scale narcotics network consisting of individuals and vehicles extracted from police records. Innovative methods were used to model network evolution. Multivariate Cox regression and a two-proportion z-test on the cyclic and focal closure metrics showed that mutual acquaintance and vehicle affiliations were significant facilitators for the network under study. We also found that homophily with respect to age, race, and gender were not good predictors of future link formation in these networks. Moreover, we examined the social causes and policy implications for the significance and insignificance of various facilitators including common jails on future co-offending. These findings provided important insights into the link-formation processes and the resilience of social networks.

Spatio-temporal Analysis and Visualization

Event visualization holds the promise of alleviating information overload in human analysis and numerous tools and techniques have been developed and evaluated in this domain. However, previous work does not specifically address either the coordination of event dimensions with the types of tasks involved or the way that visualizing different event dimensions can benefit human analysis. Research projects [Chang et al., 2008; Chen et al., 2005; Chung et al., 2005] in the University of Arizona focused on designing and implementing effective visualization tools for spatio-temporal events and proposing innovative algorithms for the identification of event hot-spots to aid in containment efforts.

Evaluating Event Visualization: A Usability Study of the Spatio-Temporal Visualizer

In this study [Chung et al., 2005], we propose a taxonomy of event visualization and present a methodology for evaluating a coordinated event visualization tool called the Spatio-Temporal Visualizer (STV), which was developed at the AI Lab. The STV tool (Figure 3) provides an integrated visualization environment that includes GIS, periodic, and timeline views along with a time slider to allow simultaneous examination of the same data. The GIS view displays a map of Tucson to help locate geographic clusters of crime incidents. The periodic pattern view provides aggregated information of a collection of incidents. A circular chart is used to display how many incidents occurred over a specified period in a selected time unit. The timeline view on a chart shows crime incidents as square boxes arranged in chronological order, with groups of incidents displayed in a hierarchy on the left of the chart, the time slider adjusts the temporal viewing window [Chung et al., 2005]. The evaluation methodology examines different event dimensions and different task types, thus juxtaposing two important elements of evaluating a tool. To achieve both internal and external validity, a laboratory experiment with students and a field study with crime analysis experts were conducted. Findings showed that STV could support crime analysis involving multiple, coordinated event dimensions as effectively as it could analyze individual, uncoordinated event dimensions. STV performed better using various metrics (see Chung et al., 2005, for details) as compared to Microsoft Excel (which was the tool primarily used by crime analysts to perform their tasks). User comments also showed STV to be intuitive, useful, and preferable to existing crime analysis methods.

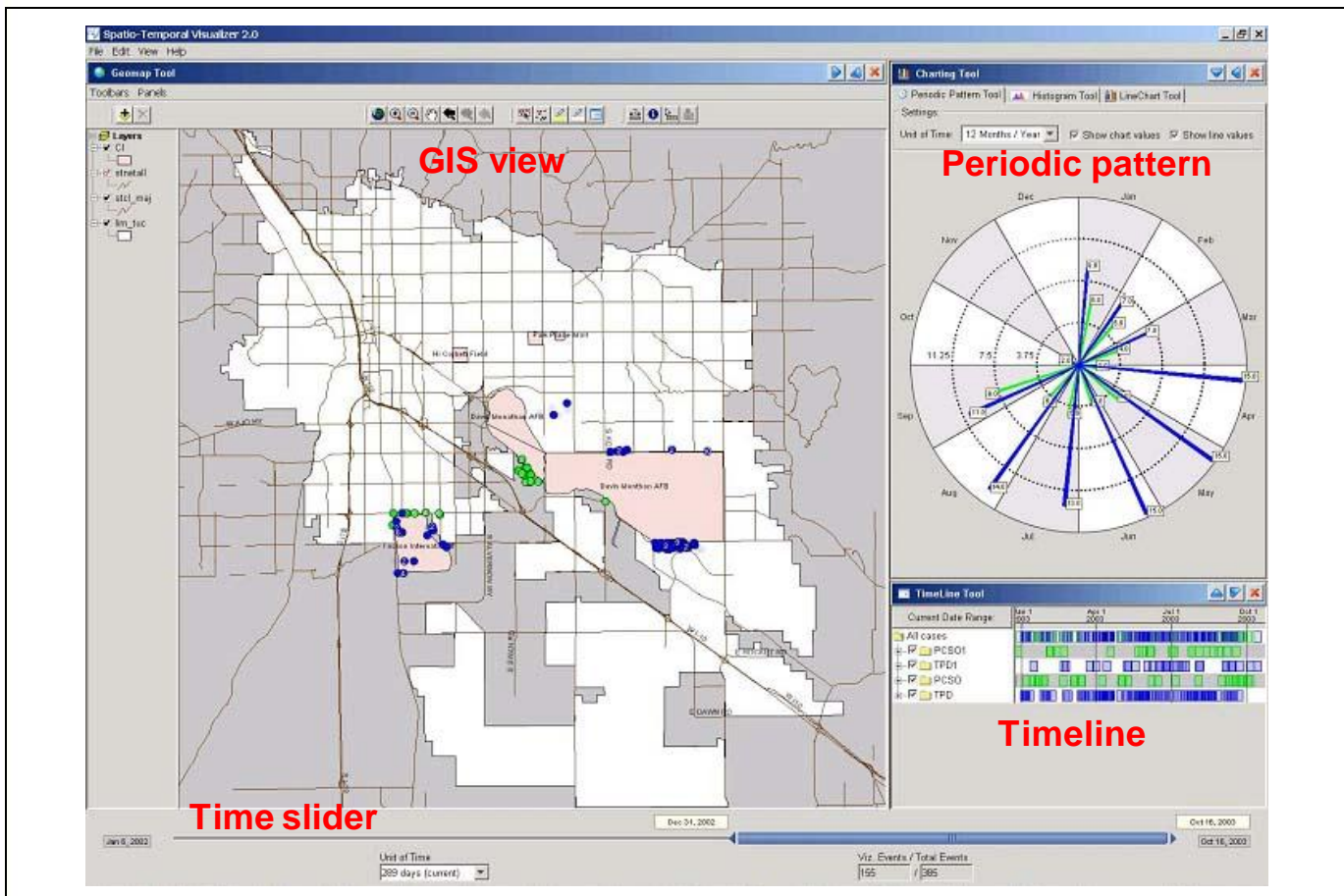


Figure 3. The Spatio-Temporal Visualizer Designed for Crime-Event Visualization and Analysis

A Stack-based Prospective Spatio-temporal Data Analysis Approach

In this study [Chang et al., 2008], we developed a new spatio-temporal data analysis approach aimed at discovering abnormal spatio-temporal clustering patterns. We also proposed a quantitative evaluation framework and compared our approach against a widely used space-time scan statistic-based method. Our approach is based on a robust clustering engine using support vector machines and incorporates ideas from existing online surveillance methods to track incremental changes over time. Experimental results using both simulated and crime datasets indicate that our approach is able to detect abnormal areas with irregular shapes more accurately than the space-time scan statistic-based method implemented in the widely used SaTScan tool. This innovative algorithm can be used in the STV tool to aid analysts identify emerging hotspots in crime, disease, and other spatio-temporal data.

Identity Resolution

Identity deception is a serious problem encountered in the law-enforcement and intelligence communities. Most of the existing techniques are experimental and cannot be easily applied to real applications because of problems such as missing values and large data size. In this stream of research, we developed techniques that can automatically detect identity deception.

A Study of Criminal Identity Deception and Deception Detection in Law Enforcement

This study [Wang et al., 2004b] focused on uncovering patterns of criminal identity deception observed through a case study performed at TPD. We defined criminal identity deception based on an understanding of the various theories of deception and interviewed a police detective to refine the definition of criminal identity deception. A novel taxonomy for criminal identity deception was built to represent the various patterns identified in the case study. This taxonomy formed the basis for the development of deception detection models.

Automatically Detecting Criminal Identity Deception: An Adaptive Detection Algorithm

In this study [Wang et al., 2006], we proposed an adaptive detection algorithm that adapts well to incomplete identities with missing values and to large datasets containing millions of records. We described three experiments to show that the algorithm is significantly more efficient than the existing record comparison algorithm with little loss in accuracy. A study conducted at TPD showed that our algorithm was useful in detecting both intentional deception and unintentional data errors. Figure 4 shows a snapshot of the ID resolution tool developed as part of this research. The tool can be used to determine similar identity clusters in databases and provide an interface to merge them. A comparison of the tool using compression ratio, precision, and recall metrics to the industry leading IBM Identity Resolution Software showed that the Arizona ID Matcher obtained better recalls and overall F-measure [Wang et al., 2007].

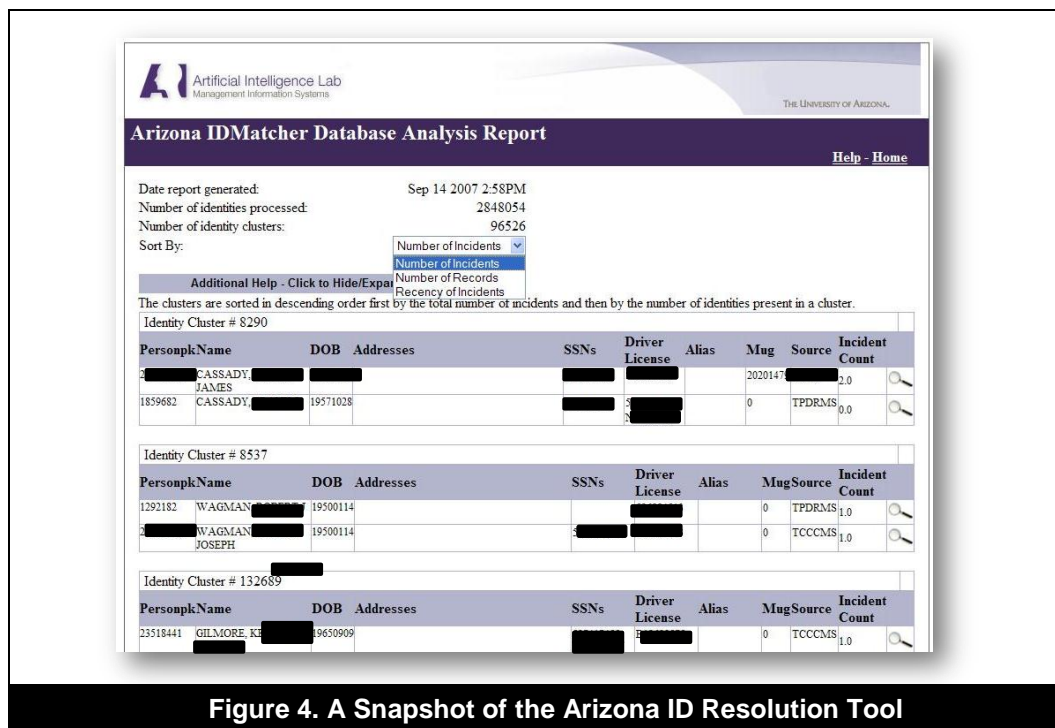


Figure 4. A Snapshot of the Arizona ID Resolution Tool

Association Analysis

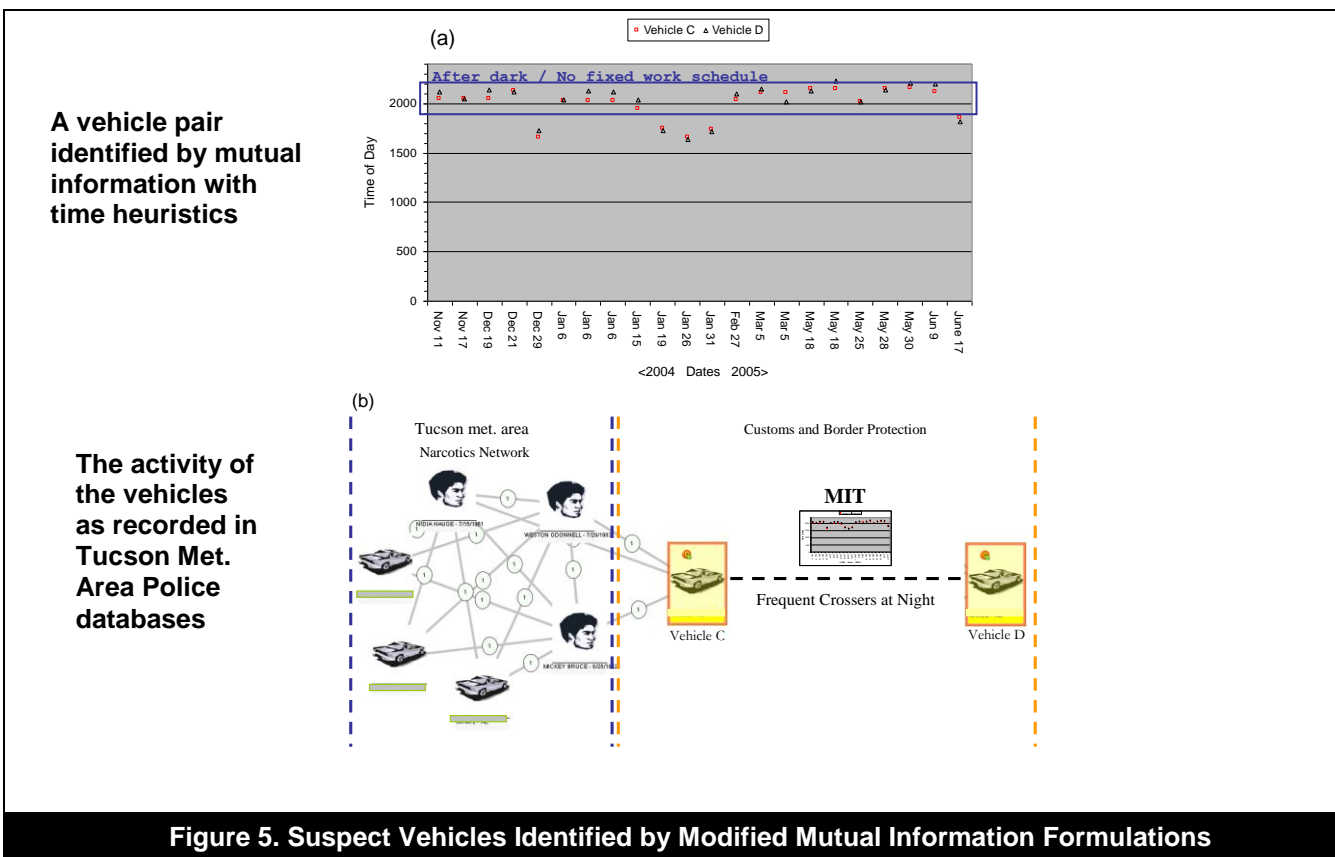
In recent years, border safety has been identified as a critical part of homeland security. Customs and Border Protection (CBP) agents search vehicles entering the country for drugs and other contraband. This process is time consuming, and long waiting times impair the flow of people, vehicles, and commerce. So agents at the border are under pressure to balance security needs with operational efficiency.

CBP agents believe that vehicles involved in smuggling operate and cross the Southern border in groups. When one vehicle approaches the checkpoint, the others wait and join the line only if the vehicle crosses into the U.S. successfully. This ensures that the others can turn back into Mexico if the vehicle before them is inspected and caught. So, if the criminal links of one or more vehicles in a group are known, the group's crossing patterns may be used to identify other partner vehicles. Law-enforcement data can be used as a good anchor to perform such

analysis and identify quality suspect vehicles. However, CBP agents do not always have access to local law-enforcement information and sometimes lack the methods to perform such large-scale analysis on millions of crossing vehicles.

We performed this association analysis by using mutual information (MI) [Kaza et al., 2007] to identify groups of vehicles that cross the border and may be potentially involved in criminal activity. CBP agents also suggest that criminal vehicles may cross at certain times or ports to try and evade inspection. We use law enforcement information from border-area jurisdictions to identify times and ports that criminal vehicles prefer and modify the MI formulation to incorporate this knowledge. Statistical tests and selected cases judged by domain experts show that modified MI performs significantly better than classical MI in identifying potentially criminal vehicles. The new formulations are likely to help CBP agents identify better quality target vehicles more efficiently.

Figure 5 shows an illustrative case of suspect vehicles (Vehicles C and D) identified by the modified MI formulations. This case was reviewed and evaluated by domain experts. In Figure 5(a) the X-axis are the dates when the vehicles were seen crossing together. On the Y-axis are the times of crossing (0-2400). As can be seen in the figure, this vehicle pair crossed together frequently, and, in addition, all the crossings were after dark and did not follow a standard work schedule. Since, Vehicles C and D are interesting with respect to the frequency and times of crossing together; we explored their police contacts further. Figure 5(b) shows the criminal links of Vehicle C and Vehicle D as visualized in a social network visualizer developed as part of the project. Vehicle C was found to have strong connections to a narcotics network in the Tucson metropolitan area. It had links to other people and vehicles that had been arrested/suspected for narcotics sales and possession in the region. These connections suggested that the vehicle might be an active member of a narcotics sale and smuggling ring. Domain experts also suggested that viewing the vehicles' border crossing activity in this context made them a candidate for further investigation. The modified MI formulation identified many other such examples and was shown to be statistically superior to the classical MI formulation.



IV. USER TECHNOLOGY ACCEPTANCE STUDIES

User acceptance is vital to the success of COPLINK in law enforcement agencies. It is a critical dependent variable of Information Systems success [DeLone et al., 1992] and has been shown to be a common challenge impeding the proliferation of an advanced Information System in various organizational settings, including law enforcement [Lin et al., 2004]. Law enforcement officers need constant, timely information access and effective knowledge support for crime fighting and investigation activities. However, the deployment of COPLINK by an agency cannot guarantee its

use by the targeted officers. Therefore, our technology evaluation included the examination of key factors influencing individual officers' technology acceptance decisions. We conducted two empirical studies to investigate law enforcement officers' acceptance of COPLINK. Both studies addressed the following questions:

- What are the important factors influencing a law enforcement officer's acceptance of COPLINK or COPLINK Mobile?
- What are the inter-relationships between these determinants that explain an officer's decision on whether to use COPLINK or COPLINK Mobile?

We took a theory-based approach by developing research models for explaining officers' technology acceptance on the basis of the theory of planned behavior [Ajzen, 1991], the theory of innovation diffusion [Rogers, 1983], technology acceptance model [Davis, 1989], and the unified theory of acceptance and use of technology [Venkatesh et al., 2003]. As depicted in Figure 1, we anchored appropriate theoretical premises to develop factor models explaining or predicting officers' technology acceptance decisions. We then empirically tested each model and the associated hypotheses by conducting a survey study involving the targeted officers in their work context. Our investigations responded to the need for further examining user technology acceptance in various professional work settings [Chau et al., 2001]. In the next section, we detail each study in terms of research model, measurements, instrument revalidation, data collection, and key results.

Examining Officers' Acceptance of COPLINK

Research Model

We posit that an officer's decision to accept or not accept COPLINK can be jointly explained by important characteristics of the technology, the targeted user group, and the adopting agency context, congruent with the suggestion by Chau and Hu [2001]. According to our model (shown in Figure 6), officers' acceptance of COPLINK is directly determined by their attitudes toward the technology, perceptions of its usefulness and availability, as well as the agency's subjective norm toward using the technology. In general, availability refers to an officer's perception of the availability of the computing equipment necessary for accessing and using COPLINK, and subjective norm is an officer's assessment or perception of significant referents' opinions regarding his or her use of COPLINK [Taylor et al., 1995]. Perceived usefulness refers to the extent to which an officer considers COPLINK to be useful for his or her job tasks [Davis et al., 1989]. This perception is influenced by efficiency gain, perceived ease of use, and subjective norm. The efficiency gain refers to the degree to which an officer perceives that his or her task performance efficiency can be improved through the use of COPLINK [Davis, 1989]. The perceived ease of use refers to an officer's perception of his or her use of COPLINK to be free of effort [Davis et al., 1989]. Attitude also affects user acceptance and refers to an officer's positive or negative attitudinal beliefs about using COPLINK [Taylor et al., 1995] According to our model, attitude is influenced by perceived usefulness and perceived ease of use.

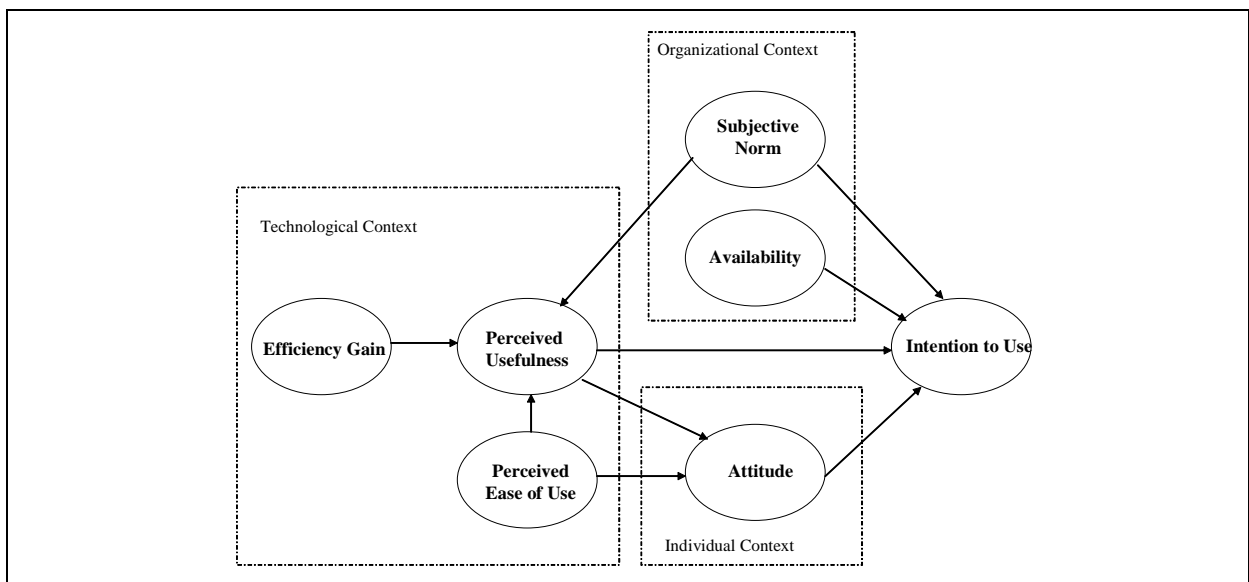


Figure 6. A Factor Model for Explaining Officers' Acceptance of COPLINK

Measurements

We used behavioral intention to measure officers' acceptance of COPLINK, a dependent variable choice that is theoretically justifiable and has ample empirical support. To measure the constructs in our model, we adapted items from previously validated scales and used a focus group, consisting of law enforcement officers, to verify them at face value. Using their feedback and suggestions, we selected items appropriate for our intended investigation from each scale and made several wording changes appropriate for the targeted law enforcement context. Specifically, we measured perceived usefulness, perceived ease of use, and intention using the respective items adapted from Venkatesh and Davis [1996]. We operationalized attitude and availability with items from Taylor and Todd [1995]. We measured efficiency gain using items from Davis [1989]. All the measurement items employed a 7-point Likert scale ranging from "strongly disagree" to "strongly agree." To reduce potential ceiling or floor effects that may induce monotonous responses from subjects, we randomized the items in the questionnaire and negated half of the questions.

Instrument Revalidation

We conducted a pilot study to revalidate our instrument [Straub, 1989], involving a total of forty-two officers who had completed the mandatory user training program but had not participated in the development of COPLINK or our survey instrument development. We used their evaluative responses to reexamine the instrument's reliability as well as its convergent and discriminant validity. According to our results, the instrument exhibited satisfactory reliability; i.e., the Cronbach's alpha value for the investigated constructs ranged from .73 to .93, exceeding the common .7 threshold [Nunnally, 1978]. To examine the convergent and discriminant validity, we performed a confirmatory factor analysis using a varimax with Kaiser normalization rotation. Our results show that items measuring the same construct have loadings significantly higher than those measuring a different construct. In addition, each component extracted has an eigenvalue greater than 1.0. Taken together, our pilot results show that the instrument exhibits satisfactory convergent and discriminant validity.

Data Collection

Our study agency is a police department of a medium-sized city located in southwestern United States. With the assistance of the administrators, including assistant chiefs and captains, we distributed the survey to 481 officers who had completed the mandatory user training program three months prior. Each officer had two weeks to complete and return the survey. Officers who had not responded in the normal response window were contacted and offered another two weeks to do so. A final one-week window was then offered to officers who had not returned the survey during the extended response window. We received a total of 283 completed surveys, representing a 68.9 percent effective response rate. Most of our subjects were from the Investigative and Field Operations divisions, the two largest in the study agency. The gender distribution of the respondents shows an approximate 4-to-1 ratio, in favor of males. Most of the responding officers had a two-year college degree (41 percent), followed by those with a high school diploma (30 percent) and those holding a bachelor's degree (29 percent). As a group, our subjects were 38.4 years of age and had accumulated 12.1 years of experience in law enforcement services. Our analysis shows no significant differences between the early and late respondents (i.e., those returning the survey in the normal two-week response window versus those who needed additional time to do so) in home division, gender distribution, education background, age, or prior experience in law enforcement. Thus, the threat of nonrespondent bias was reduced.

Results

We took a structural equation modeling approach to test our model and hypotheses (i.e., causal paths). Specifically, we used LISREL to examine the measurement model and the structural model. Overall, our data show a good fit to the research model, as suggested by common model fit indexes exceeding the respective thresholds; e.g., Comparative Fit Index being .91, Non-norm Fit Index being .89, Standardized Root Mean Square Residual being 0.06. Our model exhibits satisfactory explanatory power, accounting for 58 percent of the variance in officers' intention to use COPLINK, 66 percent of the variance in their attitudes toward COPLINK, and 60 percent of the variance in perceived usefulness. Judged by both the statistical significance and the magnitude of influence, perceived usefulness seems to be the most important determinant of user acceptance and is significantly influenced by efficiency gain and subjective norm. This finding suggests a pragmatic orientation in officers' technology acceptance decision-making.

Examining Officers' Acceptance of COPLINK Mobile

COPLINK Mobile provides field officers with a core set of COPLINK functionalities through a lightweight, handheld device or mobile applications running on a limited bandwidth. It represents a crucial extension of COPLINK because law enforcement activities are becoming increasingly networked and mobile. COPLINK Mobile can be implemented on PDAs, mobile phones, or tablet devices, thereby providing field officers with anytime, anywhere access to core COPLINK applications with a small screen space. With COPLINK Mobile, a field officer can use general packet radio

service (GPRS) communications to query and access, through a secured channel and in a nearly real-time fashion, important information regarding specific suspects, locations, weapons, vehicles, and/or crime events, with few spatial or temporal constraints.

Research Model and Measurements

In order to make meaningful comparison with prior study examining officers' acceptance of COPLINK, we adapted the same research model and empirically tested this model by conducting a survey study for explaining field officers' voluntary use of COPLINK Mobile. We also used the same measurements and employed a 7-point Likert scale ranging from "strongly disagree" to "strongly agree."

Data Collection

We targeted all the officers (153 in total) who had received a custom-made hand-held device for using COPLINK Mobile and completed the mandatory user training program. We obtained important demographic data from each officer during the training program and distributed the survey three months after the training, with assistance of their administrators. All officers had two weeks to complete and return the survey and those who did not return the survey had two additional weeks to do so. A total of forty-two officers returned the survey; one of which was partially completed and thus was removed from our subsequent data analyses. As a result, our sample consists of forty-one responses, showing an effective response rate of 26.8 percent. Our sample is representative of the overall field officers, as suggested by the insignificant between-group differences in age, number of years in law-enforcement services, and computer competence; *p*-values all greater than 0.10. We further examined the non-respondent bias by comparing officers returning their completed surveys in the normal two-week response window versus those needing additional time to do so. Both groups are highly comparable in age, number of years in law-enforcement services, and computer competence (*p*-value > 0.10). Together, our results suggest that the non-respondent bias does not appear to be a serious problem in the study.

Instrument Revalidation

We first examined our instrument in terms of reliability and convergent and discriminant validity. For item reliability, we examined the loading of each item on its corresponding construct. We adopted the suggested cutoff thresholds and observed almost all the measurement items showing a factor loading higher than 0.7, a threshold suggested by Nunnally [1978]. The loadings of all the remaining items are statistically significant at the 0.001 level. We assessed our instrument's construct reliability in terms of internal consistency and composite construct reliability. We used Cronbach's alpha to examine internal consistency and adopted the common threshold of 0.7 [Nunnally, 1978] and our results showed that each construct exhibited a Cronbach's alpha value greater than 0.7, thus showing satisfactory internal consistency. The composite reliability of each construct also exceeded 0.7, a threshold commonly used in social science research to signify satisfactory construct reliability [Fornell et al., 1981]. Overall, our results suggest the instrument exhibited satisfactory construct reliability. We then examined convergent validity, using average variance extracted (AVE) that denotes the variance captured by the indicators. Each construct had an AVE value greater than 0.5, suggesting our instrument's adequate convergent validity [Fornell et al., 1981]. We further examined the convergent and discriminant validity of our instrument, on the basis of the cross-loadings computed from the correlation between each construct's component score and the manifest indicators of other constructs [Chin, 1998]. According to our results, all items load substantially higher on their own construct than on any other constructs. Furthermore, the square roots of the AVEs were also greater than the correlation among any pair of latent constructs [Chin, 1998]. Taken together, our results suggest the instrument had appropriate convergent and discriminant validity.

Results

We tested our model and the associated hypotheses using partial least squares (PLS), which supports factor analysis with linear regressions and requires minimal distribution assumptions [Gefen et al., 2000]. PLS supports both measurement and structural model testing and is advantageous over other alternative data analysis techniques (e.g., LISREL) because our sample is relatively small and the data distribution may not confirm multivariate normality. We tested our research model by examining the variance of each non-endogenous variable; i.e., R^2 value. Our model explains a significant portion of the variance in perceived usefulness (77 percent), attitude (71 percent), and behavioral intention (71 percent). Collectively, the model offers significant utility for explaining field officers' acceptance of COPLINK Mobile. Compared to previous study that examines the officers' intention to use COPLINK, this model explains more variances in the officers' intention to use COPLINK Mobile, their attitudes toward COPLINK Mobile, and perceived usefulness. Perceived usefulness appears to be a single most critical acceptance determinant and is directly influenced by efficacy gain and subjective norm, judged by the statistical significance and effect magnitude.

Summary of User Acceptance Studies

The results of our studies show that each research model is capable of explaining officers' decision on whether to accept COPLINK or COPLINK Mobile. We make several important observations from our study results. First, in both of our studies, a consistent, prominent core influence path from efficiency gain to perceived usefulness and then to user acceptance measured by intention. In turn, this suggests a tendency that law enforcement officers anchor their technology acceptance decisions from a utilitarian perspective. Officers are not likely to use a technology offering marginal utilities to job tasks just because it is easy to use or people important to them (e.g., commanders, supervisors, colleagues) are in favor of the technology. Second, availability is also important; providing sufficient equipment necessary for accessing and using COPLINK or COPLINK Mobile can affect officers' acceptance and actual use of the technology. Third, perceived ease of use contributes to officers' use of COPLINK, perhaps through its influence on perceived usefulness; however, the perceived ease of use does not seem to have significant effects on officers' perceptions about COPLINK Mobile's usefulness or their attitudes. In our context, the influence of perceived ease of use on an officer's decision whether or not to use COPLINK or COPLINK Mobile seems limited. In addition, law enforcement officers appear to place a relatively small weight on the opinions of their important referents regarding their use of COPLINK or COPLINK Mobile. According to our findings, subjective norm influence officers' perceptions of a technology's usefulness, but does not affect their acceptance decisions directly.

As Chau and Hu [2001] noted, people are likely to exhibit subtle differences in their technology acceptance decision making, partially because of their professional context. For example, specialized personnel require specialized training, are accustomed to professional work arrangements, and normally have considerable autonomy in their work practices [Chau et al., 2001]; this implies that law enforcement officers may consider different factors when deciding whether to use a new technology. Our results reveal that compared to prior literature in technology acceptance by ordinary users, police officers exhibit different considerations while making the technology acceptance decisions. According to the reported surveys, neither the perceived ease of use, nor the subjective norm affects the officers' adoption decision. The most important determinants of the officers' adoption decision seem to be whether the use of COPLINK or COPLINK Mobile can help to improve job performance in their routine tasks and operations in the field. Our findings, therefore, provide important insights into user acceptance of an advanced technology in mandatory settings and highlight the utilitarian focus of the officers' decision making.

V. CONCLUSIONS AND LESSONS LEARNED

Algorithms, methodologies, techniques, and the resulting systems developed as part of the COPLINK project have been used successfully within law-enforcement agencies at the local, state, and national levels for several years. Each research project was informed by theories, methodologies, and instruments from IS and its various reference disciplines and has contributed back to the knowledge bases by developing new design techniques, data analysis methodologies, and evaluation methods. Various studies within the projects have aimed to understand the environment within law-enforcement organizations with a focus on designing effective artifacts to address important Information System-centric problems. All artifacts have been developed in consultation with stakeholders and evaluated within their environmental contexts in spirit of the design science philosophies of building and evaluating [March et al., 1995; Simon, 1996].

A combination of several factors are the key to the success of COPLINK as a large-scale DSR project:

- *Relevant problems*—As suggested by all DSR researchers [Hevner et al., 2004; Nunamaker et al., 1991], DSR should focus on relevant real-world problems. Our relationship with law-enforcement agencies played a very important role in the identification of problems to be solved. Right from the inception of the project, the research team identified problems based on input from crime analysts and officers at the Tucson Police Department, Customs, and Border Protection, and several other agencies. Most of these problems were time-sensitive in nature and required workable solutions applicable in government agencies. The incentive to produce working systems along with the added satisfaction of aiding law-enforcement encouraged high quality research.
- *Application of established theory to new areas*—Hevner et al. [2004] mentioned that success in a DSR project is predicated by the researcher's skilled selection of appropriate techniques to develop an artifact and the selection of appropriate means to evaluate it. We placed the problems faced by government agencies in the context of theoretical research in the MIS and related disciplines. This not only allowed us to publish research and enhance theories, but also produced creative solutions by drawing on established ideas never applied to this problem domain. Various related disciplines (like sociology and computer science) were searched for techniques like social network analysis and record linkage, both of which had clear applications to law-enforcement issues.
- *Communication of research in academia, industry, and media*—We presented our research in various conferences and published in many tier-1 design science oriented journals. This provided credibility to the

project not just in academia, but also in the eyes of funding and law-enforcement agencies. In addition, COPLINK received notable coverage in the media with articles in the *New York Times* [Sink, 2002] and the *Washington Post* [O'Harrow et al., 2008], among others. The media coverage and the presence of academic credibility through the University of Arizona further encouraged outside organizations to trust and implement the artifacts produced [Linder, 2007]. This allowed the research team to test and evaluate algorithms and prototype systems on real data and often in the actual IT infrastructure at the agencies. The feedback obtained from these evaluations could be readily incorporated back into the research to produce systems that had a significant amount of end-user buy-in. Thus, the problem diagnosis-technology invention-theory building-technology evaluation loop shown in Figure 1 went a full circle several times during the duration of the project.

- *External funding and commercialization*—We believe that external funding both from national agencies like NSF, DHS, and NIJ and the industry plays an important role in design science research. External funding allowed police agencies to implement the artifacts, provide salaries for personnel to liaison with the university, and support research staff at the university. Since system prototypes were tested and implemented at agencies with success, this allowed us to leverage a variety of agencies (both research and practice oriented) for funding. Even though many artifacts constructed are rarely full-grown Information Systems that are used in practice [Hevner et al., 2004], the initial systems developed within the research project were commercialized using venture capital funding. The systems were rewritten to make the code robust, reliable, and commercial-grade [Linder, 2007]. This led to the research project's growth as more organizations approached the AI Lab with newer and relevant problems.

The success of the COPLINK project at the University of Arizona has led to other large-scale projects that plan to use the same model to identify problems and conduct high-impact design science research. These projects include the Dark Web project that aims to computationally analyze information systematically obtained from the Internet, the BioPortal project that aims at developing a cross-jurisdictional information sharing and data analysis environment, and the business intelligence projects that include research on opinion mining, analysis of the Web 2.0, and recommender systems among others.

ACKNOWLEDGMENTS

The COPLINK, BorderSafe, RISC, and associated projects were supported in part by the NSF Digital Government (DG) program: "COPLINK Center: Information and Knowledge Management for Law-enforcement" #9983304, NSF Knowledge Discovery and Dissemination (KDD) program: "COPLINK Border Safe Research and Testbed" #9983304, NSF Information Technology Research (ITR) program: "COPLINK Center for Intelligence and Security Informatics Research—A Crime Data Mining Approach to Developing Border Safe Research" #0326348, NSF/CIA: "A Data Mining Framework for Deception Detection," Department of Homeland Security (DHS)/CNRI through the "BorderSafe" initiative #2030002, NSF/DHS: "Regional Information Sharing and Collaboration," National Institute of Justice (NIJ): "COPLINK: Database Integration and Access for a Law-enforcement Intranet" # 97-LB-VX-K023, and the Compaq Computer Corporation External Technology Grants Program #US-1998004.

We thank our project partners who played a very important role in the success: Tucson Police Department, Phoenix Police Department, Pima County Sheriff's Department, and Tucson Customs and Border Protection.

We greatly appreciate the excellent COPLINK team members and officers at TPD and CBP for their time and contributions to this research project.

REFERENCES

Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor or are reading the article on the Web, can gain direct access to these linked references. Readers are warned, however, that:

1. These links existed as of the date of publication but are not guaranteed to be working thereafter.
2. The contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
3. The author(s) of the Web pages, not AIS, is (are) responsible for the accuracy of their content.
4. The author(s) of this article, not AIS, is (are) responsible for the accuracy of the URL and version information.

Ajzen, I. (1991) "The Theory of Planned Behavior", *Organizational Behavior & Human Decision Processes* (50)2, pp. 179–211.

- Atabakhsh, H., et al. (2004) *Information Sharing and Collaboration Policies Within Government Agencies*, Paper presented at the Symposium on Intelligence and Security Informatics (ISI 2004), Tucson, AZ.
- Chang, W., D. Zeng, and H. Chen (2008) "A Stack-Based Prospective Spatio-Temporal Data Analysis Approach", *Decision Support Systems* (45)4, pp. 697–713.
- Chau, P.Y.K. and P.J.-H. Hu (2001) "Information Technology Acceptance by Individual Professionals: A Model Comparison Approach", *Decision Sciences* (32)4, pp. 699–719.
- Chen, H., et al. (2005) *Visualization in Law Enforcement*, Paper presented at the CHI '05 Extended Abstracts on Human Factors in Computing Systems, Portland, OR.
- Chen, H., et al. (eds.) (2008) *Digital Government E-Government Research, Case Studies, and Implementation*, Berlin, Germany: Springer.
- Chen, H., et al. (2003a) "COPLINK Connect: Information and Knowledge Management for Law Enforcement", *Decision Support Systems* (34)3, pp. 271–285.
- Chen, H., et al. (2003b) "COPLINK: Managing Law Enforcement Data and Knowledge", *Communications of the ACM*, (46)1, pp. 28–34, doi: [10.1145/602421.602441](https://doi.org/10.1145/602421.602441) (current Nov. 30, 2011).
- Chin, W.W. (1998) "The Partial Least Squares Approach for Structural Equation Modeling" in Marcoulides, G.A. (ed.) *Modern Methods for Business Research*, Mahwah, NJ: Lawrence Erlbaum Associates.
- Chung, W., et al. (2005) "Evaluating Event Visualization: A Usability Study of COPLINK Spatio-Temporal Visualizer", *International Journal of Human-Computer Studies* (62)1, pp. 127–157.
- Davis, F.D. (1989) "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology", *MIS Quarterly* (13)3, pp. 319–340.
- Davis, F.D., R.P. Bagozzi, and P. R. Warshaw (1989) "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models", *Management Science* (35)8, pp. 982–1003.
- DeLone, W.H. and E.R. McLean (1992) "Information Systems Success: The Quest for the Dependent Variable", *Information Systems Research* (3)1, pp. 60–95.
- Denning, P.J. (1997) "A New Social Contract for Research", *Communications of the ACM* (40)2, pp. 132–134.
- de Vreede, G.-J. and D. Vogel (2000) "Group Support Systems for the Collaborative Design of Organizational Systems: Introduction to the Special Issue", *Group Decision and Negotiation* (9)2, pp. 93–96.
- Fano, R.M. (1961) *Transmission of Information*, Cambridge, MA: MIT Press.
- Fellegi, I. and A. Sunter (1969) "A Theory for Record Linkage", *Journal of the American Statistical Association* (64)328, pp. 1183–1210.
- Fornell, C. and D.F. Larcker (1981) "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error", *Journal of Marketing Research (JMR)* (18)1, pp. 39–50.
- Gefen, D., D.W. Straub, and M. Boudreau (2000) "Structural Equation Modeling and Regression: Guidelines for Research Practice", *Communications of the Association for Information Systems* (4) Article 7, pp. 1–76.
- Granovetter, M.S. (1982) "The Strength of Weak Ties: A Network Theory Revisited" in Marsden, P.V. and N. Lin (eds.) *Social Structure and Network Analysis*, Beverly Hills, CA: Sage.
- Han, J. and M. Kamber (2006) *Data Mining: Concepts and Techniques, 2nd edition*, San Francisco, CA: Morgan Kaufmann Publishers.
- Hevner, A., et al. (2004) "Design Science in Information Systems Research", *MIS Quarterly* (28)1, pp.75-106.
- Hu, D., S. Kaza, and H. Chen (2009) "Identifying Significant Social-Network Link Formation Facilitators: A Study of Dark Networks", *Journal of the American Society of Information Science and Technology (JASIST)* (60)2, pp. 1–11.
- Hu, P.J.-H., C. Lin, and H. Chen (2005) "User Acceptance of Intelligence and Security Informatics Technology: A Study of COPLINK", *Journal of the American Society for Information Science and Technology* (56)3, pp. 235–244.
- Hutchinson, R.W., S.L. English, and M.A. Mughal (2002) "A General Problem Solving Approach for Wicked Problems: Theory and Application to Chemical Weapons Verification and Biological Terrorism", *Group Decision and Negotiation* (11)4, pp. 257-279.

- Kaza, S. and H. Chen (2008) "Mapping Ontologies Using WordNet and Mutual Information: An Experiment in Public Safety Information Sharing", *Decision Support Systems* (45)4, pp.714-728.
- Kaza, S., Y. Wang, and H. Chen (2007) "Enhancing Border Security: Mutual Information Analysis to Identify Suspect Vehicles", *Decision Support Systems* (43)1, pp. 199–210.
- Kaza, S., et al. (2009) "Topological Analysis of Criminal Activity Networks: Enhancing Transportation Security", *IEEE Transactions on Intelligent Transportation Systems* (forthcoming).
- Kuechler, B. and V. Vaishnavi (2008) "On Theory Development in Design Science Research: Anatomy of a Research Project", *European Journal of Information Systems* (17), pp. 489–504.
- Land, F., et al. (2009) "ICIS 2008 Panel Report: Design Science in Information Systems: Hegemony, Bandwagon, or New Wave?" *Communications of the Association for Information Systems* (24) Article 29, pp. 501-508.
- Lin, C.T., P.J.H. Hu, and H.C. Chen (2004) "Technology Implementation Management in Law Enforcement—COPLINK System Usability and User Acceptance Evaluations", *Social Science Computer Review* (22)1, pp. 24–36, doi: 10.1177/0894439303259881 .
- Linder, J.C. (2007) *Spiral Up: And Other Management Secrets Behind Wildly Successful Initiatives*, New York, NY: AMACOM.
- March, S.T. and G.F. Smith (1995) "Design and Natural Science Research on Information Technology", *Decision Support Systems* (15)4, pp. 251–266, doi: [10.1016/0167-9236\(94\)00041-2](https://doi.org/10.1016/0167-9236(94)00041-2) (current Nov. 30, 2011).
- Marchionini, G., H. Samet, and L. Brandt (2003) "Digital Government", *Communications of the ACM* (46)1, pp. 25–27.
- Marshall, B., H. Chen, and S. Kaza (2008) "Using Importance Flooding to Identify Interesting Networks of Criminal Activity", *Journal of the American Society of Information Science and Technology (JASIST)* (59)13, pp. 2099–2114.
- Nunamaker, J.F., C. Minder, and T. Purdin (1991) "Systems Development in Information Systems Research", *Journal of Management Information Systems* (7)3, pp. 89–106.
- Nunnally, J.C. (1978) *Psychometric Theory, 2nd edition*, New York, NY: McGraw-Hill.
- O'Harrow, R. and E. Nakashima (2008) "National Dragnet Is a Click Away", *Washington Post*, March 6.
- Rogers, E.M. (1983) *Diffusion of Innovations, 3rd edition*, New York, NY: Free Press.
- Simon, H. (1996) *The Sciences of the Artificial, 3rd edition*, Cambridge, MA: MIT Press.
- Sink, M. (2002) "An Electronic Cop That Plays Hunches", *New York Times*, November 2.
- Straub, D.W. (1989) "Validating Instruments in MIS Research", *MIS Quarterly* (13)2, pp. 147–169.
- Taylor, S. and P.A. Todd (1995) "Understanding Information Technology Usage: A Test of Competing Models", *Information Systems Research* (6)2, pp. 144–176.
- Vapnik, V. (1999) *The Nature of Statistical Learning Theory*, Berlin, Germany: Springer.
- Venable, J.R. (2006) *The Role of Theory and Theorising in Design Science Research*, Paper presented at the Design Science Research in Information Systems and Technology (DESRIST), Claremont, CA.
- Venkatesh, V. and F.D. Davis (1996) "A Model of the Antecedents of Perceived Ease of Use: Development and Test", *Decision Sciences* (27)3, pp. 451–481.
- Venkatesh, V., et al. (2003) "User Acceptance of Information Technology: Toward a Unified View", *MIS Quarterly* (27)3, pp. 425–478.
- Wang, A., et al. (2007) *The Arizona IDMatcher: A Probabilistic Identity Matching System*, Paper presented at the IEEE International Conference on Intelligence and Security Informatics, New Brunswick, NJ.
- Wang, G., H. Chen, and H. Atabakhsh (2004a) "Automatically Detecting Deceptive Criminal Identities", *Communications of the ACM* (47)3, pp. 71–76.
- Wang, G., H. Chen, and H. Atabakhsh (2004b) "Criminal Identity Deception and Deception Detection in Law Enforcement", *Group Decision and Negotiation* (13)2, pp. 111–127.
- Wang, G., et al. (2006) "Automatically Detecting Criminal Identity Deception: An Adaptive Detection Algorithm", *IEEE Transactions on Systems Man and Cybernetics, Part A—Systems and Humans* (36)5, pp. 988–999.

- Wasserman, S. and K. Faust (1994) *Social Network Analysis: Methods and Applications*, New York, NY: Cambridge University Press.
- Xiang, Y., et al. (2005) "Visualizing Criminal Relationships: Comparison of a Hyperbolic Tree and a Hierarchical List", *Decision Support Systems* (41)1, pp. 69–83.
- Xu, J.J. and H. Chen (2004) "Fighting Organized Crimes: Using Shortest-Path Algorithms to Identify Associations in Criminal Networks", *Decision Support Systems* (38)3, pp. 473–487.
- Xu, J.J. and H. Chen (2005a) "CrimeNet Explorer: A Framework for Criminal Network Knowledge Discovery", *ACM Transactions on Information Systems* (23)2, pp. 201–226, doi: [10.1145/1059981.1059984](https://doi.org/10.1145/1059981.1059984) (current Nov. 30, 2011).
- Xu, J.J. and H. Chen (2005b) "Criminal Network Analysis and Visualization", *Communications of the ACM* (48)6, pp. 100–107.

ABOUT THE AUTHORS

Siddharth Kaza is an assistant professor in the Computer and Information Sciences Department at Towson University in Towson, MD. He received his Ph.D. degree in Management Information Systems from the University of Arizona. Dr. Kaza's research interests lie in data mining and knowledge discovery, social network analysis, and security informatics. His pedagogical research interests lie in secure coding and computational thinking. Dr. Kaza's work has been published journals like *Decision Support Systems*, *IEEE Transactions*, and *Journal of the American Society for Information Science and Technology*, and various international conferences and has been funded by the National Science Foundation, Department of Defense, and the Maryland Higher Education Commission.

Dr. Paul Jen-Hwa Hu is a professor and David Eccles Faculty Fellow at the David Eccles School of Business, the University of Utah. He has a Ph.D. in Management Information Systems from the University of Arizona. His current research interests include healthcare information systems and management, technology implementation management, human–computer interaction, and knowledge management. He has published papers in *Decision Support Systems*, *Journal of Management Information Systems*, *Decision Sciences*, *Communications of the ACM*, *Journal of the American Society for Information Science and Technology*, etc.

Han-Fen Hu is a doctoral student at the David Eccles Faculty Fellow at the David Eccles School of Business, the University of Utah. Her research interests include technology implementation management and technology acceptance.

Dr. Hsinchun Chen is a McClelland professor of Information Systems and the director of the Artificial Intelligence Lab, University of Arizona. He received the BS degree from the National Chiao-Tung University, Hsinchu, Taiwan, the MBA degree from SUNY Buffalo, and the Ph.D. degree in Information Systems from New York University. He has authored/edited eighteen books, seventeen book chapters, and more than 180 SCI journal articles covering digital library, intelligence analysis, biomedical informatics, data/text/web mining, knowledge management, and Web computing. He received the IEEE Computer Society 2006 Technical Achievement Award. He is a fellow of the IEEE and the AAAS.



Copyright © 2011 by the Association for Information Systems. Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and full citation on the first page. Copyright for components of this work owned by others than the Association for Information Systems must be honored. Abstracting with credit is permitted. To copy otherwise, to republish, to post on servers, or to redistribute to lists requires prior specific permission and/or fee. Request permission to publish from: AIS Administrative Office, P.O. Box 2712 Atlanta, GA, 30301-2712, Attn: Reprints; or via e-mail from ais@aisnet.org.



Communications of the Association for Information Systems

ISSN: 1529-3181

EDITOR-IN-CHIEF
Ilze Zigurs
University of Nebraska at Omaha

CAIS PUBLICATIONS COMMITTEE

Kalle Lyytinen Vice President Publications Case Western Reserve University	Ilze Zigurs Editor, CAIS University of Nebraska at Omaha	Shirley Gregor Editor, JAIS The Australian National University
Robert Zmud AIS Region 1 Representative University of Oklahoma	Phillip Ein-Dor AIS Region 2 Representative Tel-Aviv University	Bernard Tan AIS Region 3 Representative National University of Singapore

CAIS ADVISORY BOARD

Gordon Davis University of Minnesota	Ken Kraemer University of California at Irvine	M. Lynne Markus Bentley University	Richard Mason Southern Methodist University
Jay Nunamaker University of Arizona	Henk Sol University of Groningen	Ralph Sprague University of Hawaii	Hugh J. Watson University of Georgia

CAIS SENIOR EDITORS

Steve Alter University of San Francisco	Jane Fedorowicz Bentley University	Jerry Luftman Stevens Institute of Technology
--	---------------------------------------	--

CAIS EDITORIAL BOARD

Monica Adya Marquette University	Michel Avital University of Amsterdam	Dinesh Batra Florida International University	Indranil Bose University of Hong Kong
Thomas Case Georgia Southern University	Evan Duggan University of the West Indies	Andrew Gemino Simon Fraser University	Matt Germonprez University of Wisconsin-Eau Claire
Mary Granger George Washington University	Åke Gronlund University of Umea	Douglas Havelka Miami University	K.D. Joshi Washington State University
Michel Kalika University of Paris Dauphine	Karlheinz Kautz Copenhagen Business School	Julie Kendall Rutgers University	Nelson King American University of Beirut
Hope Koch Baylor University	Nancy Lankton Marshall University	Claudia Loebbecke University of Cologne	Paul Benjamin Lowry City University of Hong Kong
Don McCubbrey University of Denver	Fred Niederman St. Louis University	Shan Ling Pan National University of Singapore	Katia Passerini New Jersey Institute of Technology
Jan Recker Queensland University of Technology	Jackie Rees Purdue University	Raj Sharman State University of New York at Buffalo	Mikko Siponen University of Oulu
Thompson Teo National University of Singapore	Chelley Vician University of St. Thomas	Padmal Vitharana Syracuse University	Rolf Wigand University of Arkansas, Little Rock
Fons Wijnhoven University of Twente	Vance Wilson Worcester Polytechnic Institute	Yajiong Xue East Carolina University	

DEPARTMENTS

Information Systems and Healthcare Editor: Vance Wilson	Information Technology and Systems Editors: Dinesh Batra and Andrew Gemino	Papers in French Editor: Michel Kalika
--	---	---

ADMINISTRATIVE PERSONNEL

James P. Tinsley AIS Executive Director	Vipin Arora CAIS Managing Editor University of Nebraska at Omaha	Sheri Hronek CAIS Publications Editor Hronek Associates, Inc.	Copyediting by S4Carlisle Publishing Services
--	--	---	--



Reproduced with permission of copyright owner. Further reproduction prohibited without permission.