



This paper appears in *Managing Modern Organizations Through Information Technology*, Proceedings of the 2005 Information Resources Management Association International Conference, edited by Mehdi Khosrow-Pour. Copyright 2005, Idea Group Inc.

Information Security Risk Analysis: A Matrix-Based Approach

Sanjay Goel

University at Albany, School of Business, SUNY, BA310b, 1400 Washington Ave., Albany, NY 12222, USA, goel@albany.edu

Vicki Chen

General Electric Energy, 1 River Rd., Schenectady, NY 12345, USA, vicki.chen@ps.ge.com

ABSTRACT

This paper presents an information security risk analysis methodology that links the assets, vulnerabilities, threats and controls of an organization. The approach uses a sequence of matrices that correlate the different elements in the risk analysis. The data is aggregated and cascaded across the matrices to correlate the assets with the controls such that a prioritized ranking of the controls based on the assets of the organization is obtained. The approach does not obfuscate the intermediate data in the analysis, thereby providing transparency to the risk analysis process and allowing rationalization of the data. This approach allows organizations to start with sparse data with low fidelity and the analysis can be gradually refined as additional (and high quality) data is collected over time. A sample case study based on a study at a NY State agency is presented. This methodology was applied at General Electric and some preliminary results of the case study are presented in this paper.

INTRODUCTION

Computer networks and the Internet have enabled greater productivity in both government and private sector organizations. The Internet is also deeply integrated into our personal lives and becoming a driver of social behavior. Use of email and instant messaging has grown exponentially over the years and is becoming the preferred mode of communication. Despite the rise and fall of the dot-com industry, the Internet is changing the way consumers shop and the business models of companies. For example, the alternate business model of distribution of music through the Internet has changed the landscape of the music industry and driving innovation in peer-to-peer systems as well as in formats of digitization and compression of music files.

While the impact of the Internet on electronic commerce, communication, and dissemination of information is obvious, the major impact of computer networks has been on business process reengineering. Most routine corporate functions are now handled with automated processes anchored in databases. Networked information systems form the backbone of enterprises and are used in almost all aspects of business including: payroll, procurement, human resource management, as well as, analysis and design of engineering components. Information systems have significantly improved organizational productivity. However, total dependence on information systems for critical operations has left organizations vulnerable to anomalies and attacks on networks. Business-to-business (B2B) and business-to-consumer (B2C) commerce has fueled growth in the GDP over the last decade. In the government sector, several critical infrastructure elements such as dams, power grids, and emergency-response systems are dependent on networks and computers. As the dependence of the economy on information systems increases, the financial impact of information security failures also increases. This risk of financial loss due to a security breach is a cause for concern within corporations and government.

Most organizations do not have a complete understanding of their information security risk posture. Usually, ad hoc decisions are made on security implementation based on guidelines and alerts issued by government agencies and other trusted third parties. IT departments are responsible for keeping the security in check, but it is difficult for the organizations to get a clear picture of security posture without a formal risk analysis. While IT staff may be competent in implementing security tools, they often lack the expertise in financial modeling and risk analysis. Formal risk analysis methodology is mature in several fields (finance, engineering, nuclear plants and aviation). However, it is nascent in the information security discipline. Issues with risk analysis in information security are lack of standardized metrics and processes for valuation of assets, measuring impact of threats and estimating the benefit of controls and acute shortage of data that would enable reasonable statistical analysis to estimate risks. Another problem is the poor quality of data on threats and vulnerabilities that stems from organizations fear that revealing security incidents will attract other malicious hackers to exploit vulnerabilities and lead to increased frequency of attacks. Finally, the information security risk analysis process is very weak through basis on checklists and guidelines or very expensive requiring extensive internal data collection using penetration testing and honey pots. Most organizations often outsource risk assessment tasks and often conduct these assessments periodically (annually, or bi-annually) rather than continuously. Also, organizations do not have the ability to determine the quality of assessments and have to rely on consultants' verdicts.

We present a risk assessment methodology that can be used internally, which allows organizations to start with a small data set, as well as gradually refine and improve the analysis as high fidelity data becomes available. It also allows organizations to perform qualitative analysis on a broad scope, and then perform a more detailed analysis based on a critical subset of the problem. The rest of the paper is organized as follows: section 2 provides a brief review of the risk analysis literature, section 3 provides basic methodology, section 4 supplies a sample case study, and section 5 offers conclusions for the paper.

LITERATURE

Information security risk analysis has been investigated from an audit perspective (Cerullo & Cerullo, 1994) for a long time. Auditors generally use checklists to verify if different elements of security are in place and base their judgment on these checklists. Baskerville (1993) has been investigating information security risk analysis since the mid-1980s. He has identified risk analysis checklists for tools used for designing security measures for information systems. Parker (1981) and Fisher (1984) have used risk analysis as a fundamental basis for security design in information systems. They provide extensive checklists for considerations in the security assessment. The problem with specific tools and checklists is that they become obsolete quickly and need to be constantly updated. Applications of such tools do not lead to scientific knowledge

Table 3. Threats worksheet (correlation between controls and threats)

Scale 0 – No Impact 1 – Weak Impact 3 – Moderate Impact 9 – Strong Impact	Threats							Relative usefulness of controls
Controls	Denial of Service	Spoofing &	Malicious Code	Human Errors	Insider Attacks	Intrusion (Hackers)	Spamming	
Firewalls								Relative Importance of Threats
IDS								
Single Sign-on								
DMZ								
Security Policy								
Employee Training								
Configuration of Architecture								
Hardening of Environment								

In order to protect the new technology, increase revenue, as well as enhance communication and productivity, a uniform informational infrastructure is necessary. This involves integrating business processes across different divisions into a single monolithic process shared by all the organizations. In order to be able to build security into the processes at the inception, an analysis of the security posture of the organization was conducted using the proposed methodology. This case study presents a comprehensive risk analysis of its assets, vulnerabilities, and threats inherent in the business processes. The three matrices that relate the assets with the vulnerabilities, threats and controls in the organizations are presented in Tables 4, 5 & 6 respectively.

Table 4 presents the vulnerability matrix that associates the system vulnerabilities with the impacts/assets of the organization. To construct the matrix, relative importance of assets/impacts to the business was computed. For instance, the survival of the business depends on its ability to develop and protect new technology; therefore, new technology is ranked high. Based on the assets, key vulnerabilities related to each asset/impact were determined and the impact of the vulnerabilities on assets/impacts was added to the table.

Table 4. Vulnerability Matrix for GE Energy, Wind Division

Vulnerabilities Matrix				Priority	Assets / Impacts													
Strong 9	Moderate 3	Weak 1	Not Related 0		Export Control info.	Reputation (Trust)	IP control/management	Confidential Client Secrets	Lost Sales/Revenue	Information Integrity	Services Availability	Communication	Cleanup Costs-old & new system	Software-new & old system	Hardware-new&old	Total Score	Rank (Higher more significant)	
Priority Ranking 1&2 not important 3 Important, not a Key Driver 4 Important, but impacted by Key Drivers 5 Key Driver																		
Vulnerabilities					11	10	9	8	7	6	5	4	3	2	1			
Firewalls				5	9	9	9	9	3	9	3	9	3	9	9	504	13	
Data Transmission				5	9	9	9	3	3	9	9	9	9	9	3	498	12	
Databases				4	9	3	9	9	9	9	3	3	9	9	3	474	11	
Application architecture				4	9	9	9	3	3	3	3	1	9	9	9	406	10	
Physical security				3	9	3	3	9	9	3	3	3	9	1	9	374	9	
Intranet Computer Servers – Configuration Errors				2	9	1	9	9	1	3	9	3	3	9	1	372	8	
Extranet Servers (internet facing) – Configuration Errors				4	1	9	9	9	1	3	9	3	3	9	1	364	7	
Password Strength (Password attack)				3	9	9	3	9	1	3	1	3	1	9	1	352	6	
Client Nodes (User PCs & Laptops)				3	9	3	9	9	1	3	3	1	3	3	9	350	5	
Hardware – Web server, Router...				5	1	9	3	9	3	3	9	3	9	3	9	338	4	
Insecure wireless				2	9	3	9	9	1	3	3	1	3	1	1	338	4	
Internet base service (Like VPN)				1	9	1	3	3	1	1	3	1	3	3	1	208	2	
Power outage				1	0	1	0	0	3	1	9	3	3	1	1	106	1	

The data in the vulnerability matrix was aggregated and sorted to determine the relative importance of vulnerabilities. Since external hackers need to penetrate the firewall in order to access confidential information, firewall ranks high in the vulnerability matrix. Also, since GE Wind's subsidiaries are globally distributed, data transmission ranked high. The aggregate vulnerability data was added to the threat matrix along with the threats corresponding to the vulnerabilities. Based on the perceived ability of the threats to exploit vulnerabilities the threat matrix was populated as shown in Table 5.

Table 6 shows the control matrix in which aggregate data of threats from the threat matrix and the corresponding controls were added. The relative impact of different controls on the threats was also determined using subjective judgment and the data was aggregated to determine the prioritized list of controls. This information, coupled with the cost of controls is used for security planning. The results of this analysis and the aggregate data in the matrices will be used during process integration and for selection of software and hardware.

CONCLUSION

The paper presents an easy to use methodology for information security risk analysis that the organizations can easily adapt. The methodology provides easy to use templates that can be gradually refined as more information becomes available. The methodology provides transparency to the analysis process. The case study at GE Wind highlights important security issues that the organization faces. Since the assets, threats and vulnerabilities are constantly changing an adaptive easy to use methodology is valuable to companies for conducting risk assessments internally. This simple methodology will promote a risk analysis by more companies that are often daunted by the expensive, elaborate and cumbersome methodologies proposed by auditing firms.

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Table 5. Threat Matrix for GE Energy, Wind Division

Threat Matrix					Vulnerabilities	Firewalls	Data Transmission	Databases	Application architecture	Physical security	Hardware – Web server, Router...	Password strength (Password attack)	Intranet Computer Servers – Configuration Errors	Client Nodes (User PCs & Laptops)	Extranet Servers (internet facing) – Configuration Errors	Insecure wireless	Internet base service (Like VPN)	Power outage	Total Score	Rank (Higher more significant)
Strong 9	Moderate 3	Weak 1	Not Related 0																	
<div>Priority Ranking 1&2 Not important 3 Important, not a Key Driver 4 Important, but impacted by 5s 5 Key Driver</div>					Priority															
Threats					13	13	11	10	9	9	7	6	5	4	3	2	1			
Intrusion (Hacking, Password attacks)					5	9	3	3	9	9	1	9	3	9	9	9	3	1	170	1
Server Failures					3	9	9	9	3	9	1	9	1	9	1	1	9	158	1	
Physical Damage to hardware					1	1	9	9	9	9	0	3	3	3	1	1	3	132	10	
Extortion					4	1	3	3	9	3	3	3	9	9	9	3	3	1	122	9
Insider Attacks (Malicious)					4	3	3	3	3	9	1	3	9	9	1	3	1	114	8	
Spoofing & masquerading					3	1	9	1	3	1	1	1	9	9	9	9	1	110	7	
Denial of Service					2	9	1	0	9	1	3	1	9	1	9	3	3	1	100	6
Human error (Accidents)					3	3	9	3	3	3	1	3	9	3	3	1	1	1	90	5
Theft of computers (laptops/servers)					2	1	0	1	1	9	1	1	1	9	1	3	1	1	76	4
Violation Export Control compliance					1	1	1	1	1	9	1	1	1	9	1	1	1	74	3	
Malicious Code(Viruses, Worms, etc)					4	1	1	1	3	1	1	3	9	3	3	3	1	62	2	
Buffer Overflow attacks					5	0	9	0	1	1	1	1	3	1	3	1	1	1	46	

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