

A FRAMEWORK BASED ON
CONTINUOUS SECURITY MONITORING

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF INFORMATICS
OF
THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

VOLKAN ERTÜRK

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
THE DEPARTMENT OF INFORMATION SYSTEMS

SEPTEMBER 2008

Approval of the Graduate School of Informatics

Prof. Dr. Nazife BAYKAL
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Yasemin YARDIMCI
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Dr. Ali ARİFOĞLU
Supervisor

Dr. Attila ÖZGİT
Co-Supervisor

Examining Committee Members

Prof. Dr. Nazife BAYKAL (METU, II) _____

Dr. Ali ARİFOĞLU (METU, II) _____

Dr. Attila ÖZGİT (METU, CENG) _____

Assoc. Prof. Dr. Murat ERTEN (INNOVA) _____

Dr. Altan KOÇYİĞİT (METU, II) _____

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Volkan Ertürk

Signature : _____

ABSTRACT

A FRAMEWORK BASED ON CONTINUOUS SECURITY MONITORING

Ertürk, Volkan

M.S., Department of Information Systems

Supervisor: Dr. Ali Arifoğlu

Co-Supervisor: Dr. Attila Özgit

December 2008, 164 pages

Continuous security monitoring is the process of following up the IT systems by collecting measurements, reporting and analysis of the results for comparing the security level of the organization on continuous time axis to see how organizational security is progressing in the course of time. In the related literature there is very limited work done to continuously monitor the security of the organizations. In this thesis, a continuous security monitoring framework based on security metrics is proposed. Moreover, to decrease the burden of implementation a software tool called SecMon is introduced. The implementation of the framework in a public organization shows that the proposed system is successful for building an organizational memory and giving insight to the security stakeholders about the IT security level in the organization.

Keywords: Security monitoring, continuous monitoring, security metrics, security reporting, security metric automation.

ÖZ

SÜREKLİ GÜVENLİK İZLEME ÇATISI

Ertürk, Volkan

Yüksek Lisans, Bilişim Sistemleri Bölümü

Tez Yöneticisi: Dr. Ali Arifoğlu

Ortak Tez Yöneticisi: Dr. Attila Özgit

Aralık 2008, 164 sayfa

Güvenlik izleme çatısı, kurum ve kuruluşlardaki bilişim sistemlerinin sürekli olarak gözlenmesi için oluşturulmuş bir yöntemdir. Seçilmiş ölçümlerin toplanıp, raporlandıktan sonra analiz edilerek kurumların güvenlik seviyelerinin zaman ekseninde nasıl değiştiğinin gözlemlenmesidir. Yapılan akademik yayım taramasında, kurum ve kuruluşlarda bilişim güvenliği izlenmesi alanında yapılan çalışmaların çok az olduğu gözlenmiştir. Bu tez ile, sürekli güvenlik izleme çatısı güvenlik ölçümleme methodu baz alınarak oluşturulmuştur. Bunun yanında çatının uygulanması sürecinde yaşanabilecek zorlukları azaltmak adına SecMon isimli bir otomasyon yazılımı geliştirilmiştir. Çatının bir kamu kurumunda uygulanması sonucu, önerilen çatının kurumsal hafızayı oluşturma ve güvenlik yöneticilerine kurumsal güvenlik ile ilgili anlayış kazandırmada başarılı olduğu gözlemlenmiştir.

Anahtar kelimeler: Güvenlik izleme, sürekli izleme, güvenlik ölçümleri, güvenlik raporlaması, güvenlik ölçümlerinin otomasyonu.

To ones,
Enthusiastic about production
Brave enough to look for happiness
Somehow help the earth to become a better place

ACKNOWLEDGMENTS

I would like express my gratitude to Dr. Ali Arifođlu and Dr. Attila Özgıt for their guidance and insight throughout the research.

During the development of SecMon application, expertise of Seyit ađlar Abbasođlu on C# and expertise of Tolga Özdemirel on PHP/Ajax helped me to save many critical days of work. Additionally, I am bound to Tolga Özdemirel for his touch on the visual design of the reporting module.

I want to thank Deniz Hemen and Hamdi Alper Memiř for looking closely at the final version of the thesis for English style and grammar. Their hard work and patience deserves more than thanks.

I would like to give my special thanks to Mr. Topuz for his cooperation and assistance during the pilot implementation of my thesis. Without his support, it would not have been possible to complete the pilot study in such a tight schedule.

I would to thank my colleagues and managers in inTellekt for their support and encouragement for my BS studies and thesis.

Behind every successful man, there is a woman. For my case this is not one but two. I would like to render my thanks and congratulate Alev Özbey and Zehra Tatlıcı for their great faith in me and their patience to tolerate me during this period.

TABLE OF CONTENTS

ABSTRACT.....	iv
ÖZ.....	v
DEDICATION.....	vi
ACKNOWLEDGMENTS.....	vii
TABLE OF CONTENTS.....	viii
LIST OF TABLES.....	xi
LIST OF FIGURES.....	xiii
LIST OF ABBREVIATIONS AND ACRONYMS.....	xiv
CHAPTER	
1 INTRODUCTION.....	1
1.1 Background.....	1
1.2 Problem.....	2
1.3 Objective.....	4
1.4 Structure of the Thesis.....	4
2 RELATED RESEARCH.....	6
2.1 Security and Compliance Monitoring.....	6
2.2 Security Metrics.....	8
2.2.1 Definition and introduction.....	8

2.2.2	Why do we need metrics?	11
2.2.3	Who use security metrics?	13
2.2.4	Taxonomy	14
2.2.5	Security Metrics Development And Implementation Programs	16
2.2.6	Traps of security metrics.....	23
2.2.7	Sample metrics.....	24
2.3	Security Reporting And Visualization	25
3	APPROACH AND FRAMEWORK PROPOSAL	31
3.1	Purpose and Scope	31
3.2	Assumptions.....	33
3.3	Solution Strategy and CSMF Proposal	33
3.3.1	Information Security Measures Development	38
3.3.2	Prepare for Data Collection.....	43
3.3.3	Collect Data	49
3.3.4	Security Reporting	52
3.3.5	Analyze Results.....	58
4	SOFTWARE IMPLEMENTATION OF THE PROPOSED FRAMEWORK	62
4.1	Requirements analysis of the Software Implementation.....	69
4.2	Conceptual design of the database	73
4.3	Modules of the Proposed Software Implementation	74
4.4	Implementation of the SecMon application	78
4.5	Sample Deployment of the SecMon application.....	78
5	FIELD IMPLEMENTATION OF THE PROPOSED FRAMEWORK	80

5.1	Implementation of the CSMF in a public organization.....	82
6	VALIDATION.....	100
6.1	Discussion of the objectives.....	100
7	SUMMARY AND CONCLUSION.....	113
7.1	Results.....	114
7.2	Future Work.....	115
	REFERENCES	117
	APPENDICES	
	A: List of Candidate Measures.....	120
	B: Security Metrics Employed.....	123
	C: Organizational IT Security Perception Survey.....	154
	D: Use Case Diagrams	157

LIST OF TABLES

Table 1: Security metrics: likely purpose and audience	13
Table 2: Information Security Forum metric template	20
Table 3: NIST metric template	21
Table 4: Metricsexchange metric template	22
Table 5: Proposed CSMF metric template	48
Table 6: IT Security categorization in the organization	85
Table 7: Approved List of Measures in the Organization.....	88
Table 8: Security measures responsible identification list	90
Table 9: Sample metric definition applied in the organization.....	91
Table 10: The defined procedure of Metric #1.....	92
Table 11: The defined implementation details of Metric #1	94
Table 12: Survey questions to Employed metric's mapping	101
Table 13: Organized Long List of Candidate Measures	120
Table 14: Definition of Metric #1	123
Table 15: Definition of Metric #2	124
Table 16: Definition of Metric #3	125
Table 17: Definition of Metric #4	126
Table 18: Definition of Metric #5	127
Table 19: Definition of Metric #6	128
Table 20: Definition of Metric #7	129
Table 21: Definition of Metric #8	130
Table 22: Definition of Metric #9	132
Table 23: Definition of Metric #10.....	133
Table 24: Definition of Metric #11.....	135
Table 25: Definition of Metric #12.....	136
Table 26: Definition of Metric #13.....	137
Table 27: Definition of Metric #14.....	139
Table 28: Definition of Metric #15.....	140
Table 29: Definition of Metric #16.....	142
Table 30: Definition of Metric #17.....	143
Table 31: Definition of Metric #18.....	144
Table 32: Definition of Metric #19.....	145
Table 33: Definition of Metric #20.....	146
Table 34: Definition of Metric #21.....	147
Table 35: Definition of Metric #22.....	148

Table 36: Definition of Metric #23.....	149
Table 37: Definition of Metric #24.....	150
Table 38: Definition of Metric #25.....	151
Table 39: Definition of Metric #26.....	152
Table 40: Use Case #1.....	157
Table 41: Use Case #2.....	157
Table 42: Use Case #3.....	158
Table 43: Use Case #4.....	158
Table 44: Use Case #5.....	159
Table 45: Use Case #6.....	159
Table 46: Use Case #7.....	160
Table 47: Use Case #8.....	160
Table 48: Use Case #9.....	161
Table 49: Use Case #10.....	161
Table 50: Use Case #11.....	162
Table 51: Use Case #12.....	162
Table 52: Use Case #13.....	163
Table 53: Use Case #14.....	163
Table 54: Use Case #15.....	164
Table 55: Use Case #16.....	164

LIST OF FIGURES

Figure 1: Collecting Effective Security Metrics	10
Figure 2: Audiences for security metrics.....	14
Figure 3: Flow chart simplifying the process of choosing right graph for the data.....	26
Figure 4: A sample dashboard for a Chief Information Security Officer	28
Figure 5: Identity and Access Management Scorecard	29
Figure 6: Continuous Security Monitoring Framework's SADT diagram.....	37
Figure 7: Information Security Measures Development process using SADT	39
Figure 8: Prepare for Data Collection process using SADT	44
Figure 9: Collect Data process using SADT	50
Figure 10: Security Reporting Process using SADT	52
Figure 11: Analyze Results Process using SADT	58
Figure 12: Context Diagram of the CSMF	69
Figure 13: ER diagram of the CSMF	73
Figure 14: Data Flow Diagram of the CSMF	74
Figure 15: Sample network architecture.....	79
Figure 16: Project Plan of the CSMF Implementation	83
Figure 17: IT Department's schema in the pilot organization	84
Figure 18: Security metric definitions in the SecMon application	93
Figure 19: Security metric data stored in the SecMon application	94
Figure 20: Submitting metric data using the SecMon application.....	95
Figure 21: Sample reporting page of the SecMon application.....	97
Figure 22: Sample metric report of the SecMon application	97
Figure 23: Sample report's definition of the SecMon application	99
Figure 24: Application level attack statistics to the application servers	102
Figure 25: Number of malicious codes detected in client computers.....	102
Figure 26: Total number of clients having local admin rights in their computers	103
Figure 27: The number of restricted / banned site access attempts	104
Figure 28: Total number of unapplied patches in business-critical servers	104
Figure 29: A sample metric report identifying policy compliance/non-compliance level.....	106
Figure 30: Metric report identifying technical problems Sample-1.....	107
Figure 31: Metric report identifying technical problems Sample-2.....	108
Figure 32: Sample reporting view from SecMon application	109
Figure 33: Last 5 days report of the malicious code detected in client computers	110
Figure 34: Last 2 weeks report of malicious code detected in client computers	111
Figure 35: Metric report for the total number of clients not using any 2-factor authentication.....	112

LIST OF ABBREVIATIONS AND ACRONYMS

ALE: Annualized Loss Expectancy

BSS: Balanced Security Scorecard

CFO: Chief Financial Officer

CIO: Chief Information Officer

CIO: Chief Information Officer

CISO: Chief Information Security Officer

CISWG: Computer Information Security Working Group

COBIT: Control Objectives for Information and related Technology

COTS: Commercial Off-the-Shelf

CSMF: Continuous security monitoring framework

FFIEC: Federal Financial Institutions Examination Council

FISMA: Federal Information Security Management Act of 2002

ISF: Information security forum

ISO: International Organization for Standardization

ISPE: Information Security Program Elements

ITIL: Information Technology Infrastructure Library

KPI: Key Process Indicators

NIST: National Institute of Standards and Technology

NSM: Network Security Monitoring

PCI: Payment Card Industry

SCADA: Supervisory Control and Data Acquisition

SEI CMM: Software Engineering Institute's Compatibility Maturity Model

SEM: Security Event Manager

SNMP: Simple Network Management Protocol

SOX: Sarbanes-Oxley Act of 2002

SADT: Structured Analysis and Design Technique

CHAPTER 1

INTRODUCTION

1.1 Background

Due to the fact that business processes are becoming IT oriented, security needs of the IT systems are increasing and becoming even more important day by day. Currently, internet is not the only source of information but it is also a medium that people do business. Companies have no choice but to connect their internal networks to the rest of the world, to do business with customers, suppliers, partners, and their own employees. However, this connection also poses new threats: malicious hackers, criminals, industrial spies. These threats not only steal organizational assets, but also cause service shortage or system failure, that is harming the reputation of the company and frighten customers (Schneier, 2001).

The increased complexity of the internet and its applications and unmanaged e-transformation of the organizations to seize the new business opportunities have increased the insecurity of the digital world. IDC survey results point out that IT security is a growing priority for the organizations and more than 80% of the organizations expect an increase in their IT security investments. The survey foresees that “The Western European security software market grew by 19.1% in 2006, and will continue to grow from 2006 to 2011 by 11.4%” (Kelly, 2007). Despite the fact that organizations continuously invest on the IT security products, the security threats and incidents are increasing day by day. Schneier (2001) explains this fact as: “Security based on products is inherently fragile. Newly discovered attacks, the proliferation of attack tools, and

flaws in the products themselves all result in a network becoming vulnerable at random (and increasingly frequent) intervals.”

Not only investing on security products but also employing IT security standards enhance the level of IT security in the organizations. FISMA law for USA federal agencies, Basel II and PCI financial organizations and ISO 2700X and COBIT with their success stories are chosen to be implemented either as a must or as a “need to do”. These standards and regulations change the way that IT security and the IT security operations are managed, which affects the security level of the organizations positively.

As addressed by the IT security standards and regulations, security monitoring is an essential part of the organizational security and security management is not possible when monitoring is absent. Security monitoring is critical to be able to identify control failures before a security incident occurs, to detect an intrusion or other security incident in due time to give an effective and timely response, and to support post-event forensics activities (FFIEC, 2006). Schneier (2001) in his article stresses the importance of security monitoring as: “Monitoring provides immediate feedback regarding the efficacy of a network’s security— in real time, as it changes in the face of new attacks, new threats, software updates, and reconfigurations. Monitoring is the window into a network’s security; without it, a security administrator is flying blind.”

Security monitoring can be employed by the following branches: Organizational security, standard compliance and executive reporting. Organizational security means the monitoring of the system to determine threats and vulnerabilities, to detect and interfere in the incidents as early as possible to avoid or decrease the effects of the malicious activities. Monitoring the standards compliance is measuring the program compliance level of the system on the basis of the employed standard (COBIT, ISO 27001 etc.). Executive reporting means revealing an insight into the organization by executive level reporting the organizational security and standards’ compliance issues.

1.2 Problem

Security monitoring is crucial both for operational and management perspectives. Without security monitoring, it is not possible to identify the threats and vulnerabilities which cause security incidents and it is difficult for the security administrators to detect and solve such

threats and vulnerabilities. On the other hand, lack of threat and vulnerability information renders it impossible to make risk analysis. As far as managers are concerned, risk analysis and current situation of the organization is important to make strategic planning in order to build the future of the organization. This makes security monitoring not only technically but also strategically important for the organizations.

Although security monitoring systems have the potential to make such contributions to the organizations, structured and automated security monitoring systems are not common due to technical and resource limitations. Here are some of the issues that need to be addressed by the security monitoring systems:

1. Measurement: It is hard to measure security processes and program compliance as they are mostly composed of intangible logical and software components. Measures should be defined and developed.
2. Evaluation and Analysis: It is necessary to control the measurements, to detect the conflicting measures, to resolve conflicts and to analyze the measurements to draw up reports.
3. Reporting: Being the only output of security monitoring system, the reporting capabilities of continuous security monitoring systems are vital for the success of the implementation. Goal oriented, interactive and easy to use reporting are the basic functionalities expected from the reporting modules.
4. Automation: As continuous measurements are need to be made on each of the system component on predefined time intervals to monitor the system; it will not be feasible to collect frequently needed measures manually. Doing so is waste of resources and may not be feasible for every case. For the frequent measurements some automation software has to be employed to decrease the burden and to increase the accuracy of measurement collection.
5. Management support: Security monitoring is a process that needs good planning and effort to develop and put it into production. As all the security stakeholders in the organization need to participate in the implementation of continuous security monitoring framework, management committee need to both foster and participate the process.
6. Staff participation: For the non-automated measurements, participation of the staff is needed. Prejudices and doubts of the staff prejudgments and doubts on the

measurements should be addresses as staff might take the measurements as individual evaluation.

7. Sustainability: Due to the change in IT systems of the organizations over time, the security monitoring needs and the requirements should be adapted accordingly. It is necessary to adopt the organizational changes and to make fine-tuning of the system according to the feedback received.

1.3 Objective

The main goal of this thesis is to give managers and administrators an idea about the current situation and the security trends in the organization by proposing a continuous security monitoring framework. To reach the goals of the thesis, the following objectives are defined:

Obj-1) To create an organizational memory for changing the IT security perception that is currently based on individual memory

Obj-2) To assess policy compliance

Obj-3) To determine non-compliance

Obj-4) To detect technical problems

Obj-5) To decrease the complexity of security monitoring

Obj-6) To report on the basis of users' needs

Obj-7) To give an idea to the managers and administrators about security trends and current situation IT security in the organization

Obj-8) To improve the security level of the organization in the course of time

Obj-9) To provide benchmarking

1.4 Structure of the Thesis

Proposing a security monitoring framework to give an insight into the organizational security, CSMF is organized as follows:

- Chapter 2 presents the literature survey about security monitoring, security metrics, security reporting/visualization and related projects.
- Chapter 3 discusses the writer's approach to the security monitoring concept and includes the proposal on the CSMF.
- Chapter 4 includes the discussion of need for software implementation of the proposed framework and the proposal of the proof of concept application SecMon.

- Chapter 5 covers the implementation details of the proposed framework in a pilot organization
- Chapter 6 includes the validation of the objectives stated in the introduction chapter.
- Chapter 7 concludes the thesis with review of the work done and includes some thoughts about the future directions.

CHAPTER 2

RELATED RESEARCH

This chapter introduces main issues about measurement, monitoring, visualization and reporting from information security point of view. As the continuous security monitoring is a vast concept, literature survey is narrowed only to the resources showing parallel approaches like use of security metrics while discussing security monitoring. To give an example, real time monitoring of hacking attempts with various techniques can also be reviewed under the continuous security monitoring whereas, as introduced in the introduction chapter, the approach to this case is only collecting measurement results for reporting about hacking attempts, thus doesn't include attack detection techniques, attack response or countermeasures taken during and after the attack. Each of the concepts discussed in this chapter forms the bases of the thesis approach to continuous security monitoring that are huge research topics by themselves. As this thesis utilizes each of them in the proposed framework, related research part summarize the concepts and the approaches as shortly as possible and these findings will be frequently referred in the approach chapter while defining the framework.

2.1 Security and Compliance Monitoring

To know and report what is going on, the processes and tasks in organizations' IT systems is needed to measure. Monitoring, particularly security monitoring, is the required concept to understand how the system is acting. Schneier (2001), in his article stresses the importance of security monitoring as: "Monitoring provides immediate feedback regarding the efficacy of a network's security— in real time, as it changes in the face of new attacks, new threats, software

updates, and reconfigurations. Monitoring is the window into a network's security; without it, a security administrator is flying blind.”

As discussed in FFIEC (2006) booklet, “security monitoring is primarily performed to assess policy compliance, identify non-compliance with the institution's policies, and identify intrusions and support an effective intrusion response. Because security monitoring is typically an operational procedure performed over time, it is capable of providing continual assurance.”

To detect malicious activity and security controls failures, information systems must be continuously monitored. The frequency of the security monitoring is varying up to the criticality of the systems, security policy of the company or up to the compliancy requirements. FFEIC states that security monitoring level and frequency is subject to the risks (higher risk requires frequent monitoring) that each system exhibit.

FFEIC classify the security monitoring systems into two parts based on the monitoring type. First type of monitoring is Activity Monitoring which consists of host and network data gathering, and analysis includes Network Intrusion Detection Systems, Honeypots and Host Intrusion Detection Systems and Log Transmission, Normalization, Storage, and Protection. Second type of monitoring is Condition Monitoring that is composed of Self Assessments, Metrics and Audit and Penetration tests.

In his doctorate thesis Kuperman (2004) classify computer security monitoring systems into three parts based on Decision Making Technique: Anomaly Detection, Misuse Detection and Target Based Monitoring. Anomaly detection technique is described a security violations detected from abnormal patterns of system usage by Denning (1987). Kuperman defines Misuse detection is based on a set of fixed rules (based on Expert System, Signature Matching and Policy Violation) used to determine if a particular audit event should trigger an alarm. Finally, Target Based Monitoring defined as enumerating certain actions that should never be performed by any user of a specified system or identifying objects on the system that should never be accessed by any actions.

Security monitoring is executed by various manual and automated tools and procedures that help security administrators and managers to monitor the corporate security. Employing advanced

security monitoring solutions will decrease the monitoring overhead (while increasing the budget requirements to built a monitoring system) of the security administrators, giving them more visibility and faster response possibility to the incidences. Schneier (2001) in his article stresses that: “Real security is about people. On the day you’re attacked, it doesn’t matter how your network is configured, what kind of boxes you have, or how many security devices you’ve installed. What matters is who is defending you.” So by itself security monitoring systems is not a complete but an important part of the solution, since people monitoring the system and interpreting the reports are the key factor of success in security monitoring.

Security monitoring needs and implementations are varying in different sectors like finance (auditing), SCADA (power plant systems etc.) systems and IT systems. Even security monitoring for IT systems has its own sub-branches like network security monitoring (NSM). In the book “The Tao of Network Security Monitoring beyond Intrusion Detection”, Bejtlich (2004) discusses best practices, deployment considerations and products of NSM. There is no one size fits all security monitoring policy or procedure for the companies. Companies should define their security monitoring needs up to the standards compliance, criticality of their systems, procedures/internal requirements and best practices.

2.2 Security Metrics

2.2.1 Definition and introduction

Lord Kelvin’s famous saying “You cannot improve what you cannot measure” also paraphrased as “an activity cannot be managed if it cannot be measured” is stressing the importance of monitoring in the organizations. Managers always queries the adequacy of security controls, policies and procedures in order to decide if additional information security resources are required and identify and evaluate nonproductive security controls. However, they make decisions in line with the information they get. Unanswered questions, personal comments or extreme incident examples highlighted to the managers, can be the examples of misleading the managers. Jaquith (2007) states; “fear, uncertainty and doubt can be used by the middle managers or administrators to abuse or misrepresent data for the purpose of manufacturing security scare stories, thus compel the managers to approve that is required.”

What is needed by the administrators and the managers to get relevant answers for their system, policy and procedure based questions? In other words, what can be done to objectively measure

the processes and events? The candidate for this measure may be the security metrics. Swanson et al. (2003) from NIST defines security metrics as follows: “IT security metrics are tools designed to facilitate decision making and improve performance and accountability through collection, analysis, and reporting of relevant performance related data.” There are various definitions of security metrics in the literature, all of the definitions include measurement and improvement terms but the definition varies up to the model or approach followed throughout the paper.

Measuring IT security related processes, security controls and compliance may not seem a hard issue initially. System administrators may think that they define questions and get replies in terms of percentage, size, amount etc and since everything is about numbers, which are discrete and objective, they can easily measure security controls and compliance. It is not true actually. Hinson (2006) states that, “measuring anything makes it easier to drive improvements but measuring the wrong things leads to improving wrong things. The hard part is not measurement but is figuring out the suite of parameters that need altering and to measure and work on them all.” One needs to consider some terms and conditions while defining security metrics that make the metrics: good metrics otherwise they will be the bad metrics. According to George Jelen (Payne, 2006), good metrics are goal oriented and exhibit SMART characteristics: Specific, Measurable, Attainable, Repeatable, and Time dependent. Jaquith (2007) in his book defines the good security metric as: consistently measured, cheap to gather, expressed as a cardinal number or percentage, expressed using at least one unit of measure and contextually specific. Both of the “good metric” specifications of Jelen and Jaquith are similar to each other, as the logic behind the need and development of the metrics is same. Every organization employing security metrics have to take into consideration of the good metrics defined above; else the results of the implementation will be ineffective, time-consuming and misleading.

What about the bad metrics? Jaquith (2007) defines bad metrics by negating the good metric definition as: inconsistently measured, cannot be gathered cheaply, or does not express results with numbers or units of measure. He also argues that exuberant uses of security frameworks like ISO 17799 and the annualized loss expectancy (ALE) scores are bad metrics. Jaquith also comments that being a good taxonomy and audit standard, ISO17799 standard has excessive focus on audit, subjective success criteria and insufficient attention to measurement that makes the standard suffer from serious deficiencies as a metrics framework. On the other hand,

Villarrubia et al. (2004) proposed a series of security metrics based on the ISO 17799:2000 edition of the standard. It is easily concluded that use of compliance standards as security metrics are under discussion.

Robert Frances Group’s survey (Robinson, 2005) gives important clues about the use of security metrics in the organizations. As it can be seen in Figure 1 (Robinson, 2005), even if most of the participant companies (92%) collect and report security metrics, only 39% of them feel that these practices are effective. This low rate means, rest of the companies spent time on collecting metrics, but do not use the metric data to monitor the security of the system. There is one additional criterion, which is the automation of the metrics reporting, the survey shows the real situation in security metrics implementation that is to say only 8% of the participants have an automation of the metrics reporting. The only efficient way to measure security in today’s complex and heterogeneous environments is through automation, which is covered in the coming sections. This result most probably indicates a lack of centralized metrics data collection and performing analysis and reporting tasks which are vital for the continuous security monitoring.

Security Metrics Collected

Which of the following key data elements does your organization collect?

Viruses detected in user files	92.3%
Viruses detected in e-mail messages	92.3%
Invalid log-ins (failed password)	84.6%
Intrusion attempts	84.6%
Spam detected/filtered	76.9%
Unauthorized Web site access (content filtering)	69.2%
Invalid log-ins (failed username)	69.2%
Viruses detected on Web sites	61.5%
Unauthorized access attempts (internal)	61.5%
Admin violations (unauthorized changes)	61.5%
Intrusion successes	53.8%
Unauthorized information disclosures	38.5%
Spam not detected (missed)	38.5%
Spam false-positives	30.8%
Other	23.1%

Figure 1: Collecting Effective Security Metrics

Ravenel (2006) commented on the Robert Frances Groups’ survey as: “Most participants collected and tracked metrics from products that make this process straightforward, such as virus and spam detection packages. These metrics are an attempt to measure the effectiveness of

specific technologies deployed; they are not designed to show information about current operational risk to the organization, but rather to show some type of return on investment.” This is an implicit result of the survey which is critical to understand that the security metrics concept is at the early ages in 2005. The metrics collected by most of the organizations are the effectiveness metrics that is the measurements showing how a product is performing. The missing part is that, the selected metrics is far away of providing measurements to facilitate decision making and implementation of organizations information security programs to organization-level strategic planning efforts.

2.2.2 Why do we need metrics?

Payne (2006) argues that “Metrics can be an effective tool for security managers to discern the effectiveness of various components of their security programs, the security of a specific system, product or process, and the ability of staff or departments within an organization to address security issues for which they are responsible.” While defining the security metrics it is stressed that security metrics is important for decision making, managing and improving IT controls and processes. In the preceding section importance of the security metrics is empowered by the references from the literature and standards. In this section “Why do we need security metrics?” question will be discussed and before introducing the security metric program and development process, how the security metrics help for decision making, managing and improving IT controls and processes will be discussed.

Chew et al. (2008) from NIST states that, a security metrics program provides organizational and financial benefits and these benefits include: increasing accountability for information security performance (identify security controls that are implemented incorrectly, not implemented or ineffective); improving effectiveness of information security activities (demonstrate quantifiable progress in accomplishing agency strategic goals and objectives); demonstrating compliance with laws, rules and regulations; (security metrics program will help to generate compliance reports and gathered measurements can be used as audit data) and providing quantifiable inputs for resource allocation decisions (support risk-based decision making by contributing quantifiable information to the risk management process).

In his book security metrics Jaquith (2007) lists the advantages of employing security metrics as:

- Understand security risks

- Spot emerging problems
- Understand weaknesses in their security infrastructures
- Measure performance of countermeasure processes
- Recommend technology and process improvements

Presenting a new approach, Jaquith also states that security metrics can be used for “Diagnosing problems and measuring technical security activities” and “Measuring Program Effectiveness”. He has grouped diagnosing problems and measuring technical security activities into four categories: perimeter defenses, coverage and control, availability/reliability, and applications. Measuring Program Effectiveness has the subcategories: risk management, policies compliance, employee training, identity management, and security program management.

Up to the results of the meetings and reaches the Information Security Forum (ISF) (2006), the following common reasons for employing security metrics were identified:

- Managing information security in an organization
- Providing information for management reporting
- Indicating compliance to legislation, regulation and standards
- Showing efficiency, effectiveness and performance against objectives
- Demonstrating the value of security (return on security investment)
- Supporting the adoption of a risk-based approach to information security
- Supplying information for risk management activities
- Providing information about information security risks
- Highlighting information security strengths and weaknesses
- Benchmarking information security arrangements against competitors or peers.

Why do we need security metrics is a critical question while deciding to implement security metrics in the organizations. Not being a straight forward process to do, extensive planning, management support and resource dedication is required for a successful implementation. Above discussion and answers to the why question can be good starting point in decision making process.

2.2.3 Who use security metrics?

Security metrics are directly related from the technical personnel to the CIO/board of the company. Defining the roles and responsibilities is important for developing and measuring security metrics. ISF (2006) states the possible audiences as:

- Broad/executive committee (CxO, including CIO and CISO)
- IT staff and management
- Audit (internal, external and committee)
- Information security function (staff and management)

Table 1 (ISF 2006) defines the roles and purposes of each role in the security metrics development and management lifecycle. Also Chew et al. (2008) from NIST defines the roles in responsibilities in the guide of “Performance measurement guide for information security” that is similar to the definition SIF group made. Because of the table structure notation it is preferred to annotate the ISF report in this section.

Table 1: Security metrics: likely purpose and audience

	Board	Senior Executives (CxO)	CIO	CISO	Audit	IT/information security managers	IT staff	Information security staff
Communicate with business	✓	✓	✓	✓	✓	✓	✓	✓
Identify and manage risk	✓	✓		✓	✓	✓		✓
Measure performance	✓	✓	✓	✓	✓			✓
Demonstrate compliance	✓	✓	✓		✓	✓		
Measure controls			✓	✓	✓			✓
Justify/value information security	✓	✓	✓	✓				
Manage information security				✓		✓	✓	✓

Figure 2 shows the result of a survey, that is revealing who is using the security metrics most frequently in the organization. The participants think that CISO will be the one that will use the security metric tools at most.

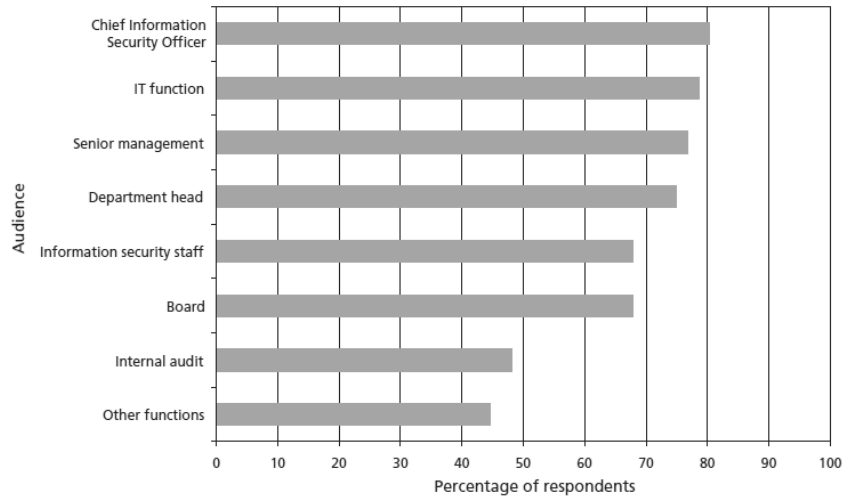


Figure 2: Audiences for security metrics

2.2.4 Taxonomy

Taxonomies are important for the classification and analysis of the security metrics. Various number of taxonomy are proposed by Seddigh et al. (2004), Savola (2007), WISSSR (2001), Vaughn et al. (2003) and Chew et al. (2008) for the categorization of security metrics. This part includes a review of the most comprehensive and publicly available taxonomies in the literature.

The WISSSR (2001) workshop provides a key venue for researchers for understanding and interpreting many issues about information security and security metrics. The workshop didn't return taxonomy on security metrics however discussions are organized in three tracks: technical track, organizational track and the operational track. Up to the Seddigh et al. (2004) there would seem to be an intuitive understanding among workshop participants that three themes would provide a useful basis around which to organize taxonomy of security metrics.

Vaughn et al. (2003) state that objective of assurance measurement could be grouped into two distinct categories: assessing an organization's information assurance (IA) posture (Organizational security) and measuring the IA capabilities of systems or products (technical target of assessment (TTOA)). Organization security metrics measure the organizational

programs and processes, thus provide feedback to improve the IA posture of the organization. TTOA metrics measure how much a technical object; system or product is capable of providing assurance in terms of protection, detection and response. For each category, sub-categories are also defined and explained in the taxonomy.

Seddigh et al. (2004) introduces an information assurance metric taxonomy to represent the IA health of an IT network. Paper extends the definition of IA as “the ability of a network or system to facilitate the timely transfer of information between two or more parties in an accurate and secure fashion” and forms the taxonomy, based on this definition, into three categories: Security, Quality of Service and Availability. The proposed taxonomy has multi tier approach; such as each category has different technical, organizational and operational metrics. Each subcategory has its own subcategories which are defined and explained in details in the paper. Being one of the complete taxonomy proposals, further work is done by El-Hassan et al., (2008) using the proposed taxonomy.

Savola, (2007) proposes a high level information security metrics taxonomy that incorporates both organizational information security management and product management, that emphasizes the need of a typical company producing information and communication technology products. Savola defines the highest category as the security metrics for business management and stresses that the security and trust metrics defined must be aligned to the business/major goals of a company/organization or a collaborating value to the business. Paper categorizes the business metrics into five: Security metrics for cost-benefit analysis, Trust metrics for business collaboration, Security metrics for business-level risk analysis, Security metrics for information security management (ISM) and Security, Dependability and Trust metrics for ICT products, systems and services.

July 2003, Swanson et al. (2003) from NIST publishes a comprehensive taxonomy for metric categorization, namely Security Metrics Guide for Information Technology Systems or SP 800-55. Categorizing the security metrics into three main categories as: Management, Technical and Operational, the document provides guidance on how an organization, through the use of metrics, identifies the adequacy of in-place security controls, policies, and procedures. The guide includes metric development and implementation process which provides useful data for managing the information security resources and simplifies the preparation of performance

related reports. Revision 1 of the guide is published in July 2008, titled “Performance Measurement Guide for Information Security” (Chew et al., 2008) is intended to assist agencies in developing, selecting and implementing security measures to be used at the IT system and program levels. “Such measures are used to facilitate decision making, improve performance, and increase accountability through the collection, analysis, and reporting of relevant performance-related data—providing a way to tie the implementation, efficiency, and effectiveness of information system and program security controls to an agency's success in achieving its mission.” guide states. In revision 1, NIST updates the initial metric categorization as: Implementation metrics (to measure execution of security policy), Effectiveness/ efficiency metrics (to measure results of security services delivery) and Impact metrics (to measure business/mission consequences of security events). Revision 1 of the guide additionally provides additional program-level guidelines for quantifying information security performance in support of organizations’ strategic goals through strategic planning process.

2.2.5 Security Metrics Development And Implementation Programs

Security metrics program is the master plan for the security metrics implementation in an organization. There are papers Lowans (2002), Payne (2006), Chew et al. (2008), Jaquith (2007), Sademies (2004) and Lennon (2003) in the literature either discussing the security metrics programs or proposing new program models.

NIST states that an information security metrics program should include four interdependent components. The four components are as follows:

1. Strong upper-level management support; is vital to establish a solid foundation of the program in the organization for a success implementation.
2. Practical information security policies and procedures; draw the information security management structure, assign information security responsibilities and lay the foundation needed to reliably measure progress and compliance.
3. Quantifiable performance measures; is designed to capture and provide meaningful performance data based on based on information security performance goals and objectives.
4. Results oriented measures analysis; emphasizes consistent periodic analysis of the measured data.

NIST also defines the success criteria's of the security metrics program:

- Degree to which meaningful results are produced
- Provide substantive justification for decisions that directly affect the information security posture
- Assist in the preparation of required reports relating to information security performance

Starting security metric development without planning may lead to wrong or misleading reports as discussed in the preceding sections. So it is advised to employ a security metrics development process before moving to the implementation process. According to Lennon (2003), “the universe of possible metrics, based on existing policies and procedures, will be quite large. Metrics must be prioritized to ensure that the final set selected for initial implementation facilitates improvement of high priority security control implementation. Based on current priorities, no more than 10 to 20 metrics at a time should be used. This ensures that an IT security metrics program will be manageable.” Parallel to Lennon, Chew et al. (2008) recommends each stakeholder to be initially responsible of two or three metrics. Thus it is wise to see the whole picture and choosing right security metrics by processing a security metrics measurement process.

Payne (2006) proposes a security metrics program which indeed coincides to the term “the information security measures development process” in the Chew et al. (2008) paper. (Since there is no common literature for the security metrics, unfortunately different wording for the same term is a common problem in the security metrics literature.) These seven key steps below could be used to guide the process of establishing a security metrics development process:

1. Define the metrics program goal(s) and objectives
2. Decide which metrics to generate
3. Develop strategies for generating the metrics
4. Establish benchmarks and targets
5. Determine how the metrics will be reported
6. Create an action plan and act on it
7. Establish a formal program review/refinement cycle

According to NIST, the information security measures development process consists of two major activities:

- Identification and definition of the current information security program
- Development and selection of specific measures to gauge the implementation, effectiveness, efficiency, and impact of the security controls.

Chew et al. (2008) states that, the information security measures development process is further divided into following activities, which need not to be done sequential:

1. Stakeholder Interest Identification
2. Goals and Objectives Definition
3. Information Security Policies, Guidelines, and Procedures Review
4. Information Security Program Implementation Review
5. Measures Development and Selection
 - a. Measure Development Approach
 - b. Measures Prioritization and Selection
 - c. Establishing Performance Targets
6. Measures Development Template
7. Feedback Within the Measures Development Process

Chew et al.'s (2008) guide discusses that, “Goals and Objectives Definition Review” activity produces business impact metrics, “Information Security Policies, Guidelines, and Procedures Review” activity produces effectiveness/efficiency metrics and “Information Security Program Implementation Review” activity produces operational metrics.

After developing the security metrics, Chew et al. (2008) guides the readers for the implementation of the developed metrics using six stepped process called information security metrics implementation process:

1. Prepare for Data Collection
2. Collect Data and Analyze Results
3. Identify Corrective Actions
4. Develop business case
5. Obtain resources
6. Apply Corrective Actions

Having defining two different lists as development and implementation of the security metrics, NIST's guide is still parallel to the rest of the security metrics development models proposed in this section. NIST's only difference is proposing the definition, identification and development of the security metrics steps as a separate process than the metrics implementation process.

ISF (2006) proposes the security measures development process phases as follows:

1. Define requirements
2. Identify relevant security metrics
3. Collect data required
4. Produce security metrics
5. Prepare presentations
6. Use dashboards and/or scorecards
7. Review the use of security metrics.

In security metrics book, Jaquith (2007) defines the life cycle of security metric program in 11 phases:

1. Identification
2. Definition
3. Development
4. Quality assurance
5. Production deployment
6. Visualization of results
7. Analysis of results
8. Scorecard layout
9. Scorecard publication
10. Notification publication
11. Scorecard archival

In his paper, Payne also advises to ground the metrics program in process improvement frameworks that are already familiar to the organization such as Six Sigma, ISO17799 and SEI-CMM. In the absence of any preexisting framework, Payne proposes: "a top-down or a bottom-up approach for determining which metrics might be desirable could be used. The top-down approach starts with the objectives of the security program, and then works backward to identify

specific metrics that would help determine if those objectives are being met, and lastly measurements needed to generate those metrics.” NIST documentation (Chew et al. (2008)) did not explicitly define such a requirement but discuss the framework need in many chapters of the guide over the SP800-53A “Guide for Assessing the Security Controls in Federal Information Systems” guide.

Developed metrics should be in a standard format to ensure the repeatability, development, measurement, analysis and reporting of the metrics. The standard format called metric template will guide the developer to provide the required details by requiring input for each field of the template. Except the general fields like metric name, value and frequency, the template definitions may vary up to the metric development model and the implementation details. Below two metric development models’ and a metric development project’s metric templates are presented.

ISF (2006) metric template:

Table 2: Information Security Forum metric template

Characteristic	Comments
Title	A meaningful title (or name) to describe the security metric
Purpose	What the security metric is designed to do
Cost	An estimate or actual cost of collecting the security metric
Type	What the security metric is, for example: technical or managerial; leading or lagging; numerical or textual
Location	Where the data for the security metric can be collected, previous data used in the security metric is located and previous instances of the security metric can be found
Frequency	How often the data needs to be collected and the security metric needs to be presented
Category	The category a security metric should be placed in such as number, frequency, duration and cost
Start/stop criteria	Criteria for starting and stopping the collection of data for the security metric and use and presentation of the security metric
Duration of collection	An estimate of, or actual, time period in which data will be collected
Duration of use	An estimate of, or actual, time period in which the security metric will be used

Chew et al. (2008) Metric template:

Table 3: NIST metric template

Field	Data
Measure ID	State the unique identifier used for measure racking and sorting.
Goal	Statement of strategic goal and/or information security goal.
Measure	Statement of measurement.
Type	Statement of whether the measure is implementation, effectiveness/efficiency, or impact
Formula	Calculation to be performed that results in a numeric expression of a measure
Target	Threshold for a satisfactory rating for the measure, such as milestone completion or a statistical measure.
Implementation Evidence	Implementation evidence is used to compute the measure, validate that the activity is performed, and identify probable causes of unsatisfactory results for a specific measure.
Frequency	Indication of how often the data is collected and analyzes and how often the data is reported.
Responsible parties	Indicate the following key stakeholders: Information Owner, Information Collector, and Information Customer.
Data sources	Location of the data to be used in calculating the measure
Reporting format	Indication of how the measure will be reported, such as a pie chart, line chart, bar graph, or other format.

Nichols' (2008) metric template proposal that is used in metricsexchange project:

Table 4: Metricsexchange metric template

Field	Data
Name	The description of the metric
Version	A sequentially assigned version number for the metric definition
Rating	A score that is derived from user ratings of the metric. Displayed as 0-5 stars
Views	The number of page views that have been served as a measure of a metric's popularity
Description of Results	A description of results produced by the metric in terms, including unit(s) of measure
Target	A description of desired result--can be as simple as "Low is good"
High Water Mark	All time record high value or a value that is considered to be in the highest 10%.
Low Water Mark	All time record low value or value that is considered to be in the lowest 10%.
Objective	A description of what the metric is designed to measure and why it is important
Abstract	A discussion of key characteristics, how to interpret, background, etc.
How to Calculate	A detailed description of how to calculate the metric from raw data sources
Sources	Description of sources that could provide needed data to compute the metric
Measurement Frequency	Suggested measurement rate, e.g. real-time, hourly, daily, weekly, etc
Default Visualization	An image that represents an effective way to visualize computed results
License	A reference to a license such as GPL, LGPL, Mozilla, etc that defines terms of use
Created/Updated	Dates
State	Possible states: Draft, Reviewed, Approved, in-Production, Passive.
Tags	A list of tags from one or more context hierarchies to indicate the metric's relevance to a topic
Owner	The name of the metric's owner who has the authority to transition the metric state
Contributors	A list of individuals that have contributed to the definition of the metric
Use Cases	A description of practical experiences in using the metric from registered Metrics Center members, can include identification of unintended consequences
Cost to Measure	Discussion of implementation costs
Scale	Discussion of issues related to scalability
Scope	Discussion if issues related to scope

2.2.6 Traps of security metrics

Up to now several facts about the security metrics is revised and discussed. Before practicing the use of security metrics in continuous security monitoring system, it will be wise to review the fallacies of the security metrics in order not to make the well know mistakes in the project.

Wiegers (1997) in the paper, "Software Metrics: Ten Traps to Avoid" explains the common fallacies of the metric program as follows:

1. Lack of Management Commitment: Educating the managers, tying the metrics program to the business goals and meeting the managerial needs will increase the manager commitment.
2. Measuring Too Much, Too Soon: Begin with employing small and balanced (from each metric type) number of metrics. Expanding the program after getting useful results is important.
3. Measuring Too Little, Too Late: User resistance may be an issue as without metrics users are more comfortable working Undercover. As with number two, the balanced set of metrics is critical to success.
4. Measuring the Wrong Things: Select measures that help steering process improvement activities, by showing whether process changes are having the desired effect. Review the audience of the metrics data, and make sure the metrics being collected will accurately answer their questions.
5. Imprecise Metrics Definitions: A complete and consistent set of definitions for the things being measured is essential to combine data from several sources.
6. Using Metrics Data to Evaluate Individuals: Clear statement and management understanding of the goals of the metrics is important and if this success the metrics won't be used for individual evaluation.
7. Using Metrics to Motivate, Rather than to understand: Metric measurement results are informative and should be used to understand and evaluate the current reality so to improve processes accordingly.
8. Collecting Data That Is Not Used: Selected public metrics trends must be made visible to all stakeholders, so that the contributors of the program will see and support the program.
9. Lack of Communication and Training: If used participation is required, the participants to the program must be trained.

10. Misinterpreting Metrics Data: Monitor the trends that key metrics exhibit over time, and don't overreact to single data points.

2.2.7 Sample metrics

There are various on purpose developed metrics in the literature. Defining the goals and targets of the security metrics program, organizations can employ the required metrics from the below resources and also develop by themselves.

Jaquith (2007) in his book developed two types of metrics to measure the technical security level and the compliance program effectiveness:

- Diagnosing Problems and Measuring Technical Security: 80 metrics defined.
- Measuring Program Effectiveness: 65 metrics defined.

Current version of the Security Metrics Catalog, by PlexLogic (n.d.) project is publishing sample program compliance metrics about the following standards:

- ISO 27002: 132 metrics defined.
- CISWG's ISPE controls: 105 metrics defined.
- NIST taxonomy applied for Application Security metrics: 41 metrics defined.

Kahraman (2005) in his thesis developed metrics to measure IT Security Performance and the adequacy of security policies and protocols. The metrics are organized as follows:

- Organizational View: 43 metrics defined
- Technical view: 47 metrics defined

Nichols et al., (2007) in the paper "A Metrics Framework to Drive Application Security Improvement" defined the key metrics for application security monitoring.

Chew et al. (2008) in the NIST guide "Performance measurement guide for information security" includes both system and program level sample metrics in the appendix based on the "Recommended Security Controls for Federal Information Systems" guide from NIST.

Additionally the key performance/goal indicators in the COBIT and ITIL guides can be referred for the development of security metrics.

2.3 Security Reporting And Visualization

Managers used to monitor or audit business by doing site visits or examining the paper work of the organization. As the IT automation ratio in business increases, the reporting and the monitoring needs changed and need increased in parallel. In this section the visualization and reporting concepts are surveyed from IT security point of view and major findings are summarized.

Literature has various articles and projects about reporting and visualization, even if the subject is limited to the “security”. For example, DAVIX (<http://davix.secviz.org>) project and Mukosaka and Koike’s (2007) paper present good security visualization approaches but these approaches are processing various types of raw (non-metric based) data that is making them unusable for the security metrics reporting. To narrow the research and get reusable approaches, the survey is limited to the reporting and visualization of the security metrics. The books and articles summarized below are chosen based on this criterion.

Jaquith (2007) thinks that the most popular security data visualization tools which are bar/pie charts and traffic lights are problematic, as bar/pie charts present little data in relatively huge space and traffics lights oversimplify issues. He states that the effective visualization of metrics data boils down to six principles:

- The presented data is important, not the design
- Just say no to three-dimensional graphics and cutesy chart junk
- Don’t use the wizards to create crowded graphs
- Erase the needless parts of the graphs
- Reconsider Technicolor for using monochromatic colors
- Label honestly and without contortions

Many types of graphs introduced in the literature can be used to visualize data. Each graph has its own features and is suited for a specific analysis scenario. Some graphs are great at visualizing large amounts of data; others are better suited for highlighting slight variations and trends.

Here is a short list of the most widely used graphs from the Jaquith (2007) and Marty (2008):

- Simple pie/bar/line charts
- Stacked pie/bar/line charts
- Histograms
- Time Series Charts
- Box plots
- Scatter plots
- Parallel coordinates
- Link graphs
- Two-by-Two Matrices
- Period-Share Chart
- Pareto Charts
- Maps
- Tables
- Treemaps

Marty (2008) summarizes the process of choosing the right graph in Figure 3. Up to aim of the graph (showing distribution, relationship, comparison or trend) and visualization needs; concerning the available data, below graphs can be chosen for security reporting.

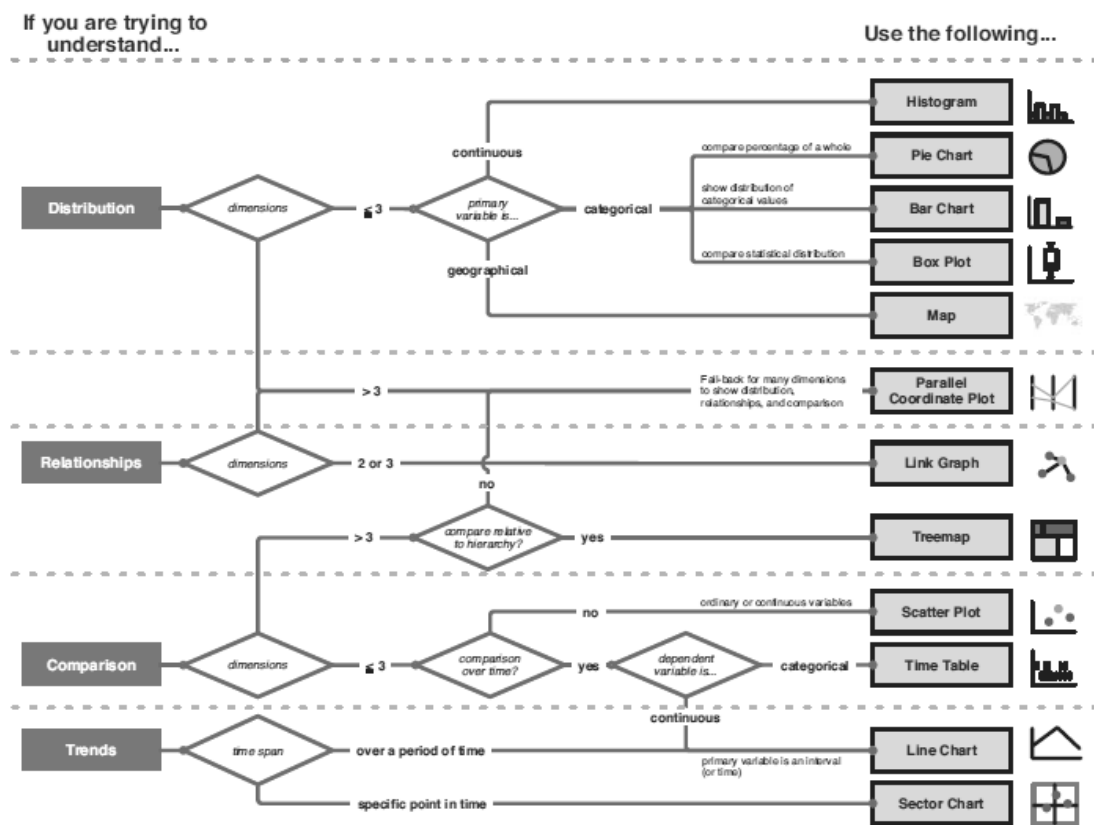


Figure 3: Flow chart simplifying the process of choosing right graph for the data

Each of the listed graphs has different capabilities and emphasizes specific aspects of the data presented. The graphs facilitate the analysis of the distribution of values in a single dimension or

the relationship between two or more dimensions in the data. The details of each of the graph format is not covered as this much detail is out of scope of the thesis.

Having various optimized graph models is not the only requirement for successful reporting, one need to define the entire process from collecting raw logs to the publishing reports to the users. The literature survey yields that Marty's (2008) approach to the process is good documented and well organized. Marty calls this process as information visualization process and defines the six stepped process as follows:

1. Define the problem

Visualization should be process/need/requirement driven not available data driven. Define the needs and the requirements and only go for that.

2. Assess available data

There is no guarantee that the required answers can be found with the available data and generated graphs. Analyze the problem to identify the log resources and the data required from each resource.

3. Process information

Collected logs from various sources need to be transformed into known format in order to be processed. Adding additional data (DNS resolution of the IP addresses etc.), filtering the relevant data and log aggregation techniques will enrich the processed data.

4. Visual transformation (Adjust Color, size and shape of the graph)

It is the mapping the data into some visual structure that produces a graphical presentation. First of all, it is needed to specify the data dimension, the dimension used as the bases in comparisons/analysis that will influence the type of the graph used for visualization. Secondly it is required to define the size and shape of the graph. Finally the coloring of the graph than can be used for differentiate various parts or to encode additional information.

5. View transformation (Adjust Scale, zoom and clip of the graph)

The initial visualization of the graph may need further scale, zoom adjustments or reduction/cut of some access data.

6. Interpret and decide

Go to the problem definition and check if the graph is presented what is required.

Using dashboards in security reporting:

A security dashboard is a visual display of security information needed that is designed up to the target audience and can be monitored at a glance. Figure 4 (Marty, 2008) presents a sample security dashboard. Marty (2008) proposes to use dashboards for real-time monitoring to understand the current state of the systems and applications and presently ongoing tasks or events of interest.

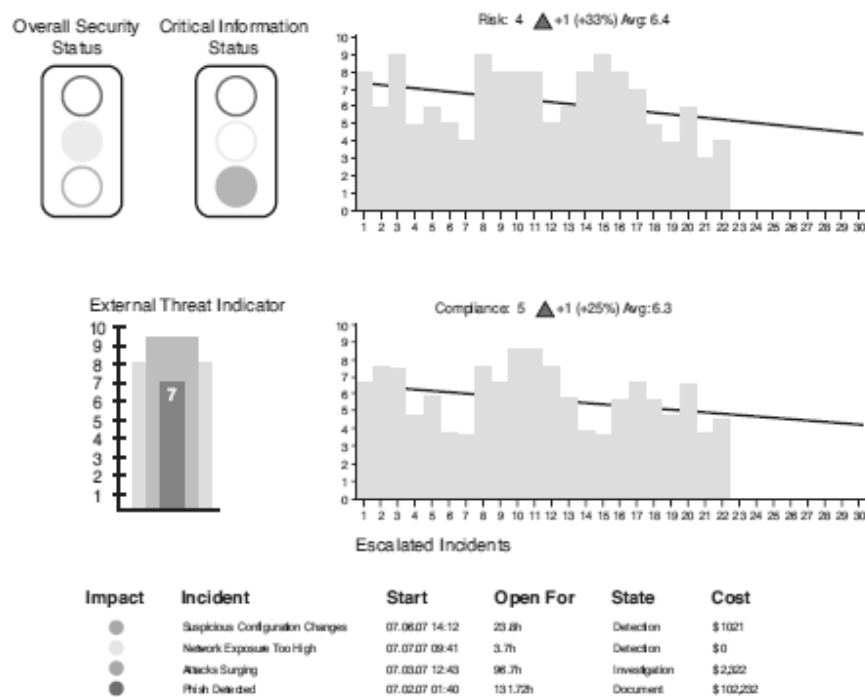


Figure 4: A sample dashboard for a Chief Information Security Officer

Marty (2008) grouped the required reporting dashboards for the computer security monitoring into three:

- 1) Strategic: A business level dashboard that helps monitoring the execution of strategic objectives.
- 2) Tactical: An IT/IS level dashboard, used for tracking processes of departments, networks, states of machines, etc.
- 3) Operational: A process level dashboard used to track core processes, metrics, and status.

Up to the organizational needs and efforts one or more of the dashboards can be built for security reporting. As it is straight forward from the definitions, operational dashboards presents low level information to the security analysts for real time monitoring the technical issues. Tactical dashboards are used for analyzing security issues to understand the root cause of the problems that are used by the managers. Strategic dashboards include business oriented trend reports used for the coordination and collaboration of the top management with the organizational security trends.

In parallel to the dashboards, Jaquith (2007) argues that Balanced Security Scorecard (BSS) provides a holistic view of organizational security performance. Parallel to general techniques, balanced security scorecard balances Financial, Customer, Internal Process, and Learning and Growth in terms of security perspectives to arrive at an overall security scorecard for an organization. Audience targeted BSS can be used for one screen reporting of the organizational IT security.

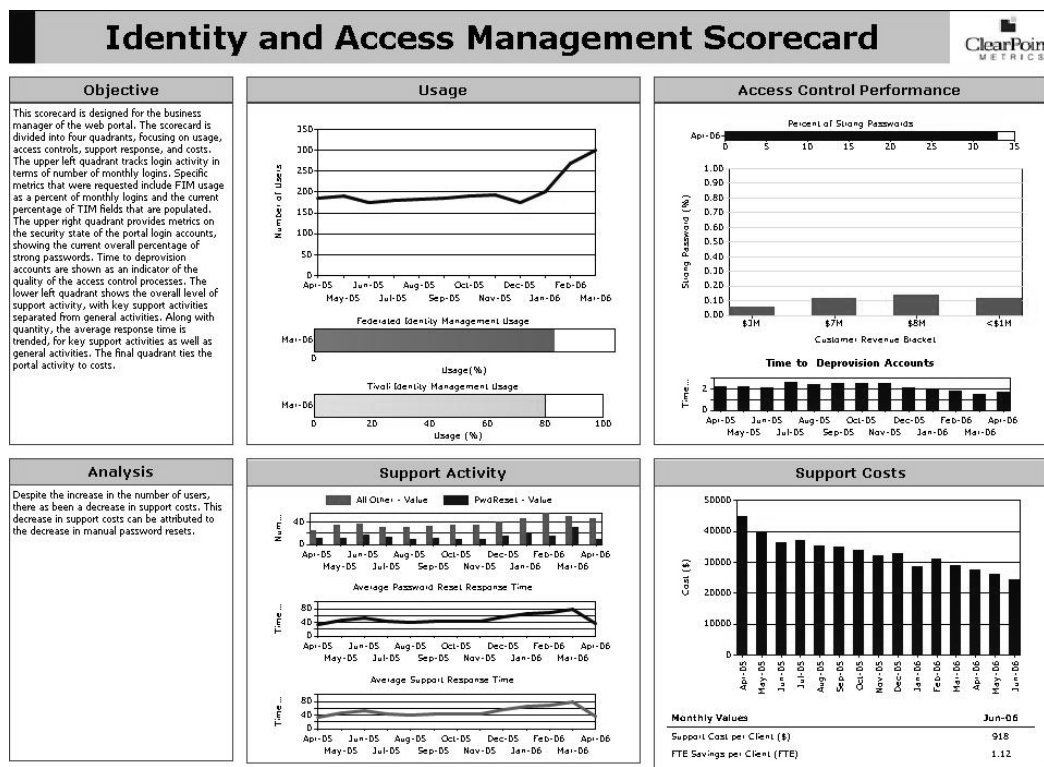


Figure 5: Identity and Access Management Scorecard

Figure 5 (ClearPoint Metrics, 2008) is a sample security scorecard developed by the ClearPoint metrics, crafted specially for monitoring the identity and access management activities. Being a successful example of security monitoring using scorecard/dashboard, it can be categorized as an operational scorecard, as it includes low level technical information to the security analysts for real time monitoring the technical issues. The proposed balanced security scorecard by Jaquith on the other hand, can be categorized as strategic scorecard that can be a powerful reporting tool for the top managers.

Nichols, E. A. and G. Peterson (2007) uses security scorecard to report on OWASP Top 10 categories. The used security scorecard provides additional indicators that show an upward, downward, or unmoving trend for the given time period relative to previous periods. Opacki (2005) in his article argues the two methods of building security scorecards and give hints for producing executive scorecards.

CHAPTER 3

APPROACH AND FRAMEWORK PROPOSAL

3.1 Purpose and Scope

How can organizational information security be monitored? As discussed in the survey chapter, one needs to collect and process the cumulative data, and to report the findings. Let's think about continuous security monitoring of an ATM. The bank installs a camera, which collects data, to record continuously the things happening around the ATM. In case of a reported incident or at a suspicious circumference, the camera recordings are reviewed and the information needed is gathered from the archived video, which processes the cumulative data. Finally the findings are reported to the related parties, which is the reporting part. Information security monitoring is not very different from this example, only the data monitoring frequency (on scheduled bases or after an incidence) and the utilization of the cameras and the recordings vary according to the implementation and the maturity of the organization.

As discussed in section 2.1, security monitoring is made to assess policy compliance, to identify non-compliance, to detect technical problems, to identify intrusions and to support an effective intrusion response. Each of these activities is comprehensive in themselves and various automation products are developed to address the detection (such as non-compliance with mobile device use policy) and reporting requirements of these issues. In other words, it is not hard to find programs or services that meet most of organization's needs with regard to the either of the above listed activities. However, this is not enough to solve the problem of security monitoring, actually the problem starts here, that is to say each organization uses tens to hundreds of products and technologies to secure its organizational assets and operations (or

decreasing/escalating security risks) and this fact makes the security monitoring complex and also renders it hard to manage the security monitoring on a daily basis.

Each security product's reports are valuable to see the performance of a product and more importantly, to track how the system is performing. These reports are mostly used by the system administrators or security officers to monitor the performance of the products in order to make fine-tuning in configurations. What about the manager of the administrators or the chief information security officer who is trying to monitor the system? Shall they need to ask a copy of every single report from the administrators and try to obtain required data for tracking organization-wide security? What if the product reports do not include the answers of the questions the managers have? What about the excessive data presented in the reports? Well, current technologies can do better; system administrators can define custom reports in line with the needs of the managers in each product to address the above-mentioned needs. This requires much effort and might not be feasible in every organization. Although this approach will provide the required data with less bulk data, processing of these various reports, like comparing values within current reports, comparing reports with old reports or analyzing and reasoning the results, is the aspect that is not addressed in this approach.

Continuous security monitoring framework (CSMF) proposes a security measurement, collection and reporting framework. Similar approach exists in the Security Event Management (SEM) products, which are implementing central log management via collection, aggregation, correlation and reporting of the raw logs and event from various system sources. However, there is a significant difference in the nature of two approaches; SEM products process logs and generate reports based on the raw logs and events whereas, CSMF collects metric data, which is based on the organizational needs and goals. Therefore, SEM tools present the data that can be obtained from the system logs and the organizations use the reports that are required, however, CSMF formulates the measurements based on the organizational monitoring/reporting needs, thus, may meet every need of the organization. CSMF may also use the SEM products' reports and findings as an input. Therefore, it is possible to say that SEM tools are more focused products that can be used by the CSMFs.

As discussed in section 1.3, the main goal of this thesis is to give an insight to the managers and administrators about the current situation and the security trends in the organization. Utilizing

the well-known security measurement guides, with enhanced usability and few prerequisites, the CSMF presents measures development and implementation methods in order to provide the managers with meaningful and mandatory security oriented information. As validated in chapter 6, organizations employing the CSMF (with or without a software implementation) gain an insight into the organizational security and will see the improvements in the security level of the organization in the course of time.

3.2 Assumptions

To be able to talk about security monitoring in an organization, first of all the organization should have some level of security. An organization having preliminary security controls (which is more than the risk tolerance of the organization) should make investments in order to increase the organizational security to an acceptable level, which is documented and agreed by the management. Although it is possible to talk about security monitoring in an organization having preliminary security controls, the limited visibility in the system and the expected findings will turn out to be a gap analysis but not security monitoring. That is to say, the proposed continuous security monitoring framework requires the organizations to have defined and well-functioning IT security in the organizations.

The proposed security monitoring framework is purely designed for the IT security needs of an organization. Applied security monitoring perspective does not cover the sectors like health care, homeland security and industrial control systems using IT technologies. Thus, this approach may not be applicable to any SCADA or purpose built IT systems.

3.3 Solution Strategy and CSMF Proposal

Solution strategy and framework proposal section includes the discussion of the security metric implementation approaches (which is covered in the research chapter) and the proposal of the developed approach for the security monitoring. The CSMF approach has a systematic approach for continuous security monitoring for the organizations, which is easy to follow and apply in production systems. Since the framework has few prerequisites but offers various implementation details, it constitutes a good reference for continuous security monitoring.

Security monitoring is not a straight-forward topic that can be easily applied in the organizations since it is a continuous process that has many fallacies, which may cause the efforts to fail. As

discussed in the survey chapter, use of security metrics is commonly agreed for security monitoring, however, the use of security metrics vary in terms of standards and guides. Therefore, use of security metrics for security measurement is taken as a fact and the discussion will be around how to use the security metrics to build a framework for security monitoring.

Categorization of the security measurements is important to link the measures to business processes and stakeholders. This categorization will help the organizations to gain a wider insight into the development and application of security measures. Metric taxonomies are used to classify the security metrics by providing logical groupings and the relationships between them. There are various taxonomies proposed in literature. The comprehensive ones reviewed in section 2.2.4 can be listed as: Seddigh et al. (2004), Savola (2007), WISSSR (2001), Vaughn et al. (2003) and Chew et al. (2008). Taxonomies reflect the motivation of approach to the metric categorization. After the revision of the listed taxonomies, the proposed taxonomy by NIST is chosen to be the most applicable to grouping metrics for use of security monitoring. Here is the short list review which explains why NIST's taxonomy is chosen:

- WISSSR (2001): Having classified the metrics as technical, organizational and operational, actually this is an intuitive understanding of the metric taxonomy. Despite being a key reference for researchers, it is far from being a complete taxonomy.
- Vaughn et al. (2003): Grouping the security metrics as the assessment of an organization's organizational security and the measurement of information assurance capabilities of systems or products, Seddigh et al. (2004) concluded that further work may be needed to refine the taxonomy in order to make it appropriate for an IT organization. On the other hand, the intention of applying it against a specific product makes the taxonomy not applicable for security monitoring in an organization.
- Seddigh et al. (2004): Defining the taxonomy on the basis of Security, Quality of Service and Availability groups. Information assurance being the main motivation, proposed taxonomy is not appropriate for to be used for security monitoring. In addition to technical controls, security monitoring may encompass (up to the implementation) process monitoring, compliance monitoring and IT governance dimensions, which makes the proposed taxonomy inapplicable or hard to apply together with a security metrics program used.

- Savola, (2007): Adoption of a wider perspective and inclusion of both information security and product management topics under five metric groups are the strong parts of the taxonomy. On the other hand, lack of application details renders this approach inappropriate for use.
- Chew et al. (2008): In the revised revision of the guide, NIST's publication categorizes security metrics as Implementation, Effectiveness/Efficiency and Impact. Implementation metrics will provide daily operational results, effectiveness/efficiency metrics will conduct the security services delivery results and impact metrics will provide the business/mission consequences of security events in the organization. This approach and metric categorization in the revised version meet the requirements of business processes of the information systems and program security controls. A supportive argument is raised by Seddigh et al. (2004): "Unlike Vaughn taxonomy's TTOA category, NIST's technical category of metrics is not intended to apply against a specific product." Here, Seddigh emphasizes that system-wide approach is vital for successful application of security monitoring. These points demonstrate that among the above-reviewed taxonomies, the NIST's taxonomy is the best-fitting one to be applied for security monitoring.

Therefore, the proposed framework will categorize the applied/developed metrics under one of the following categories:

1. Implementation Metrics
2. Effectiveness/ Efficiency Metrics
3. Impact Metrics

Compared to organizations with emerging IT systems, mature organizations are expected to apply more effectiveness/efficiency and impact metrics, and this is interpreted by Chew et al. (2008) as: "...less mature information security programs need to develop their goals and objectives before being able to implement effective measurement. More mature programs use implementation measures to evaluate performance, while the most mature programs use effectiveness/efficiency and business impact measures to determine the effect of their information security processes and procedures."

Successful implementation of security monitoring relies on the correctness and effectiveness of the measure development and implementation processes. Incorrect measures will be misleading

for the organization in various aspects, and will contradict with the objectives of the security monitoring. Correctness of the measures does not mean only to calculate metric data in a correct way; it also involves the selection and definition of correct metric set (for the organization), which is used to define what to monitor. Application of inaccurate metrics for the organization leads to the collection of useless metric data, to put it differently, waste of valuable organizational resources. On the other hand, incorrect calculation of metric data will present non-existing issues as facts. These fallacy points are addressed in the CSMF by the information security measure development and information security measures implementation processes. Information security measures development process is the development and selection of specific measures to gauge the security controls, whereas information security measures implementation process consists of identification, development, selection, collection and reporting of metrics that are defined by the information security measures development process.

While comparing the security metrics development models, it can be easily seen that each model is substitutable by one another. For example Chew et al. (2008) states that “The information security measures development process consists of two major activities; identification and definition of the current information security program, and development and selection of specific measures...” which means “Information Security Measures Development” corresponds to “Identification”, “Definition” and “Development” processes in the model proposed by Jaquith (2007) and “Define requirements” and “Identify relevant security metrics” terms in the model proposed by ISF (2006). Similar correspondences can be named for the rest of the processes in the models. As each model can correspond one to another, one of the popular and commonly used reference’s security metrics development and implementation processes are employed to utilize in the proposed framework, which is the Chew et al.’s (2008) guide known as NIST SP800-55. While keeping the governing ideas and naming structure of the Chew et al.’s (2008) information security measures development process, it is tuned for security monitoring purposes, to be adopted easily by the organizations in the CSMF.

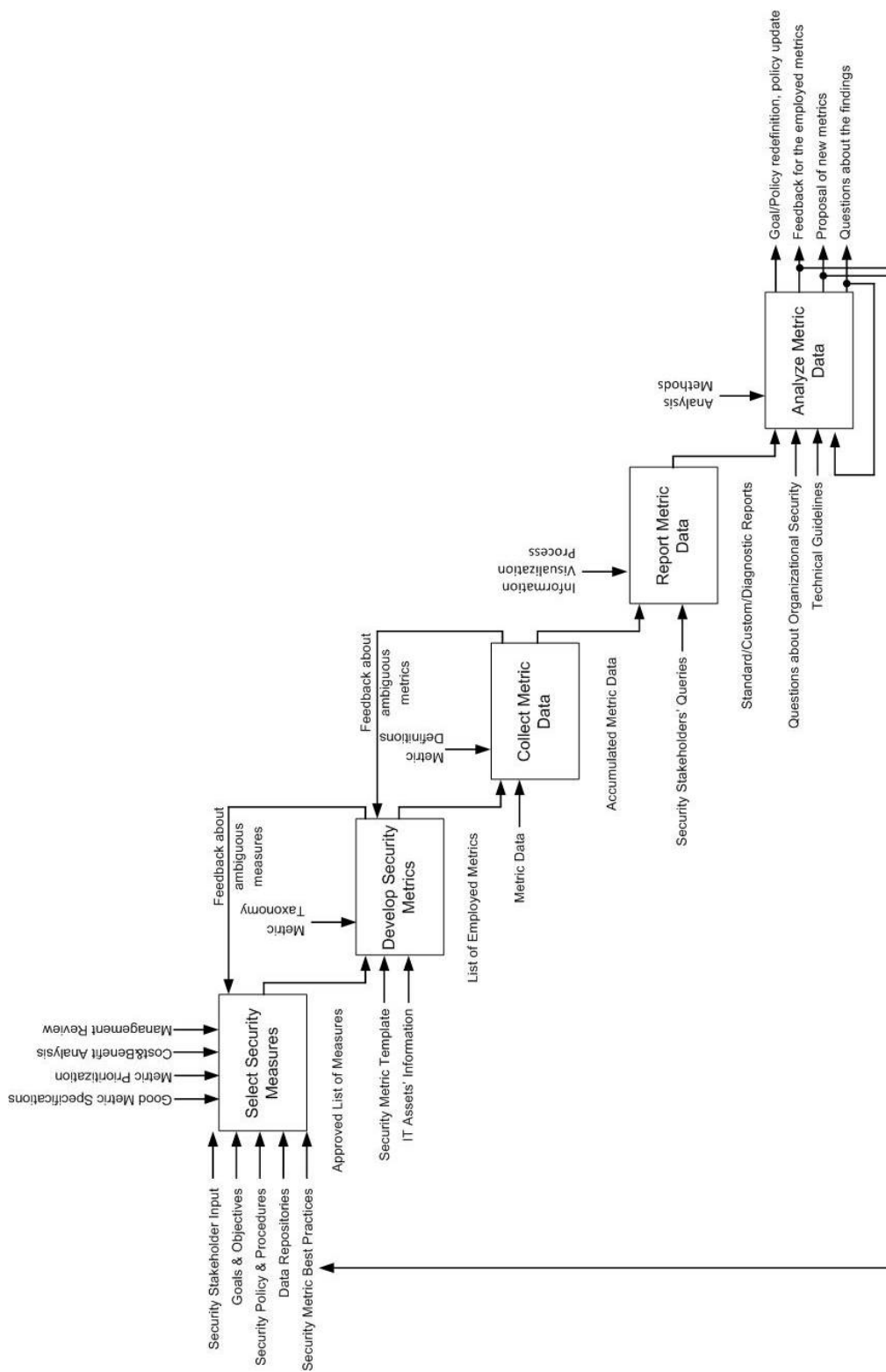


Figure 6: Continuous Security Monitoring Framework's SADT diagram

Figure 6 presents the main activities of the proposed CSMF using the structured analysis and design technique notation. While discussing each process and the proposed approach through the following sections of CSMF proposal, this figure will help the reader to stick to general perspective, and not to get lost in details. For the intuitive understanding of the processes in the figure, CSMF's process naming, which is inherited from NIST's guide, is changed as follows: "Information Security Measures Development" process is renamed as "Select Security Measures", "Prepare for Data Collection" is renamed as "Develop Security Metrics", "Collect Data" is renamed as "Collect Metric Data", "Security Reporting" is renamed as "Report Metric Data", and "Analyze Results" is renamed as "Analyze Metric Data".

As seen in Figure 6, CSMF has adopted phased approach that each defined process has a former and a follower process. Seeing CSMF as a life cycle, like PDCA cycle, each cycle starts with "Select Security Measures" process and ends with the "Analyze Metric Data" process. The outputs of the "Analyze Metric Data" process will constitute the inputs for "Select Security Measures" in the second round. While each cycle's duration may change according to implementation and sizing of the organization, approaching the CSMF as a continuous process (that does not have an end) and incorporating the feedbacks of the framework to the following cycles is one of the main strengths of the framework.

3.3.1 Information Security Measures Development

Common questions asked by the organizations for the identification of the security measurements are:

- What to measure to monitor IT security?
- Which measures do we need to develop?
- What kind of information need to be included in the measurement data?

Actually since the organizational structure, needs and technologies applied vary from organization to organization, there is no single answer to all questions. As underlined by ISF (2006) and Chew et al. (2008), organizations need to apply metrics in accordance with their IT security maturity level. This fact will guide the organizations in relation to the distribution of metric types in the metric development process; however, it does not say anything about how to develop metrics. As a possible solution, reviewed in 2.2.5, Chew et al. proposes an information security measures development process to guide users in developing metrics. The proposed

process requires a mature (at least up-to-date documented and in production) information security program, which is applicable to large scale enterprises, as already stated in the guide.

The scope of this thesis is to develop measures to be used for monitoring the IT security in organizations; and it is a fact that the more prerequisites the framework has, the less applicable framework becomes for the organizations. For that reason, CSMF does not impose a sophisticated information security measures development process in order to ensure that it is flexible and adaptive to every organization (in terms of sizing and IT maturity). Since it is well structured and compatible with the applied taxonomy and implementation process, Chew et al.'s (2008) measures development process is selected to follow as the best practice. The large scale enterprises having an information security program (including goals and objectives definition, information security policies, guidelines, and procedures review, information security program implementation review) may refer to the "Measures Development Process" chapter of the Chew et al.'s (2008) guide if a more detailed information security measures development process is required.

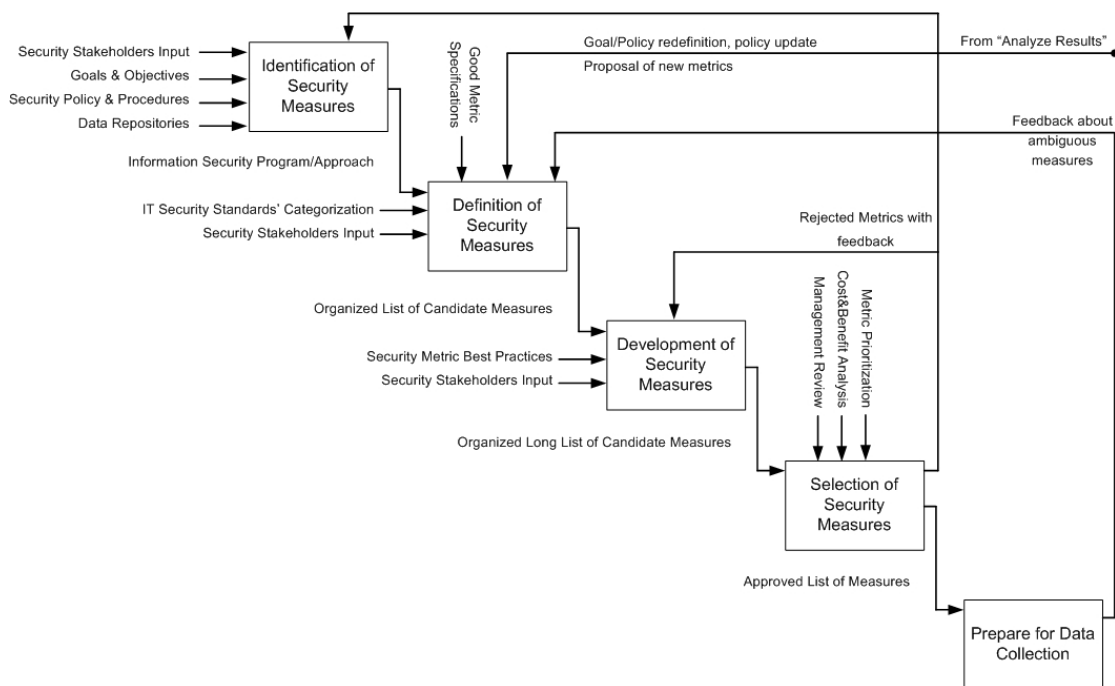


Figure 7: Information Security Measures Development process using SADT

The sub-processes of the Information Security Measures Development process are summarized in Figure 7 using the structured analysis and design technique.

Information security measures development process aims to identify and define the information security approach/program in the organization, and to develop relevant security measures to gauge the security controls. NIST recommends using four-phased security measures development process, namely, identification, definition, development and selection. Being the planning phase of the security monitoring, information security measures development process requires most participation, effort and attention from every stakeholder in the organization, since defective plans do not stand any chance of being concluded with successful implementation.

Identification of the security measures needs to be based on the information security stakeholders' inputs. Limiting identification only to certain roles or departments leads to overlook the business strategy, since each stakeholder's interest will lie on different aspects of business. In addition to executive committee, CIO, CISO, Information Security Officer, administrators and security engineers, also CFO, Training Centre and Human Resources can be counted as security stakeholders. These stakeholders' interests need to be considered to successfully identify the organizational measure needs. Although "stakeholder interests are driven by laws and regulations" (Chew et al. (2008)), during the identification phase, various methods such as interviews, brainstorming sessions need to be used to determine the interests of each stakeholder. Stakeholders' involvement to each process is vital for ensuring a sense of ownership of the information system security measures at multiple levels of the organization.

Depending on the structure and size of the organization, the responsible staffs that take role in the process vary. To give an example of the ideal case: every information stakeholder, with the help of Information Security Officers, selects and/or develops security metrics, Chief Information Security Officer can revise and review the chosen metrics and Chief Information Officer approves the work and presents it to upper management. As this example is only applicable to large scale enterprises, it is possible to have more than one task that can be undertaken by the same staff in small and medium size organizations.

Information security goals and objectives are valuable documents from which performance measurement criteria can be derived with the contribution of relevant security stakeholders. On the other hand, if available, organization specific security policies, guidelines and procedures applied can be reviewed to identify information security controls and performance targets to

develop related metrics. Finally, data repositories or data sources can be reviewed to reveal implementation evidence facts, indicating information security performance objectives being met, or the level of applicability. With the contribution of the related stakeholders, the above listed sets of information sources produce a “list of candidate measures”. These candidate measures are expected to represent the organizations’ perception and priorities in information security.

One needs to consider some terms and conditions while defining security metrics that make the metrics good metrics, otherwise they will turn out to be bad metrics to implement. As discussed in section 2.2.5, Jaquith (2007) defines the good security metric as: consistently measured, cheap to gather, expressed as a cardinal number or percentage, expressed using at least one unit of measure and contextually specific. The measures developed by the stakeholders should comply with the good metric definition; else implementation of the metric will be ineffective, time-consuming and misleading.

The candidate measures will be numerous for most of the organizations, thus requiring some leveling and categorization. For the organizations implementing any of the IT standards or frameworks (like ISO 27001, COBIT or ITIL), it is best to categorize (organize) the candidate measures according to standard/framework applied in the organization. As the standard’s approach (categorization) applied in the IT security is well-known by security stakeholders, developing a security measure system structured parallel to the standard used will ease the management and the understanding of the candidate security measures. Organizations not following any of the IT standards or frameworks may even apply one of the IT standard’s approaches or define their own categorization. (Likewise, they can generic headlines: Perimeter Security, Client Security, Physical Security and Software Security) Defining measures’ categorization will enable organizations to have an “organized list of candidate measures”.

Although getting input from security stakeholders and reviewing organizational goals, policies and procedures in order to produce candidate measures is the recommended and ideal way of developing measures, immature or inexperienced organizations in the field of security monitoring might prefer to review security measures best practices available in the literature. This review will help the security stakeholders to compare in-house built metrics with the best practices so that the measures requiring correction and measures’ categories lacking metrics can

be reinforced with appropriate best practice measures. A list of resources that include well known best practice security measures are listed in Section 2.2.7. Reinforcing best practice measures will increase the number of measures in the list; thus, will enable the organization to have an “organized long list of candidate measures”. Finalized list will be claiming that this set of measures are expressing and covering the organizational security measurement needs.

With the aim of covering the missing points in the categorized measures list, organizations, if needed, may revise the order of above discussed perspective that first defines the categorization, then reviews the best practice measures and finally (if required) develops additional metrics from scratch to cover the lacking points in the categorized measures list. Even though initial approach is recommended, organizations lacking defined policies, procedures and/or inexperienced in the field of security measurement might decide to use the alternative approach.

Measures development phase is followed by the selection phase. Reviewing the best practices or translating every objective in the procedures and guidelines may lead to have numerous metrics to collect and monitor. However, as discussed in section 2.2.5, it is important to start with a small number of metrics (around 10 to 20) then in line with the success of the program, it is wise to increase the number of metrics. This raises the question of how we can decide on the relevant metrics among the developed long list of candidate measures. Chew et al. (2008) recommends prioritization of candidate measures in accordance with the predefined organizational criteria, such as:

- Facilitates improvement of high-priority security control implementation
- Uses data that can be realistically obtained from existing sources and data repositories
- Measures processes that already exist and established.

Another important aspect that needs to be considered while prioritizing measures is the cost of collecting measures data in the organization. The burden of data collection in the chosen metrics is an important factor while applying metrics which has high collection frequency (measures data collected hourly). If an organization needs to exert days of man/hour effort to collect weekly measures data, this burden will affect the sustainability of the program in the midterm. Besides the cost/benefit balance, security measures implementation needs to balance the automation level to the burden of manual processes for the success of the program. That is to say, it is not required or needed to automate every single measure developed for the

organization, as this will limit the choice of measures or will pose technological obstacles to the measure collection.

Considering the above discussed security measure prioritization and automation recommendations, IT security manager, with the contribution of the security stakeholders, will review the organized long list of candidate measures and, if needed, the number of chosen measures is reduced to a reasonable number for the organization. The review process leads to the “organized short list of candidate measures”. Finally the short metric list is presented to the upper management to get their approval. Feedbacks of the upper management including, rejected metrics and comments on the metrics are conveyed to the information security stakeholders for further discussions and revisions. The approved list of measures will be used in the security metrics implementation process to define, collect and report on the selected measures.

3.3.2 Prepare for Data Collection

Prepare for data collection process may be confusing after reviewing Information Security Measures Development process as reader might think that why an additional preparation for data collection is required since the approved list of security measures are produced in the information security measures development process. Approved list of security measures is the approved measurement perspective of the organization for security monitoring in the organization for a period of time, however it does not include any implementation details of each measurement. Organizations need to define further details of each measure so that the approved security measures become “security metrics” that can be collected and reported for security monitoring.

Given approved list of security measures, one can directly move to the data collection process bypassing the preparation for data collection, however, it is for sure that the implementer will spend more time and make mistakes while trying to collect metrics data. Ignoring the planning of metric data collection will lead to the failure of the implementation phase as defective plans do not stand any chance of being concluded with successful implementation.

Prepare for Data Collection process will end up with the developed security metrics and it involves information security measurement identification, definition, development and selection

sub-processes. This process shows each approved measure's goal, responsible party, data source, reporting, and data collection frequency details that will be used in the data collection process.

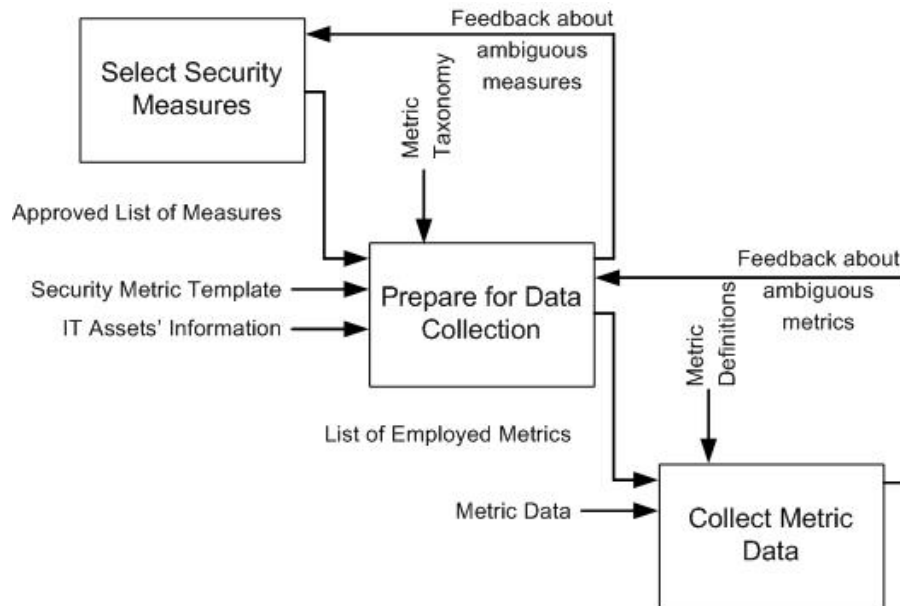


Figure 8: Prepare for Data Collection process using SADT

The Prepare for Data Collection process and its relation to other processes are stated in Figure 8 using the structured analysis and design technique.

An important aspect in metric development is the role and responsibilities of the users that are involved in the processes. Questions to define possible roles are as follows:

- Who will derive the related metrics from the approved measures?
- Who will define the metric goals, target and baseline values of the metrics?
- Who will collect the metric data from in-production metrics?
- Which users/roles are authorized to monitor each metric report?

The staff responsible for the above-mentioned duties varies according to the structure and size of the organization. In small to medium organizations, more than one task may be performed by the same staff. However, the most important point is to delegate the liability of a certain task to a specific staff so that problems related to the metric can be reported to and handled by a specific person.

Defining the goals of the measures is important to remember and follow up the main reason of metric development. It is important to remember that security monitoring is not a technical

activity but a management activity to bring an insight to the stakeholders. Definition of a goal is important in terms of revising whether the metric definition is compatible with the organizational goals and targets defined for security monitoring. On the other hand, according to the business needs, limitations, performance targets and baselines may need to be defined for each measurement. For instance, for a e-commerce organization, the uptime of the e-commerce servers are critical for the doing business and reputation, thus, may define the baseline of the availability of the e-commerce servers as 99.9% and targeting 100% as this metric is business critical for the organization. Finally the metric data frequency defines how often the metric data is collected and reported. According to the rate of change in particular security control and the criticality of the measurement, the frequency is defined as follows: hour, day, week, month, quarter and year. The ambiguous measures detected via the identification and definition sub-processes are reported to the relevant information security stakeholder for review.

As a last point, CSMF recommends to define alert criteria and alert type for each metric. (Most probably alerting functionality will be useful in a software implementation of the CSMF.) As baseline and target measurement values are defined for each metric, for the real time or average metric measures not satisfying the defined business or technical condition, alert condition can be defined.

Identification and definition of the security metrics is followed by the development of the related metrics. Different from the measures development, metric development defines how to calculate the metric data via a written procedure and covers the consequences of the concepts discussed during the identification and definition sub-processes. This procedure should be replicable and need to be based on the organizational resources only. That is to say, procedures should not use evaluation products to generate metric data or non-replicable inputs like statistics from the output of an audit report generated quarterly to feed a metric having weekly frequency. The procedures formulate how to collect the metric data to be used in the metric calculation formulae.

Metric calculation is required to be well defined to avoid any ambiguity during the data collection process. Therefore, for each metric definition, a mathematical formula including the explanation of the terms/parameters used in the formulas need be defined. It is common to have more than one metric formula and collected data (can be named as sub-metric) to calculate the

require metric, an example of this implementation type can be observed in the Appendix chapter of the Chew et al. (2008). This approach increases the complexity during the data collection and reporting processes as one metric might become a dozen of metrics, and decreases the reuse of the sub-metrics. Hence, CSMF employs the approach of naming each data collection and formulation as a single metric in other words, calling the sub-metrics of the above approach as metrics. As this approach significantly increases the number of defined metrics, organizations can introduce grouping or numbering (with sub-numbers) of the metrics to better organize and manage the metrics. This approach will decrease complexity and ambiguity in the metric formulas by using the (sub) metric numbers instead of names. Moreover, this will enhance the drill down reporting capability of the CSMF as each (sub) metric can be inquired easily.

Selection sub-phase stands for the decision making on conflicting issues encountered in the metric development process. As is the case in the selection of data collection and tracking tools, organizations may have more than one way of implementing metrics in certain conditions, thus selection sub-phase is introduced to resolve this issue.

As it is discussed in the solution strategy, the measures developed in the information security measures development process are grouped under the NIST taxonomy as: Implementation Metrics, Effectiveness/ Efficiency Metrics and Impact Metrics, however, distribution of the number of employed security metrics in each metric group varies by the maturity of the information security program. Considering that the CSMF has a life cycle, at the establishment period of the program, it is expected to have more implementation metrics. In the subsequent cycles, more effectiveness and efficiency metrics can be developed according to the success of the implementation metrics and the change in the organizations maturity level. Chew et al. (2008) describes this metric development and metric change cycle as follows: “Although different types of measures can be used simultaneously, the initial concentration is on the implementation metrics. As the implementation of the information security program matures and performance data becomes more readily available, measuring will focus on the program effectiveness/efficiency and the operational results of security control implementation. Having integrated the information security into organization's processes, the mission or business impact of information security-related actions and events can be determined by analyzing and correlating the measurement data.”

To ease the management of the implementation metrics, although not available in the chosen taxonomy, the framework further divides the implementation metrics into two:

1. Technical security measurement
2. Compliance measurement

By the further partitioning, it becomes easier to follow up two distinct and significant topics in addition to easy management and reporting in line with the metric types.

Discussion of what needs to be done to develop security metrics from the security measures demonstrates that many points need to be clarified and documented. In order to represent security metrics in a standard and formal way, as reviewed in section 2.2.5, ISF (2006), Chew et al. (2008) and Nichols (2008) propose security metric templates. It is a fact that these templates guide people so that it becomes easier to define the metric via answering certain questions. In addition to representation of the security metrics, employing a security metric template will also contribute to the detailed and complete definition of each metric developed.

The analysis of each template reveals that the basic fields are same in each template, such as: Metric Name, Goal, Value, Type, How to Calculate, Target, Frequency and Responsible Party. Chew et al. (2008) states that "...depending upon internal practices and procedures, organizations may tailor their own performance measurement templates by using a subset of the provided fields or adding more fields on their environment and requirements." The metric templates under discussion are good examples of NIST's statement. For example Nichols (2008) proposes a detailed template having 24 metric data fields to be used in the metrics-exchange project since the web-based user interface, metric editor, metric rating & ranking and metric licensing features employed requires these fields. On the other hand, ISF (2006) and Chew et al. (2008)'s templates have 10 and 11 metric data fields respectively. It must be noted that metric data fields in each template can be extended/restricted in accordance with the implementation needs of the security metric development process.

The proposed CSMF requires the metric template to have data source information, reporting requirements, production state, reference information and alerting requirements in addition to the common requirements defined by the reviewed templates. As there is a need for this set of additional requirements, none of the proposed templates is fully appropriate for the security monitoring framework. Thus, extending the proposed security templates with the current needs

of the framework, CSMF metric template is defined in Table 5. While defining the CSMF template only the must-to-have fields are employed from the reviewed templates in order to decrease the burden of the metric development/collection and increase the usability without missing any functionality. CSMF metric template including the explanation of each metric data field is as follows:

Table 5: Proposed CSMF metric template

Field	Description
Metric Definition	State the unique identifier used for measure racking and sorting.
Goal	Statement of strategic goal and/or information security goal.
Value	Value of the metric measurement.
Unit	Unit of the value
Type	Statement of whether the measure is implementation, effectiveness/efficiency, or impact
Category	State in which category the metric definition is under based on employed standards or in-house defined categorization.
How to Calculate	Calculation to be performed that results in a numeric expression of a measure
Target	Threshold for a satisfactory rating for the measure, such as milestone completion or a statistical measure.
Baseline	Value that is considered to be least tolerable threshold.
Frequency	Indication of how often the data is collected and analyzes and how often the data is reported.
Responsible parties	Indicate the following key stakeholders: Information Owner, Information Collector, Information Customer and Metric Owner
Data sources	Location and type of the product/information to be used in calculating the measure
Reporting format	Indication of how the measure will be reported, such as a pie chart, line chart, bar graph, or other format, including unit(s) of measure
Reference	Specify the reference if the metric is employed from other sources.
State	Possible states: Draft, Reviewed, Approved, inProduction, Passive.
Alert Criteria	Alert criteria definition that will trigger an alert, such as not receiving metric data or metric data is below the baseline etc.
Alert	Alert type definition (e-mail, SMS, event log etc.) and alert content.

In the implementation sub-process, organizations are expected to build their security metric lists based on the above template including the metric data calculation procedures. After the completion of security metrics list, organizations may pass to the “collect data” process.

3.3.3 Collect Data

Collect Data phase involves methods of metric data collection, metric data storage and identification of collected metrics meeting the goals defined. Chew et al. (2008) puts data collection and result analysis steps in the same process as Collect Data and Analyze results.

Details of this phase can be listed as follows:

- Collect measures data
- Aggregate measures as appropriate to derive higher level measures
- Consolidate collected data and store in a format conducive to data analysis and reporting
- Conduct gap analysis to compare collected measurements with targets and identify gaps between actual and desired performance
- Identify causes of poor performance
- Identify areas that require improvement

As data collection and result analysis, including security reporting, are the key points of security monitoring, according to the CSMF, the best approach would be to discuss each process on distinct sections. Thus, approach chapter will be better organized and reader will be able to follow each phase easier. Therefore, only the first three steps will be covered under data collection phase, while the rest of the steps will be discussed in the Analyze Results phase.

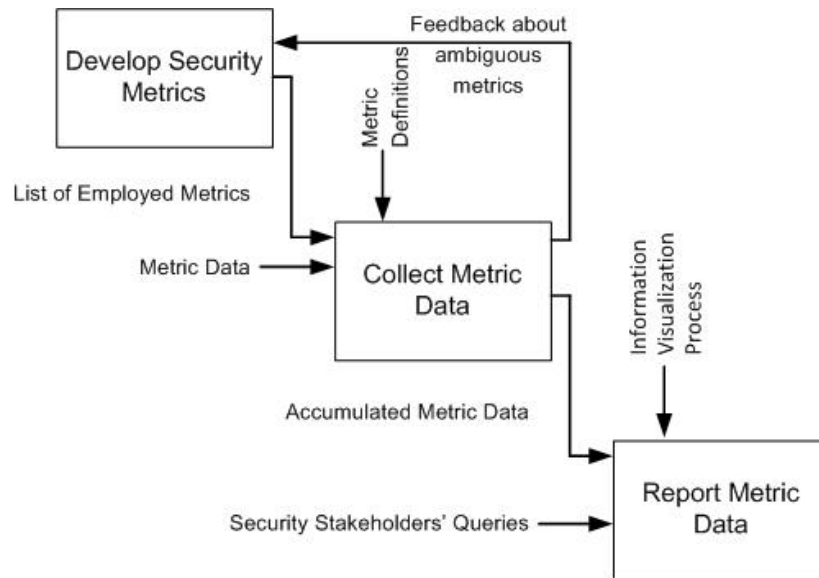


Figure 9: Collect Data process using SADT

The Collect Data process and its relation to other processes are given in Figure 9 using the structured analysis and design technique.

As security metrics are identified by the information security stakeholders, data source can be any business asset or process that can be measured according to the business needs. Due to the unforeseeable nature of the data sources, the metric data collection tools need to be flexible to ease the integration of the security measurement system into the organization's architecture. Depending on CSMF approach, possible data sources can be grouped into three as:

1. System Users
2. System Devices
3. Administrative Units

System users are the employees of the organization observing or learning about the security issues while communicating with colleagues in daily operations. Examples of the system users can be: managers, (CIO, executive committee members, etc.) human resources department members, security officers and administrators (DB, System, Application, Security and Network). System devices are the system assets used by the organization to enable communication and security in the organization such as firewall, IPS/IDS, vulnerability scanner, antivirus management system, proxy, mail server, switch, user database, router, web server, application server, database, ERP and CRM systems. Administrative units stand for both paperwork and

digital data-stores and reports in the organization such as penetration test reports, audit reports, asset database, configuration management reports, patch management reports, incident management reports, and identity and access management reports. Although this categorization does not help the manual implementation of the CSMF, data sources' categorization will be important to identify the data flows for the organizations planning to use software implementations.

An important point that requires clarification is the security metric collection and storage issues. Although the best way to implement the CSMF is to use a digital data-store in order to keep metric data and employ a software tool in order to ease the submission of metric data to the defined data-store, the CSMF does not force to use any software automation. Organizations can employ any kind of paper work or spreadsheet kind of office automation tools to run the CSMF. Each choice offers certain advantages both from technological and financial point of views. Small to medium enterprise organizations, having a small set of metrics and a dedicated staff for the management of security operations, may perfectly implement the CSMF. On the other hand, large scale enterprises which have numerous security stakeholders and security metrics need to implement software automation in order to centrally collect metric data and communicate reports to the related users.

As discussed in section 3.3.1, security metrics automation is vital for the employed metrics having high frequency of collection. Security metrics automation means, automatic collection metric data collection on defined intervals. This automation does not need to be the software implementation of the whole CSMF, but the automation of a method that produces the metric data. To illustrate, one may need to get the statistics file from the anti-spam gateway to collect number of spam e-mails daily, and this can be done by writing down the statistics from the GUI of the program at noon every day. Automation of the method can be achieved by writing a script that copies the statistics file to another location and by scheduling the script to run daily at noon.

During the implementation of the CSMF, implementers will observe that excessive but valuable information will be collected and processed for calculating the required metric data. An example of this may be metric reporting the number of client computers having out-of-date antivirus signatures. Although metric definition only requires the number of the computers, one needs to make a list of computers having out-of-date antivirus signatures to count them and report as the

metric data. Even though not required by the metric definition, the list may be required during the security evaluation meetings. Although it is not a requirement of the CSMF, keeping the details of the metric data is recommended.

In any phase of the metric data collection process, cases such that the metric definition and the real world implementation does not match and metric data collection may not be possible as documented can be encountered. As long as it is possible to handle this problem with minor updates in the metric definition within the security manager’s knowledge, the metric will be used in the production environment and related security stakeholder will not be informed about the case. The metric data collected on the predefined intervals is used for the reporting and analysis of the security measurements as described in the following section.

3.3.4 Security Reporting

The major aim of the security reporting in the scope of the CSMF is to get to understand of the collected metric data and it does not include developing a model to predict about possible future incidents in the organization. Because of this, time-series analysis methods (like statistical time-series analysis) are not covered, only approaches and tools that help to get to understand of the collected data is analyzed and some of them are employed by the framework.

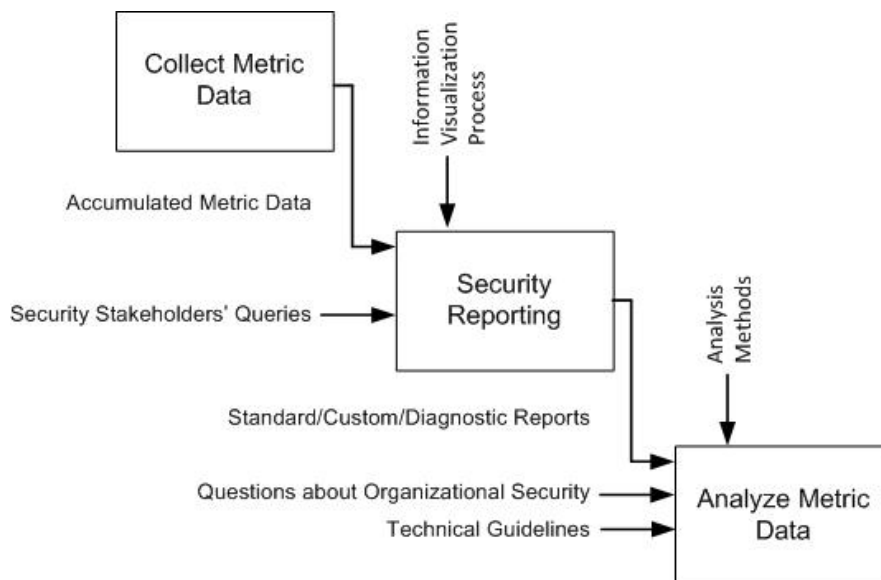


Figure 10: Security Reporting Process using SADT

The Security Reporting process and its relation to other processes are stated in Figure 10 by using the structured analysis and design technique.

As every single security and network product has detailed reporting facility, detailed technical reports are easily generated and commonly used in the organizations. On the other hand, consolidated security reports (made up of numerous products, giving insight about information security) are expensive to prepare and mostly drawn manually but this type of reporting is the most needed type, since custom designed reports inform the target audience on need to know bases. Based on this fact, the CSMF recommends using role based dashboards for the overview of the organizational security based on the dashboard grouping discussed in section 2.3 based on Marty's (2008) proposal:

- 1) Strategic dashboards
- 2) Tactical dashboards
- 3) Operational dashboards

In this way, every single user will see a role based, personalized, global information security view of the organization, with respect to the authorization and responsibility of the staff. This will help the users (especially for the users using operational and tactical dashboards) to see the security-wide whole picture of the organization before drilling down into the details of each business issue. Thus, security dashboards help users to:

- Make prioritization about the current issues
- Avoid missing or ignoring important issues
- See all the problems in the same window, therefore helping the user to approach the case from different perspectives.

Fundamentally, security dashboards use the reports described/designed by the framework. The metrics developed or chosen to be used in the design of the dashboard identify the type of the dashboard (strategic, tactical or operational). It is logical to link the type of the metrics developed (Implementation, Effectiveness/ Efficiency, Impact) to the type of dashboards, that is to say impact metrics will be commonly used in the strategic dashboards. On the other hand, as an alternative approach, organizations may choose to use the balanced security scorecard approach, which is proposed by Jaquith (2007) and discussed in section 2.3 to create their dashboards. This approach proposes to use Financial, Customer, Internal Process, and Learning

and Growth metrics in terms of security perspectives to reach an overall security scorecard for an organization. First approach is straight forward to apply since there is one to one mapping between the metric types and the dashboard types. However, the main drawback of this approach is that especially tactical and strategic dashboards might be lacking the required measurements in the initial phases of the implementation as the impact and effectiveness/ efficiency metrics require organizational maturity and functional operational metrics. Presenting four different perspectives in the same dashboard, the second approach requires considering each perspective while defining and developing the security metrics. This might be applicable for some organizations; however, it is obvious that it makes the metric development cycle complicated. It is up to the organizations' dynamics and requirements to choose any or a mixture of the approaches stated above.

In addition to dashboards, standard and customizable reports will be available to visualize the security metric data. As the reports are the only output of the system and most of the success criteria of the framework rely on the usability and efficiency of reporting, metric data visualization is the key factor of success in the proposed framework. Standard reports are predefined reports in the system, containing frequently monitored data and they need to be flexible to some extent, like supporting change of time frame or the shape of the graph up to the visualization needs. On the other hand, custom reports are required to create additional reports, meeting the further reporting needs of the users, which are mainly the comparison of various standard reports. To illustrate, after examining the virus infection distribution in Turkey and Italy branches of the organization, the security manager would like to compare both of the reports in the same report, thus, use custom reports to combine different reports.

In addition to the dashboards and standard/custom reports, the CSMF introduces diagnostic reports. Diagnostic reports can be defined as the reporting of lacking metric data in the expected time frame. This report will describe the problematic situation in a product, collection method or the stakeholder who is responsible for collecting the metric data.

As discussed in the metric data collection process, the automation issues need to be discussed for the security reporting part. Although a software implementation of the reporting process enhances the usability and increases the efficiency of the reports, proposed CSMF does not

force organizations to use a software implementation. The organizations doing manual reporting may use the publicly available, spreadsheet based, tools building reports and dashboards.

To design required security visualization reports, the CSMF employs the information visualization process proposed by Marty (2008) as summarized in section 2.3. The usage of the six stepped process in the framework is discussed as follows:

1. Define The Problem

Visualization should never be data driven; it must be based on requirements. At this very first step, the visualization requirements must be specified clearly. Security metric reporting is the visualization of developed security metrics' data thus, fulfilling the requirements of security metric identification and definition sub-process also means defining the visualization problem. The metric definition and metric goal fields defined in the metric template corresponds to the visualization problem definition.

It is possible that users may request reports that are not available in the system. Although it might be possible to address the request using the information visualization process, it should be kept in mind that reporting is only one of the steps in the information security metrics development process and starts from the initial step of metric development (as most of the visualization definitions are inherited from metric templates). Metric development process will end either by defining a new security metric or by guiding about how to use the available metric data to create the requested report. If a new security metric is developed as the result of the request, the newly defined metric's definition includes the reporting details. Else, the requested report can be created using the custom reports creation function and can be added to the standard reports if required.

2. Assess Available Data

Aligning the visualization problem definition to the metric definition and identification, which is discussed in step 1, brings the advantage of simplified process of assessing the available data in the metric visualization. Assessing available data is simplified because business requirements trigger security metric development (including metric data production) and at the end of this process, data visualization is triggered by the developed security metrics based on the metric data. Thus, assessed data in terms of raw logs and events is the responsibility of the security

metrics development process, whereas assessing the available data in the security metric data storage (as discussed in 3.3.2) is the responsibility of the reporting process.

As discussed in section 2.3, there is no guarantee that inquiries of the users can be answered with the available data and generated graphs. Information visualization model recommends identifying the log resources and data required from each resource to determine if additional data is required for reporting. Therefore, if the data is not available for reporting, as acquiring metric data is beyond the scope of reporting process, it is only possible to report the case to the user and system administrator. It is expected that through the feedback received from the reporting process, the metric development process would be able to cover the missing metric data and of the metric report would be regenerated.

3. Process Information

Information processing step is described in section 2.3 as log parsing, filtering and aggregation of the collected raw logs and events. As raw log and event processing steps were covered in the metric data collection section, information processing step can be interpreted as processing of accumulated metric data in the data-store. Having a metric template, including the reporting format enables direct reporting without any metric data processing. However, for some cases, like a user requesting a yearly report based on hourly collected metric, require processing of hourly metric data to calculate monthly metric values before visualizing the report.

4. Visual Transformation

This step is mapping the metric data into some visual structure, which produces a graphical presentation. The metric data has one dimension: the metric value collected at time t . The distribution of metric data over time is mainly required type of reporting, thus appropriate type of reports applicable to this prerequisite needs to be chosen. From the graph types discussed in section 2.3, the unidirectional ones that can be used in reporting are as follows:

- Pie/Bar/Line Charts
- Histogram
- Map
- Treemap
- Time series Charts
- Pareto Charts

With respect to the implementation, in the design of strategic dashboards or up to the reporting needs of the users, the number of reporting dimensions may increase, thus, other graph types may be introduced. The proposed CSMF is neither limiting nor forcing the organizations to employ above graph types only. CSMF's metric template includes the reporting format specification, which defines the visualization reporting format preferred by the information stakeholder.

Size, color and shape are important factors for the presentation of the data. If effectively used, these factors make the reports more readable and understandable. In section 2.3, Jaquith (2007) presents the six principles of effective visualization of metrics data that certainly contribute to the implementation of the reporting. Despite not forcing, as parallel to Jaquith's principles, CSMF recommends keeping the size of the data visualization as small as possible without affecting the readability of the graph including the units and legend. With regard to the use of coloring in the reports, framework discourages the organizations to use color as an additional dimension of reporting, as the metric data does not need much dimensions in reports. On the other hand, colors can be used for differentiating various parts of a graph such as, the values exceeding the threshold values of a measurement.

5. View Transformation

Although the graph choice for each of the defined metric is made by the information stakeholders, from time to time, the generated graph for reporting the metric data may not meet the user requirements. For such conditions, arming the reporting tools with graph customization functions will increase the efficiency of reporting. These functions can be:

- **Scaling:** Adjusting the timeline of the graph to drill down a specific time period or browse past trends is an important requirement.
- **Zoom:** Adjusting the size of the graph might be useful for the user to increase the readability or fit more reports in a single view.
- **Color:** Changing color template of the reports may affect the seriousness of the reports that might be preferred by the user.
- **Timeline:** Adjusting the timeline covered for reporting may be useful for the user to increase or decrease the number of data in the report to monitor different trends.

6. Interpret And Decide

If the predefined reporting format does not meet the information stakeholders' requirements, the reporting definitions must be updated to meet the user requirements. Although this report customization can be done manually, it can be automated such that through the view transformation step, user can update the default report definition as the customized view.

3.3.5 Analyze Results

Security monitoring enables organizations to be aware of and manage the security state in their organizations. It is a fact that, increasing usage of intelligent systems (automation) used in security monitoring, lowers the burden of security monitoring. Even though the CSMF proposes tools to ease analyzing results, the framework mainly relies on the users for the analysis of the reports generated. Although various automation tools might be introduced to ease the report analysis, further analysis of the analyzed metric data will not contribute much to the result, as the result analysis process needs human intervention ultimately. The importance of human intervention to the framework is underscored in section 2.1: "...security monitoring systems is not a complete but an important part of the solution, since people monitoring the system and interpreting the reports are the key factor of success in security monitoring." Thus, the CSMF leaves analyzing the report to framework users and user groups while proposing tools to support users' analysis.

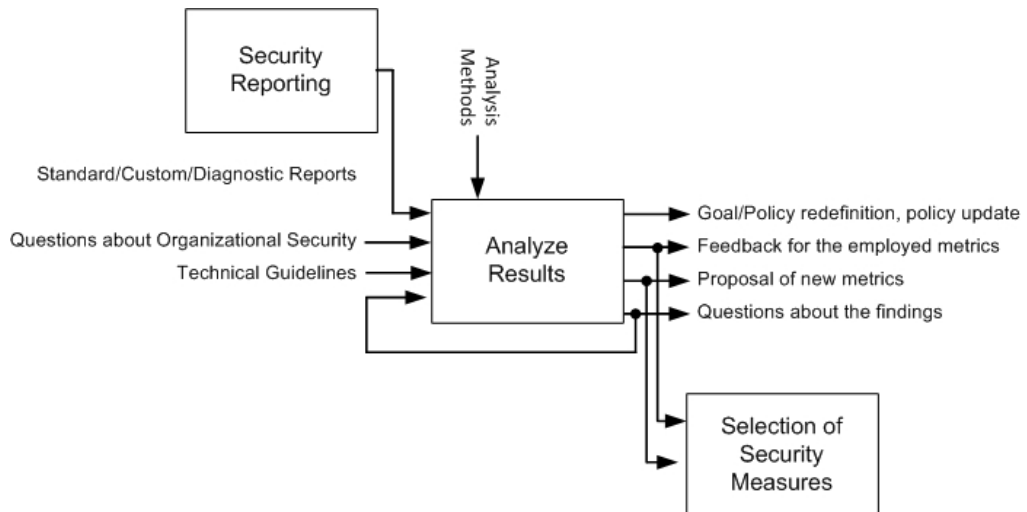


Figure 11: Analyze Results Process using SADT

The Analyze Results process and its relation to other processes are given in Figure 11 using the structured analysis and design technique.

Chew et al. (2008) defines Collect Data and Analyze results phase in six stepped approach. As the first three steps were covered in section 3.3.2, the following steps will be discussed in this section:

- Conduct gap analysis to compare collected measurements with targets and identify gaps between actual and desired performance
- Identify causes of poor performance
- Identify areas that require improvement

While analyzing the reports, CSMF users utilize two major analysis methods:

1. Gap analysis of the collected measurements with targets
2. Trend analysis of the current measurements with past data.

Analysis of each method including implementation tips will be discussed for the automated reporting implementation. Organizations employing manual reporting may adopt these methods to their own reporting implementation.

For the gap analysis method, the CSMF uses the baseline and target metric definitions laid down in the metric template to guide the users. Thus, users will be able to better analyze the metric values by considering the organizational baselines and targets. With respect to the framework, the baseline and target values of each metric should be specified within the metric reports either using different coloring or should be noted in the explanation part of the graphs. On the other hand, traffic lights based on overview reporting may be used for presenting the baseline and target compliance of the organizations. Although it will vary from implementation to implementation, one example of the usage of traffic lights might be as follows:

- Meeting the target for that metric:
 - Yes → Green light highlighted
 - No but above baseline → Orange light highlighted
 - No and below baseline → Red light highlighted

Trend analysis becomes easy with the time scaling and custom reporting functions as explained in the reporting section above. Users are able to see hourly, daily, weekly, monthly and yearly reports with time scaling. Moreover, they are able to combine reports having same metric definition but different time scales in the same view. In addition to easy reporting functions, traffic lights based on overview reporting may be used for presenting the general trend of the organizations. Although it will vary from implementation to implementation, one example of the usage of traffic lights might be as follows:

- Does the metric improved over time? :
Yes → Green light highlighted
No → Red light highlighted

While analyzing the reports, users generally need to discuss the reports or ask questions to other users in related topics. Although it is possible to communicate through various ways (i.e. e-mail, telephone etc.), discussing the reports while monitoring them may enhance the analysis capabilities of the users and increase the usage of the system. Using this feature, various users may interact with each other by asking questions or answering them based on their knowledge. For these reasons, incorporating a forum feature to the reporting module might increase the efficiency and effectiveness of the reporting module. Although it is not a must in the implementation of the framework, employing a forum feature is strongly recommended.

In addition to the forum feature, “guideline presenting” feature can be developed for guiding the users in relation to the definitions and best practices of the concepts that help them to analyze the reports if they need. This feature will help to answer questions such as: “How does the decreasing number of un-patched machines help us to become more secure?” by redirecting user about the importance of patch management. Although it is not imposed by the framework, this feature can be especially requested by the managers to understand some technologies to analyze the reports. For the implementation, the defined security metric template by the framework can be extended to include links to the related guidelines and definitions of the terms used in the metrics.

Performing the discussed analysis techniques including “recommended to have” features help the framework users to analyze the security reports to gain an insight into the security practices in the organizations. Although discussed analysis techniques and features ease the analysis of the

reports, from time to time they will not be enough to analyze the root cause of the problem. An example to better express the concept might be: “the increase in the number of virus infections in the user terminals of the organization”. Unless the organization employs any other security metric to measure other aspects of virus infections, it will be possible to find the root cause of the problem. For example employing patch management metrics, mobile storage unit usage metrics or gateway antivirus protection systems effectiveness metrics might help to detect the root cause of the problem. This issue cannot be solved immediately and can be addressed in the security metrics life cycle by employing additional metrics related to virus infection monitoring. The average round trip of the security metric life cycle is up to the organization and will vary from organization to organization.

Although NIST’s guide proposes to employ “Identify Corrective Actions”, “Develop business case and Obtain resources” and “Apply Corrective Actions” processes in the guide, it is believed that these contents are out of the scope of the CSMF. Although security monitoring is directly linked to the business processes and involves management activities, the results of the security monitoring processes are thought to be employed by other models and approaches which are not a part of the security monitoring framework. Else these processes will extend the scope and goals of the security monitoring, as they are including the business level analysis, which will change whole baseline and core functionalities of the framework.

CHAPTER 4

SOFTWARE IMPLEMENTATION OF THE PROPOSED FRAMEWORK

As discussed in the survey chapter, use of security metrics for continuous security monitoring is not common in the literature (Literature introduces intrusion prevention systems or network sniffers for continuous security monitoring). It is observed that while addressed in some standards (like Basel-II and SOX), continuous monitoring (with security metrics) is more commonly discussed in the industry compared to the literature. Additionally, COBIT, ITIL and ISO27001 standards define metrics and KPI's for the continuous measurement of the processes and programs defined in the standards. Although it was addressed by the guides and standards, continuous security monitoring based on security metrics was not commonly implemented in a structured way in the organizations. Despite giving an insight into and providing technical information about security metrics, the valuable resources such as Jaquith (2007), Chew et al. (2008) and ISF (2006), are not enough to fill the gap of implementation of security metrics approach for continuous security monitoring.

Considering the above needs, the thesis not only proposes a framework for security monitoring utilizing security metrics, but also includes the software development and field application of the CSMF. This chapter consists of the discussion for the need of implementation, requirements analysis, design of the database, description of the software modules and implementation details.

Before discussing the requirements of the proposed framework, it is wise to start with the question: Is there a need for Software Implementation of the CSMF? The rest of this section is discussing the need for a software implementation of the CSMF.

The Continuous Security Monitoring Framework proposed in Chapter 3 includes brief discussion of the “need for automation” for each process composing the framework. Although the CSMF does not force to use software automation for the implementation of the CSMF, software automation of the CSMF offers various benefits to the organization. This section will be discussing the need for developing software, the processes that provide the most advantage in return and the advantages of the software implementation.

It is possible for the organizations to implement the CSMF using standard office automation tools like word processors and spreadsheets. As office automations tools are commonly used in the organizations and many free distributions of these tools are available in the market, do the organizations need to buy or implement a software program for the CSMF? The answer of the question depends on the organization. Organizations may answer this question considering certain parameters in their organization. Here is a list of the concepts that deserve consideration:

1. Cost of the implementation: Remember the saying which goes as: “IT is an investment decision”. The cost of implementation is one of the leading factors that affect the decision of the managers. Both software implementation/purchase of COTS product (including maintenance costs) and manual implementation of the CSMF bring a certain cost. Organizations need to analyze the cost of the both choices.
2. Number of the security stakeholders in the organization: The number of security stakeholders contributing to the CSMF implementation increases both the implementation burden and complexity of the applied method. On the other hand, this parameter increases criticality of fifth, seventh and eight items.
3. Number of security metrics in the repository: Management of the developed metrics includes managing metrics in different states such as: draft, reviewed, approved, in production and passive. Following CSMF’s second or third cycle, the management of the metric definitions (including measure definitions) brings extra burden.
4. Confidentiality, Integrity and Availability (CIA) of the metric data: The criticality of the CIA in collected metric data changes according to the organization. Integrity and Availability of metric data directly affects the reporting and trend analysis of the CSMF,

whereas confidentiality of metric data may affect many issues like reputation of the organization. The number of metrics in production, the number of metric data collected and the number of participated stakeholders affects the management of the metric implementation, which includes the CIA concerns of the metric data. Central and secure storage of metric data and the access of security stakeholders to be able to submit/query metric data may be main concerns. Another point worth mentioning is that the percentage of human intervention included in the metric data collection processes is directly proportional to the probability of errors in data processing.

5. Number of high frequency metrics: High frequency metrics are most commonly required for monitoring critical systems'. Increased frequency decreases the time interval for collecting metric data from the data sources, thus, increases costs and decreases the feasibility and sustainability of the system for manual implementations of the CSMF.
6. Need of reporting: The interactive reports and dashboard views defined by the CSMF are feasible for the software implementation whereas standard reports can be generated in both of the implementation type. The organizations which want to have flexible reports both in content and timeline for the analysis need software automation.
7. Review meetings and communication: Although review meetings can be organized at scheduled times, effective report analyzing process requires frequent communication of the security stakeholders with each other. Asking questions and comments and stressing some trends or drawing attention to an incident can be the reasons of communication. Defining the means of communication for security monitoring is important for the privacy and efficiency of the communication.
8. Criticality of the response time: Manual implementations of the framework dramatically increase the response time of the organization for the incidents detected using the CSMF. On the other hand, software implementation leads automatic response and/or alerting to the related security stakeholder depending on the defined alert method.

Although the need for software implementation is discussed in the above list, actually managers are not limited to make a choice between two choices. While reviewing the CSMF, organizations may evaluate the framework process-wide for the manual/software implementation. According to the priorities of the organization it may be feasible to implement only some of the processes. Below list is discussing the benefits and drawbacks of software implementation for each process of the CSMF.

1. Information Security Measures Development

As discussed in section 3.3.1, Information Security Measures Development process aims to identify and define the information security approach/program in an organization and development of the relevant security measurements to gauge the security controls. The process consists of:

- Identification and definition of the current information security program: Considering inputs of security stakeholders and organizational targets and policies.
- Development and selection of related measures: Considering current information security program and best practices, developing list of security measures and selecting the measures on the basis of certain criteria. Process is completed with the approval of the selected measures by management.

As summarized above, the process derives the current information security policy from organizational targets, policies and stakeholders contribution. Although it is possible to do software implementation to capture the inputs of the stakeholders and manage organizational targets and policies, automation neither enhances the efficiency nor decreases the cost (time and budget) of the implementation of the process. Therefore, software implementation is not recommended for this process. Use of word processing tools to capture the knowledge and manage the list of measures should be enough for most of the organizations.

2. Prepare for Data Collection

As discussed in section 3.3.1, Prepare for Data Collection process defines further details of each measure so that the approved security measures become “security metrics” that can be collected and reported for security monitoring. This process defines each approved measure’s goal, responsible party, data source, reporting, and data collection frequency details that will be used in the data collection process and it uses metric template formatting to keep the metric definitions. Although there are many similarities between the previous and this process, Prepare for Data Collection process produces metric definitions which have various specifications, and produced metric definitions are used in each step of the CSMF, which are not valid for the Information Security Measures Development process.

Having sub-processes parallel to Information Security Measures Development process, the same arguments about automation of the process (neither enhances the efficiency nor decreases the cost) are valid for Prepare for Data Collection process. On the other hand, to be able to effectively manage metric definitions in the CSMF and ease the use of metric definitions in the Collect Data and Security Reporting processes, software implementation for managing the security metric definitions is recommended for the implementation. Software implementation of the metric data/definition will have the following advantages:

- Eases the management of metrics in multi-user environments
- Helps managing revisions of the metric definitions
- Helps managing various states (approved, in-production, passive etc.) of the metrics

3. Collect Data

Collect Data process is composed of collection, validation and storage of the metric data. Metric data is collected from system users, system devices and administrative units, as discussed in section 3.3.3. Validation is controlling the validity of metric data that is submitted to the CSMF. Metric data storage addresses the storage concerns of the metric data including backup and multi-user support for accessing the past metric data.

Although it is possible to collect, store and share the metric data manually using spreadsheet kind of tools, it is recommended to make a software implementation that addresses the below points:

- Supporting central data storage: employing a database facilitates the management of metric data and backups.
- GUI enhancing the metric data submission: facilitates the manual metric data submission process by guiding users with menus.
- Service validating and receiving metric data: Data validation service will control the submitted metric data on the basis of defined criteria and will support automation of metric data submission from various system components.

An important point that needs discussion is the metric data collection process that is defined by procedures in the metric definitions. In terms of automation, metric data collection can be categorized as:

1. Full automatic: The metric data collection procedures have full automation if the metric data is generated and submitted to the CSMF without any human intervention.
2. Partial automatic: The metric data collection procedures have partial automation if the users only use the pre-calculated (the raw logs and events are processed by 3rd party products/methods) measures to calculate metric data and submit it to the CSMF.
3. Manual: The metric data collection procedures are manual if the raw logs and events need processing by the users to calculate the metric data.

An example for the above categorization may help the reader to clarify the differences of each category. A SEM tool, collecting and processing raw logs and events in the organization, can be configured to calculate metric data if required raw data is available in the system. SEM tool can be configured to submit the metric data to the CSMF (or CSMF can be configured to get the data from SEM); that is to say automation of the every step of data collection. On the other hand, metric data sources can be configured to generate the required metric data or the measures that are used in the calculation of the metric data via reporting components, custom scripts etc. Then, the stakeholder responsible for the metric, if required, calculates the metric and then submits it to the CSMF. As human intervention is required for data submission, this method is partially automatic. Finally manual data collection performs every step defined in the metric definition procedure manually, including processing raw logs, calculation of metric data and submission the metric data to the CSMF.

Full automation seems the best choice to implement in the CSMF, however full automation has some drawbacks to consider such as:

- Full automation is applicable to the system devices only; to the metrics having data sources since system users and organizational units requires manual collection.
- Full automation requires sophisticated products like SEM products or development of advanced tools; therefore, it is more costly compared to other methods.
- Full automated CSMF has high maintenance costs as each change in the system devices affects the automation tools.

For the organizations not utilizing full automation, partial automation method is strictly recommended for the collection of metric data from system devices. By incorporating system devices' reporting components, system devices can be utilized to generate the needed measures. The metric data obtained from system devices' reports are submitted to the CSMF by the responsible stakeholder. If required measures cannot be obtained from reporting components or the reporting components are not available, then it is recommended to use custom scripts/tools to generate required measures, which is followed by the submission of metric data to the CSMF by the responsible stakeholder.

4. Security Reporting

Security Reporting is the reporting of the current and past metric data to the system users based on user preferences and metric definitions. Software implementation is recommended to enhance the usability and increase the efficiency of the reporting process. Software implementation of the security reporting will have the following advantages:

- Eases the access of system users to reports
- Removes the burden of report processing with initial investment,
- Supports authorization to enable access control rights
- Supports interactive reporting
- Supports customization of the reports in accordance with the needs of users
- Supports executive level dashboard based reporting

Linking the Metric Definition Management, Collect Data and Security Reporting processes with software implementation will enhance the sustainability and success of the implementation, considering the tight relation built in the CSMF between the processes.

5. Analyze Results

As discussed in section 3.3.3, CSMF mainly relies on the stakeholders for the analysis of the reports generated; therefore Analyze Results process depends on stakeholder participation. For this reason, software automation is not required for Analyze Result process while minor enhancements on Security Reporting implementation can be done to support stakeholders' report analysis.

This section discusses the need for software implementation of the CSMF considering the advantages and burden of the implementation. The aim of the chapter is help the reader to find the answers of the questions that may arise before deciding on a software implementation of the CSMF. It is recommended to go through this section before launching the implementation of the CSMF.

4.1 Requirements analysis of the Software Implementation

After the discussion on the need of a software implementation for the CSMF in the preceding section; this section moves a step forward; that is analyzing the requirements of the software implementation of the CSMF. Although it is possible to make complete requirement analysis of the framework, only the processes recommended for implementation will be discuss in the section for practical reasons.

As security metrics are identified by the information security stakeholders, data source can be any business asset or process that can be measured depending on the business needs. As discussed in section 3.3.3, CSMF approach states that, possible data sources can be grouped into System Users, System Devices and Administrative Units. The proposed framework is designed to interact with data source groups, namely system users, system devices and administrative units, depending on the defined security metrics. Figure 12 summarizes the relations between the CSMF with the external entities.

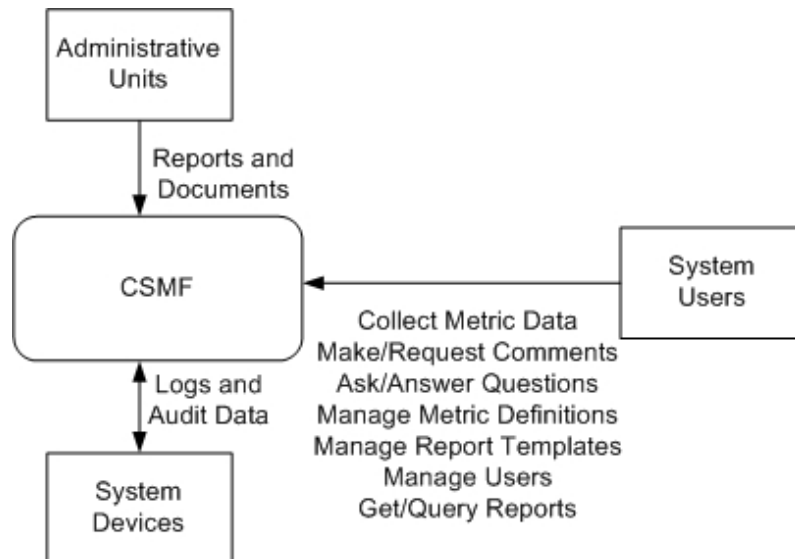


Figure 12: Context Diagram of the CSMF

System Users are the generic name of the personnel having roles in the IT Security related operations. It is not possible to give a perfect matching full list since the organization schema and role definitions vary from organization to organization, however, just to give an idea, the most common role definitions used are as follows: Managers, Human Resources department members, Security Officer and Administrators (as stated in section 3.3.3). Mentioned system users are a sample list of users, if needed some of the duties/roles can be grouped or further divided into sub-roles. In terms of data input, members of the system users are responsible for collecting metric data for the non-automated metrics, making comments on specified reports and answering system directed questions that may be raised by other users or by the system-wide defined security metrics. The members may also direct questions to the related system users of the system or ask for comments based on reports. Authorized users are capable of defining/updating standard report templates and metric definitions or use reporting functionality to monitor the IT security of the organization. Interaction between the system users and the CSMF is crucial in terms of giving insight into the organizational security, monitoring how the IT security evolves over time and detecting the root cause of the abnormalities or problems reported.

System Devices is the generic name for the network equipments, business applications/servers and IT security related systems that are the part of the corporate infrastructure producing operational and audit logs. As discussed in introduction of Chapter 4, organizations need to be careful while employing metrics with high frequency if automation is not available for the employed metrics. CSMF neither aims nor is designed to store any forensic or raw (operational and audit) data. CSMF is designed to store metric data which is defined by the security metrics definitions. The details of the required data (i.e. definition, format and unit) are set by the security metric definitions employed. For instance, “total number of attacks in the last 24 hours” and “total number of successful attacks in the last 24 hours” sample metrics can be used to give an idea on what kind of data may be obtained from the IPS system.

Considering the nature of human being and business limitations (limited resources etc.), it is not feasible to employ high frequency metrics for the system users. In other words, it is not feasible to design a system that asks questions and requests answers every hour or day to the system users. Therefore, each data source group interacts with the system differently; for instance

system users are expected to use the reporting to analyze the reports and perform manual metric data collection, whereas system devices only provide metric data to the CSMF.

Administrative Units is the generic name for the internal departments of the organization which represents the reports and tests prepared (internal audits etc.), acquired (from 3rd parties) and generated (using IT security and risk management software tools). The data processing approach is similar to the one defined in the system devices part, which processes and collects data from the reports in the required format as defined by the security metrics, and submits the metric data to the CSMF.

Specification of the external entities and their relation to the CSMF is followed by the definition of the requirements of the CSMF implementation using use case technique. To ease following the functional requirements, they are organized in accordance to the defined processes in the CSMF.

1. Information Security Measures Development

No software implementation is planned for this process.

2. Prepare for Data Collection

For effective management of metric definitions in the CSMF, software implementation is recommended to manage the security metric definitions having following requirements:

- UC1: Submit metric definitions to the system
- UC2: Manage (query/update/delete) metric definitions
- UC3: Manage (define/update) users
- UC4: Delete users
- UC5: Define log sources
- UC6: Define system authorization rights
- UC7: Define schedules for metric data collection
- UC8: Submit metric data manually
- UC9: Submit metric data manually automatically

The details of each use case can be found in Appendix D.

3. Collect Data

Proposed CSMF is recommending software implementation of the Collect Data process which is composed of collection, validation and storage of the metric data. This process doesn't have any functional requirements that are interacting with the external entities.

4. Security Reporting

To enhance the usability and increase the efficiency of the reporting process in the CSMF, software implementation is recommended for reporting the security metric data collected in the system having following requirements:

UC10: Browse metric categories/definitions

UC11: Generate report based on metric definition

UC12: Browse interactive reports

UC13: Customize home page

UC14: Ask/Answer questions

UC15: Make/Request comments

UC16: Manage report templates

The details of each use case can be found in Appendix D.

5. Analyze Results

No software implementation is planned for this process.

4.2 Conceptual design of the database

As discussed in the preceding sections, a data store is required for the management of the metric definitions, metric data and the reporting. Thus the database having the following design is developed:

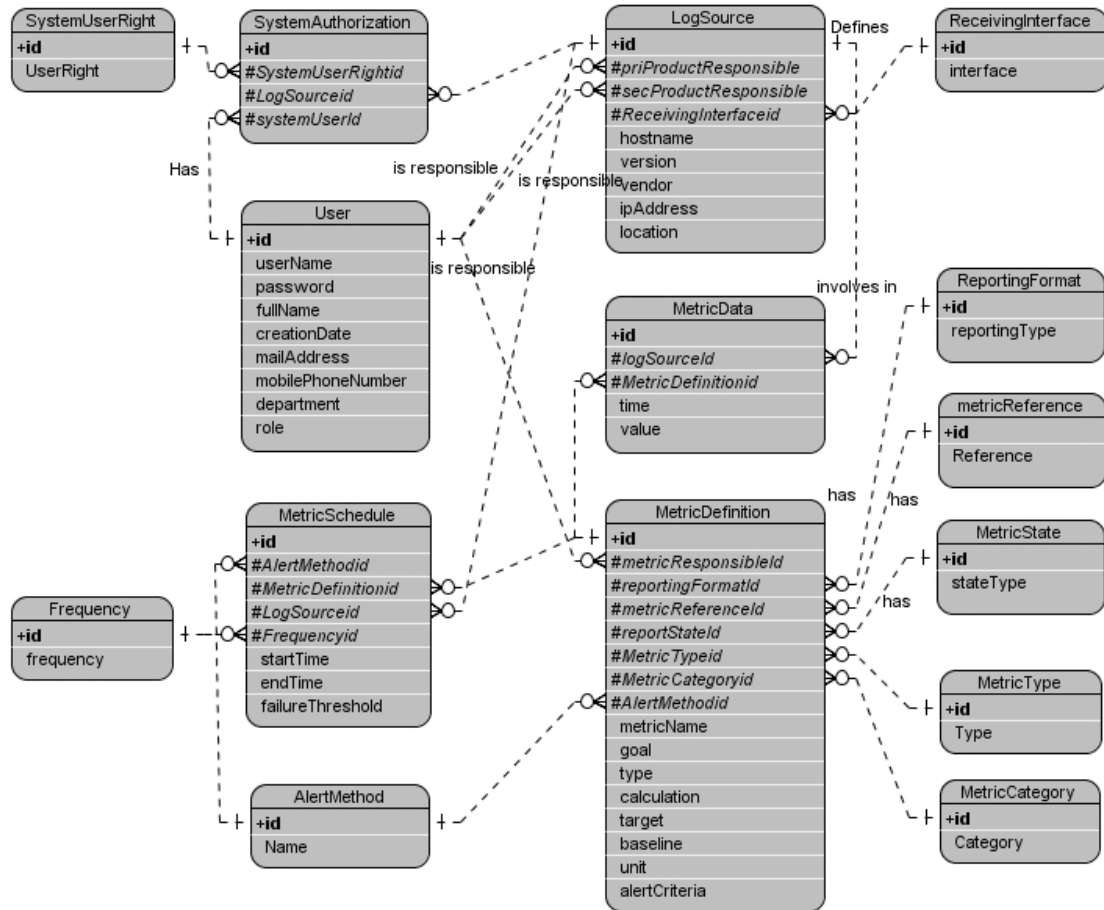


Figure 13: ER diagram of the CSMF

Figure 13 presents the Entity Relationship Diagram of the CSMF that is illustrating the logical structure of the database used in the developed software implementation.

4.3 Modules of the Proposed Software Implementation

SecMon is the name of the application that is developed to automate the CSMF. SecMon is developed for the validation of the proposed CSMF. It has a proof of concept approach and used in the pilot work carried out in a government organization.

Following the definition of the requirements for the software implementation of CSMF in the previous section, this section explains the SecMon application that has a modular architecture. First of all the data flow between the modules are discussed to give a general understanding of the system. It is followed by the detailed explanation of the modules that form the SecMon application.

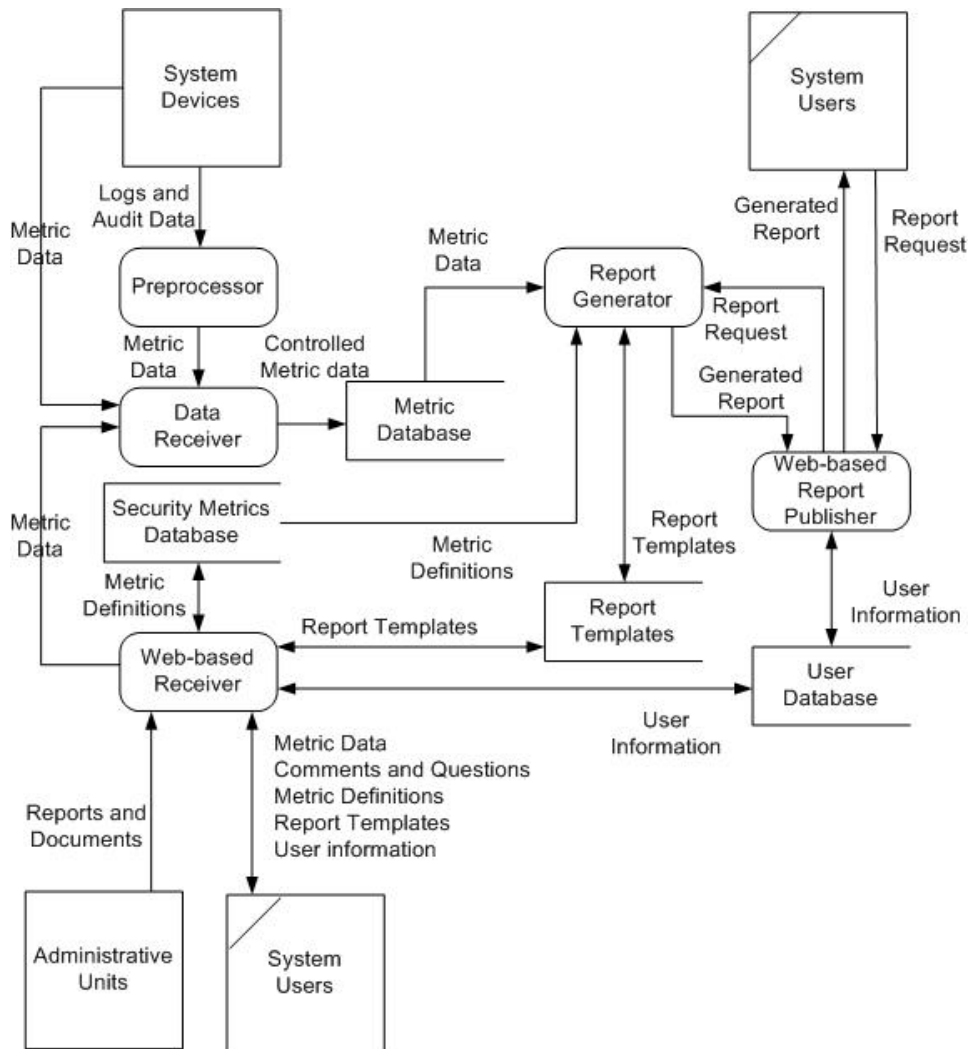


Figure 14: Data Flow Diagram of the CSMF

Figure 14 shows the Data Flow Diagram of the CSMF. The diagram presents the data flows between the external entities, processes and data stores.

CSMF proposes obtaining or receiving data from various sources defined by the data source groups. The metric definitions define the format, content and the frequency of the metric data that will be collected from the data sources. System users and administrative units are more or less similar in every organization, whereas the system devices can be any commercial, open source or in house built application. For example the firewall solution employed in the organization can be Check Point to Iptables; CRM application can be SAP to the in house built one. As discussed in introduction of Chapter 4, full automation, partial automation and manual collection methods can be employed to collect metric data from system devices. Partial and manual automation only requires a GUI in terms of automation which will be addressed by Web-based Receiver component, whereas the full automation needs discussion to meet the “Automatically submit Metric Data” requirement.

Metric data collection from system devices can be achieved in two ways: Data sources can be configured in a way to generate the required metric data and submit it to the Data Receiver or Pre-processors can be introduced to provide integration between the log sources and the Data Receiver. **Pre-processor** is the component which fetches and processes raw operational and audit logs from system devices to generate the required data with the given format defined by the related security metric. **Data Receiver** is the component which receives the metric data, controls the authentication/authorization of the sender and the validity of the metric data, finally if validated, submits the metric data to the security metric database. As it is technically not possible to configure every single application or fine-tune the system in a way to generate and send the metric data, the pre-processors introduce great flexibility to the system. Introducing pre-processors gives the flexibility to the SecMon to have an open architecture that is capable of receiving data from every single application.

Considering the requirements of the system users in the CSMF, a user interface is introduced by the SecMon to meet the defined requirements. **Web-based receiver** is designed for the easy management of metric definitions, metric data, user information and report templates. Due to fact that the system devices and the administrative units’ reports are critical components of the organizational security, the metric data collected from these sources will contain sensitive

information, which increases the CIA criticality of the metric data. Therefore, authentication and authorization controls are introduced in SecMon to adopt the “need to know” principle in the system. User information and access rights are stored in the user database and managed over the web-based receiver.

The metric data which is received from external entities is stored in **Metric Database**. On the other hand, the metric database stores the metric definitions that are developed via information security measures development process. CSMF approach recommends the storage of log source and system users’ information in the database to enable central and practical management of the users and log sources. Authorized users are able to inquire and update the metric database via defined processes up to the current needs of the organization. The other processes have access to the metric definitions and metric data stored in the database.

Reports are the only output of the framework, thus they have a critical role to realize the “monitoring” part of the framework. Being discussed in the approach chapter, a critical requirement in the analysis part, both report pulling and report pushing methods are implemented as interactive reports and standard reports respectively in the SecMon software. Standard reports are predefined reports by the system that answer the question of “What is needed to be monitored by the system?”. Best practices, benchmarks, compliance/security standards or organization specific monitoring needs can be used to design the reports. Interactive reports are the drill down reporting part of the system. Interactive reports are based on the standard reports, however, the difference is that the interactive reports support drill down reporting, which helps the user to get detailed information by means of making detailed inquiries based on the standard report outputs. Interactive reports are powerful when evaluating the reports. By using interactive reports, users can access the dynamically needed information while evaluating the reports via a few clicks.

Constituting the only output of the CSMF, reporting functionality needs to be easy to use and flexible to increase the usability and efficiency of the CSMF. Parallel to the requirements defined for security reporting, **web-based publisher** component is introduced. By using the web-based publisher, users generate standard reports or browse the interactive reports. Using the component, reports can be scheduled in a way to be generated and transmitted to the users

automatically. **Report generator** component is introduced to interact with the metric database to query metric data then to generate and transfer the required reports to the web-based publisher.

Although neither specified as a requirement nor discussed by the CSMF, other components can be introduced to the SecMon application. Even if not implemented, it is argued that in order to get more useful information from the stored metric data, metric database can be designed to work with an analyzer component, which can be named as the business logic of the system. One of the methods that can be utilized by the analyzer component is the evaluation method. Evaluation method compares the values of different metric data received from same log source using the same metric definition for the same time period. (Identical metric data collection using different methods for the same log source and metric definition can be used for validation purposes.) This conflicting metric data pair can be used in two ways: In case an evaluation technique is not implemented in the system, some mathematical algorithms (Jaquith, 2007) can be used to merge different data for the same metric to calculate the required data to be stored for that metric. Thus, different answers for the same metric are converged in a single data and this situation is not reflected to the users, which means a potential security problem is ignored. In case evaluation techniques are implemented, different data for the same metric can be used to perform a cross check analysis to justify the data stored or to determine contradictions before calculating the actual data to be stored for that metric. The contradictions found in the received data for the same metric can be highlighted in the published reports; even special reports can be designed like, conflict analysis report. For the calculation of the actual data, again the above discussed mathematical algorithms can be employed and evaluation technique can be used to ignore the incorrect data in the calculations.

In addition to the evaluation method, correlation method can be introduced as a part of the analyzer component, which continuously crawl the metric database to analyze and relate data collected from numerous devices using various security metrics. As defined by DeRodeff (2002), correlation is the ability to access, analyze, and relate different attributes of events from multiple sources to bring something to the attention of an analyst that would have otherwise gone unnoticed. Correlation of the data from various metrics will contribute intelligence to the framework and lead to “smarter” reports. As security metrics state the data format required, the correlator will only see the processed data whereas similar log correlator modules are able to see

and analyze every single line of the log from the devices. Therefore, it is not possible to use the commonly used correlation algorithms, thus different correlation logic needs to be developed.

4.4 Implementation of the SecMon application

SecMon application is developed using two different platforms. Due to the flexibility and available libraries Visual Studio .NET 2003 using C# language is used for the implementation of metric definition management and data collection components. For the reporting component, PHP and AJAX is chosen for the implementation of the reporting requirements. As report generator, a PHP based open source charting library is used.

Microsoft SQL Server 2005 Express version is used as the database of the SecMon application. All the components use the same database as the data-store.

4.5 Sample Deployment of the SecMon application

It is depending on the organizations size and security policy to decide on the implementation of the SecMon application; for instance to install each module on the same machine or distinct machines.

Every single organization has various types of security devices; the SecMon application is designed to be a flexible system to be able to collect metric data. The pre-processors can be used for the full automation of data collection from system components. The pre-processors of the SecMon application can either be installed on the operating system or the system devices can be configured to send the logs/events to a server by syslog then the pre-processor installed on the server generates the metric data from the logs.

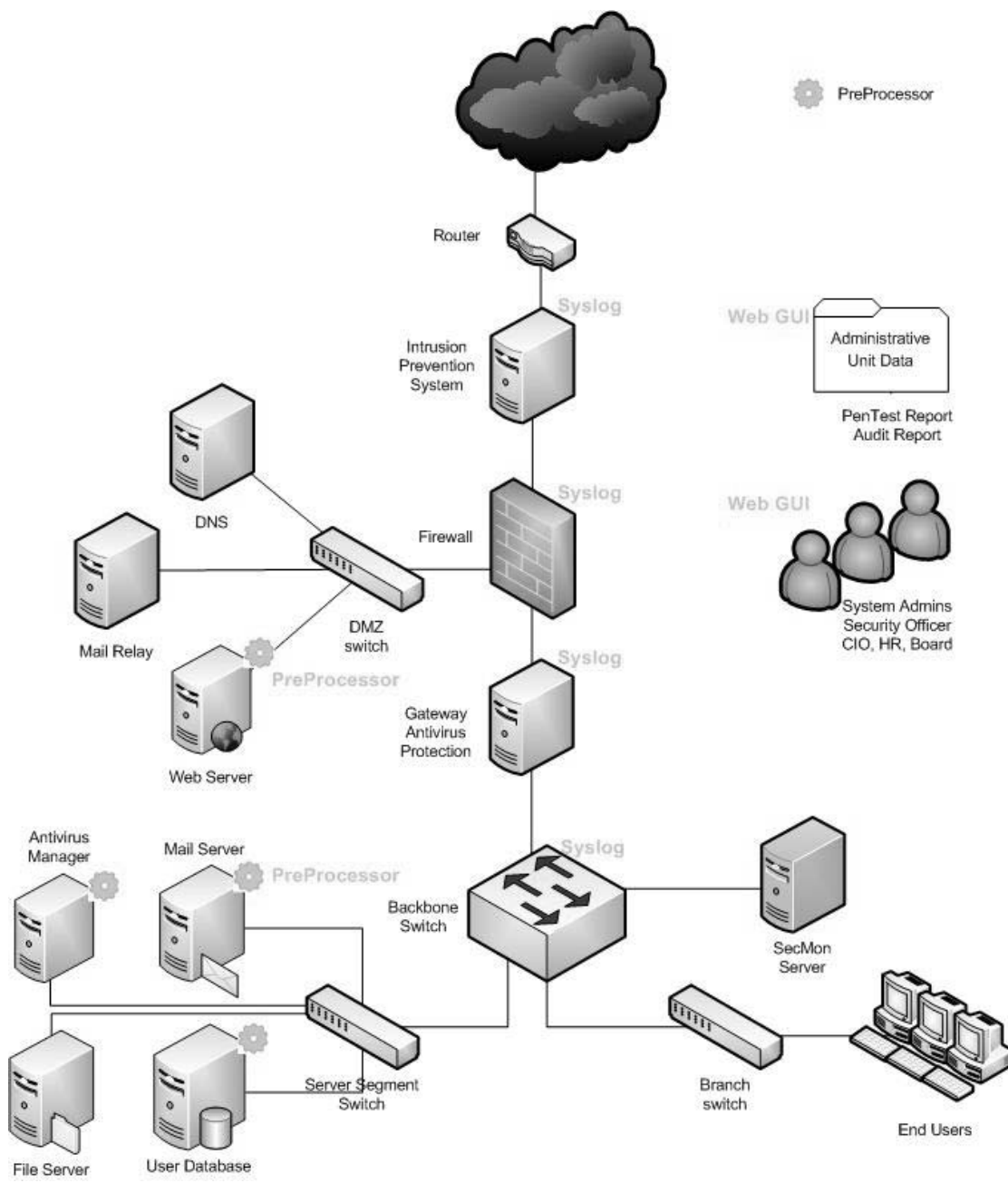


Figure 15: Sample network architecture

Figure 15 presents the network topology of a sample deployment of SecMon software.

CHAPTER 5

FIELD IMPLEMENTATION OF THE PROPOSED FRAMEWORK

Regarding the design and the prerequisites of the proposed framework, it can be easily employed by any corporate organization. The implementation time and cost of the framework vary by maturity level and approach of the organization to security monitoring.

- Since they have a defined, documented and in-production IT security program, probably mature organizations will spend less time and budget to build the framework compared to the evolving organizations.
- It is a common knowledge that it is hard to find a defined, documented and in-production IT security program in small and medium private organizations due to budget and skilled human resources constraints.
- Public organizations are obligated to comply with certain regulations and standards which outnumber the ones that any private sector company has to comply with. On the other hand, IT security is strategically important to keep the CIA of the organizational services.

As there are not many private large-scale enterprise organizations in Ankara (where the author resides), no other choice was left except for making a choice between small- and medium-sized private organizations and public institutions. Due to limited time and resources for the completion of the thesis, public organizations' corporate structure and available (both human and IT) resources to employ the proposed framework makes the public sector best fitting one to

the pilot needs of the CSMF. Thus government sector is chosen as the pilot sector for the planned pilot implementation of the CSMF.

It is foreseen at least 4 weeks is needed to be able to launch the CSMF and integrate the IT system of the organization with SecMon application. Actually this is the minimum duration required to implement the first round of the CSMF and it does not include the reviewing and planning phases of the framework. First week of the foreseen schedule is reserved for developing the security metrics and the following three weeks is reserved for the collecting, reporting and analyzing the metric data. The 4-week-period ends with the review of the first round.

Considering the time schedule of the thesis and the duration of each pilot study, it has been agreed to carry out the pilot study only in one of the chosen organizations. Although ideal one is to carry out the implementation work in more than one organization in order to support the validation of the proposed CSMF, other techniques are also employed to support the single-organization limited pilot study. Decision of carrying out the pilot in public sector is followed by finding a public agency which will be interested in security monitoring and which will agree to dedicate time and resource to the project.

After grouping the public organizations into three, namely big enterprises and medium- and small-sized enterprises, a medium-sized public organization has been opted for. Considering that

- the time needed to be spent in each phase of the framework is proportional to the size and maturity level of the organization and
- required implementation time of the CSMF to be able to get significant reports is inversely proportional to the organization's size

medium-sized public organizations are found the most eligible ones in the face of above-mentioned targets and limitations. On the other hand, big public organizations are eliminated due to time constraint and small public organizations are eliminated due to hesitations about the low profile reports resulting from the limited metric data available. Medium-sized public organization can be defined as organizations having 400 to 800 users with at least one e-government project in production.

Three medium-sized public organizations meeting the requirements have identified and have been contacted for the pilot work. The meeting held with the first candidate public organization was very positive and it has been agreed to carry out the pilot study in that organization.

Due to organizational security reasons (while defining and arguing security metrics much of the organizational private information needs to be discussed, including the system components) and possible use of the sensible security measurement results (if exists, poor performance measure results can be used by third parties like newspapers and hackers for different purposes) the identity of the public organization will not be disclosed. Nevertheless, just to give readers an idea about the size and organizational details, the pilot public organization has,

- 4 core business units.
- One headquarters without any branch offices.
- 500 employees and each user have a computer.
- 20 business critical servers and totally 46 servers in the system room.

Hereinafter the chosen pilot organization, whose details are revealed above, will be referred to as the public organization.

5.1 Implementation of the CSMF in a public organization

Before discussing the implementation details of the CSMF, it will be useful to give some basic information about the launch of the CSMF implementation work. After agreeing on the pilot study, first week is spent on:

- Meeting with security stakeholders
- Identifying the organizational structure
- Understanding the IT infrastructure
- Addressing the prerequisites (a work place for the onsite operations and a workstation to install the SecMon application)
- Introducing and explaining the CSMF to the security stakeholders
- Planning the pilot study

in the organization. Actually first week can be identified as the preliminary work which aims the aligning the goals and targets of the public organization and the framework. During preliminary work, two presentations are made to the security stakeholders (one is about security monitoring and the other one is about CSMF) with the aim of meeting with the security stakeholders and

informing them about the pilot study. An additional site visit is organized to understand the IT infrastructure.

ID	Task Name	Duration	Start	Finish
0	Implementation of the CSMF	35 days	Wed 10/29/08	Mon 12/15/08
1	Preliminary work	3 days	Wed 10/29/08	Fri 10/31/08
2	1st Cycle	16 days	Mon 11/3/08	Fri 11/21/08
3	Information Security Measures Development	3 days	Mon 11/3/08	Wed 11/5/08
4	Identification & Definition	2 days	Mon 11/3/08	Tue 11/4/08
5	Development	2 days	Mon 11/3/08	Tue 11/4/08
6	Selection	1 day	Wed 11/5/08	Wed 11/5/08
7	Prepare for Data Collection	3 days	Thu 11/6/08	Sat 11/8/08
8	Identification & Definition	2 days	Thu 11/6/08	Fri 11/7/08
9	Development	2 days	Thu 11/6/08	Fri 11/7/08
10	Selection	1 day	Sat 11/8/08	Sat 11/8/08
11	Collect Data (1st)	4 days	Mon 11/10/08	Thu 11/13/08
12	Security Reporting (continuous)	5 days	Mon 11/10/08	Fri 11/14/08
13	Analyze Results (weekly)	1 day	Fri 11/14/08	Fri 11/14/08
14	Collect Data (2nd)	4 days	Mon 11/17/08	Thu 11/20/08
15	Security Reporting (continuous)	5 days	Mon 11/17/08	Fri 11/21/08
16	Analyze Results (weekly)	1 day	Fri 11/21/08	Fri 11/21/08
17	Collect Data (3rd)	4 days	Mon 11/17/08	Thu 11/20/08
18	Security Reporting (continuous)	5 days	Mon 11/17/08	Fri 11/21/08
19	Analyze Results (monthly)	1 day	Fri 11/21/08	Fri 11/21/08
20	2nd Cycle	16 days	Mon 11/24/08	Mon 12/15/08

Figure 16: Project Plan of the CSMF Implementation

Figure 16 presents the project plan of the CSMF implementation in the pilot organization. Following the preliminary work, only the 1st cycle of the CSMF is implemented due to time limitations. The implementation work includes one week of metric development and 3 weeks of metric data collection. During the metric data collection users was able to access the reports anytime they needed. Report analysis meetings were held weekly to discuss the findings in the metric reports.

Although every organization can implement the CSMF without the support of any 3rd party, the author of the thesis has participated in every stage of pilot study to measure the effectiveness and to identify the problematic aspects (if any) of the CSMF.

CSMF employed a phased iterative approach that is discussed in the previous chapters. To help the reader to easily follow the implementation details as well as to keep the section well-organized, rest of this section is organized in sub-sections and each sub-section corresponds to a phase of the CSMF.

5.1.1 Information Security Measures Development

In the first week of the pilot study numerous meetings have been held to identify the information security program or approach of the organization. Not only the staff in the IT department, but also the staffs in other units have been visited to collect the required information. The aim of the meetings is to identify the business critical processes and assets in the organization including the CIA criticality of each process and asset. Following the completion of meetings with the units the meeting, notes taken during meetings have been gathered to work on them with the security stakeholders.

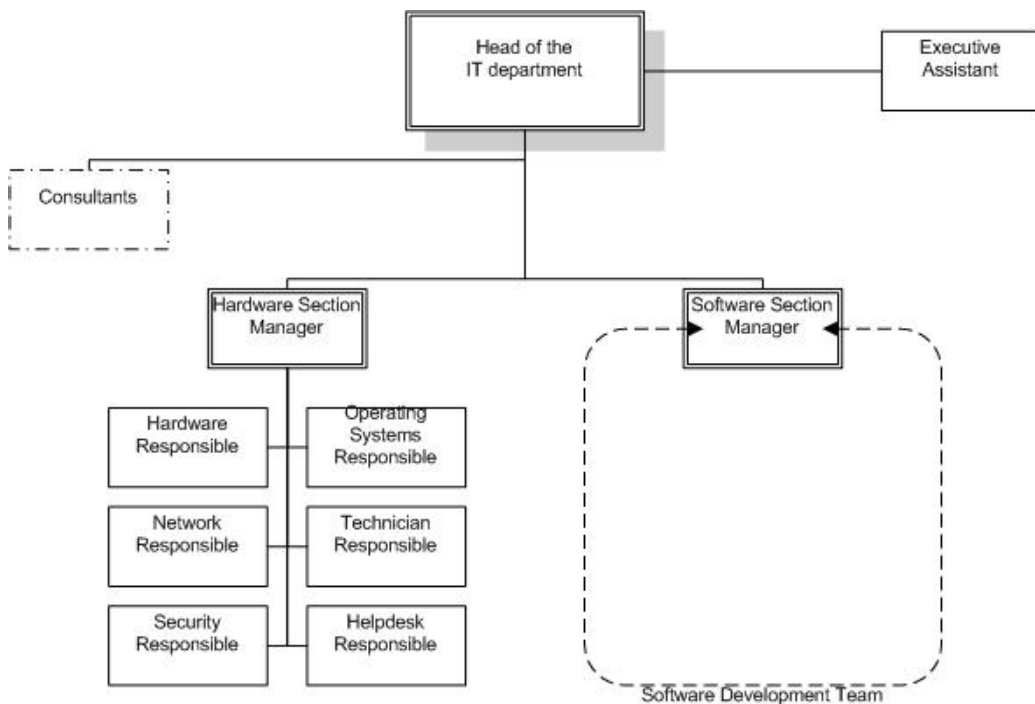


Figure 17: IT Department's schema in the pilot organization

Figure 17 presents the diagram of IT department in the organization. Head of the IT department, who reports to the executive committee, manages two sections in the department namely: Hardware section and Software section. Although the software section manager has participated in the meetings, the details of the software section are not given in the figure as the section is out of the scope of the pilot work (at least for the first round of the CSMF, which is decided after the review meeting). Hardware section of the organization is given in details since each member of the section has participated actively in the pilot work.

In addition to the inputs of the stakeholders, organizational goals and objectives have been obtained from the organization's web site to go through them. Additionally, organization's security policy and procedures have been provided by the hardware section manager. One interesting thing about the procedures is that they have not been updated in the last two years. Hardware section manager has stated that this is because of the limited human resources dedicated to the IT security. Nonetheless, the security policy of the organization is up-to-date and is approved by the executive committee of the organization. On the other hand, the organization is required to comply with the Turkish laws and regulations. These laws and regulations basically require logging of internet activity and doing URL filtering for the specified websites by the Telecommunications Agency. Other than the laws and regulations stated, the organization has neither employed nor have any preparation to employ any IT security standard like ISO 27001, COBIT or ITIL.

The extensive information collected about the organization is reviewed in a meeting with the employee in charge of security. As the organization has neither applied any of the security standards nor has followed the written procedures, it has been decided to focus on identifying an information security approach in the organization instead of exerting efforts to identify a non-existent information security program. Having large volumes of information islands of collected information made it even harder to identify the information security approach of the organization. Thus, it has been decided to identify the information security approach by categorizing the IT security with respect to the criticality of each category for the organization. After reviewing the ISO 27001 standard, it has been decided to define organizations' own categorization since the categorization of the ISO 27001 standard is not applicable to the organization.

Table 6: IT Security categorization in the organization

1) Perimeter Security
i) Network Security
ii) Servers Security
iii) Security and Communication Devices (Firewall, Router Etc.)
2) Client Security
i) Software (Client Antivirus, Firewall etc.)

Table 7: (Cont.)

ii) Authentication
iii) Network Access
3) Application Security
i) Protect Integrity of Application Data
ii) Authorization
4) Compliance
i) Internet Access Policy
5) Backup Management
6) Vulnerability and Patch Management

Table 6 demonstrates the defined IT security categorization in the organization. It is important to indicate that the IT security categorization list in Table 6 is not an exhaustive list of security categorization; however, it includes the categories that are mostly referred and identified as critical in the information collected about the organization. Although the topics like physical security, disaster recovery, software security, security consciousness trainings and data leakage prevention was under discussion in the meeting, it has been decided not to include any category/sub-category that cannot be monitored in the near future due to non-replicable nature of the process in the organization. Actually, this decision can be argued as an early prioritization and selection of the measures. This selection is valid only for the first round (cycle) of the CSMF and will not affect other rounds of the framework, as the organization may expand the list of items in latter rounds. Although selection of measures at an early stage is not discussed in the CSMF, being in the first round, it has been argued that this decision will not harm the targets of the framework. In the following rounds, the organization may extend the number of items in the categorization to improve the security perspective in the organization.

As they do not have any previous experience in security measures development for the development of the security measures, security stakeholders have preferred to start with reviewing the best practice measures in the literature. This is the alternative approach defined for developing the security measures in the CSMF. Therefore, the best practice measures referred in section 2.2.7 have been reviewed and each chosen measure has been categorized with respect to the developed categorization. This activity forms the “organized list of candidate measures” of

the organization. Choosing suitable measures from the best practice measures does not necessarily form a complete list of security measures for the organization. As discussed in the CSMF, organizations need to define their own measures in line with organizational needs. Therefore, security stakeholders have discussed the missing points in the organized list of candidate measures and developed additional measures especially in client security, application security and backup management categories. Development of additional measures was expected as the organization is managing many in-house built applications and defining strong authentication schemas for these applications. Extending the organized list of candidate measures with the additional in-house built measures forms the “organized long list of candidate measures” (see Appendix A). While choosing the security measures among best practices or developing them from scratch, good security metric specifications have been considered.

Development of the security measures is followed by the selection of the measures. The hardware section manager, security responsible and the software section manager have participated in the meeting held with a view to selecting the security measures. Participants have discussed each candidate measure in terms of metric prioritization criteria to decrease the number of candidate measures and, furthermore, have made cost-benefit analysis to finalize the short list of measures. The prioritization criteria of “Using data that can be realistically obtained from existing sources and data repositories” and “the burden of collecting metric data” are the most referred terms while eliminating measures from the long list of candidate measures. Then, “organized short list of candidate measures” have been sent to the head of the IT department for his consideration. The head of the IT department has approved the “organized short list of candidate measures” without demanding any update; however he has asked questions especially about the application security measures. For the approved list of security measures, see Table 7. With this approval, the “approved list of measures” has been formed. With the completion of this step the information security measures development process has been completed.

Table 8: Approved List of Measures in the Organization

<p>1) Perimeter security</p> <ul style="list-style-type: none">i) Host uptime percentage of mission critical serversii) Service uptime percentage of mission critical serversiii) Unplanned service downtime of mission critical servers to the total downtime.iv) Number of not approved open ports on mission critical serversv) Number of incoming Spam detected and filtered in e-mail messagesvi) Number of incoming Spam not detected/missed in e-mail messagesvii) Number of outgoing email viruses and spywares caught at gatewayviii) Number of detected attacks targeting application servers <p>2) Client security</p> <ul style="list-style-type: none">i) Number of malicious codes detected in client computersii) Percentage of client computers covered by antivirus softwareiii) Percentage of client computers with current antivirus signaturesiv) Total number of clients having local admin rights in their computersv) Percentage of directory accounts dead or disabledvi) Total number of clients not using any two factor authenticationvii) Total number of clients' failed logins to the computersviii) Total number of denied connection attempts from client computers to the low ports of the servers located in the server segment. <p>3) Application Security</p> <ul style="list-style-type: none">i) Total number of transaction done in the application serversii) Total number of researchers using the application serversiii) Average number of transactions done by each researcher using application serversiv) Maximum number of transactions done from a single IP address using the

Table 7: (Cont.)

application servers
4) Compliance
i) Malicious codes detected on websites browsed by the clients
ii) The number of restricted / banned site access attempts
5) Backup management
i) Back up percentage of critical servers' business data up to the defined back up policy
ii) Back up percentage of critical servers' operating systems up to the defined back up policy
6) Vulnerability and Patch management
i) Percentage of hosts not compliant to policy patch level
ii) Total number of unapplied patches in business-critical servers

The approved list of measures will be used for the development of the security metrics.

5.1.2 Prepare for Data Collection

As discussed in the CSMF, the development of the security metrics necessitates the definition of the terms like metric goal, how to calculate, collection frequency, responsible party, data source and alerting options. As the definitions of the metrics require much time and system analysis, it has been decided to identify which party is responsible from each measure and then each party will work separately to define the required details of the measures. It has been agreed that to a final meeting will be held to review and discuss the uncertain points before passing to the Collect Data phase.

Table 9: Security measures responsible identification list

Metric #	Metric Definition	Responsible
Metric 1	Host uptime percentage of mission critical servers	Network Responsible
Metric 2	Service uptime percentage of mission critical servers	Network Responsible
Metric 3	Unplanned service downtime of mission critical servers to the total downtime.	Network Responsible
Metric 4	Number of not approved open ports on mission critical servers	OS Responsible
Metric 5	Number of incoming Spam detected and filtered in email messages	Security Responsible
Metric 6	Number of incoming Spam not detected/missed in email messages	Security Responsible
Metric 7	Number of outgoing email viruses and spywares caught at gateway	Security Responsible
Metric 8	Number of detected attacks targeting application servers	Security Responsible
Metric 9	Number of malicious codes detected in client computers	Security Responsible
Metric 10	Percentage of client computers covered by antivirus software	Security Responsible
Metric 11	Percentage of client computers with current antivirus signatures	Security Responsible
Metric 12	Total number of clients having local admin rights in their computers	Hardware Sec. Manager
Metric 13	Total number of clients not using any two factor authentication	OS Responsible
Metric 14	Total number of clients' failed logins to computers	OS Responsible
Metric 15	Percentage of directory accounts dead or disabled	OS Responsible
Metric 16	Total number of denied connection attempts from client computers to the low ports of the servers located in the server segment.	Hardware Sec. Manager
Metric 17	Total number of transaction done in the application servers	Software Sec. Manager
Metric 18	Total number of researchers using the application servers	Software Sec. Manager
Metric 19	Average number of transactions done by each researcher using application servers	Software Sec. Manager
Metric 20	Maximum number of transactions done from a single IP address using the application servers	Software Sec. Manager
Metric 21	Malicious codes detected on websites browsed by the clients	Security Responsible

Table 8: (Cont.)

Metric 22	The number of restricted / banned site access attempts	Hardware Sec. Manager
Metric 23	Back up percentage of critical servers' business data with respect to the defined back up policy	Hardware Sec. Manager
Metric 24	Back up percentage of critical servers' operating systems with respect to the defined back up policy	Hardware Sec. Manager
Metric 25	Percentage of hosts not compliant to policy patch level	OS Responsible
Metric 26	Total number of unapplied patches in business-critical servers	OS Responsible

Table 8 identifies the responsible parties that are responsible for the approved list of measures. Each responsible party defines the type and the goal of the measures that help to figure out the purpose of the measure. Considering the purpose of the measure and its criticality for the organization, the frequency, baseline value, target value and alerting criteria of the measure is again defined by the responsible party. By analyzing the IT systems, responsible parties seek the most applicable data source(s) that can be utilized to collect the required measure data. After making a decision on the data source, calculation of the metric value (using the measures collected from data sources) is formulated.

Table 10: Sample metric definition applied in the organization

Field	Description
Metric Definition	Host uptime percentage of business-critical servers
Goal	Keep the business critical systems up and running by availability measurement for business-critical hosts and systems
Value	between 0 and 100
Unit	%
Type	Implementation/technical
How to Calculate	Average (host uptime percentage of each business critical server)
Target	99.9
Baseline	99
Frequency	Daily
Responsible Party	Network Responsible
Data sources	PRTG Network Monitor
Reporting format	line graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value < Baseline → e-mail alert
Alert	e-mail to Network Responsible

Using the metric template of the CSMF, the metric definitions are organized as shown in Table 9. An addition to the metric definition, each security metric requires having a procedure which describes how to collect the metric data from the defined data source. Metric procedure is the set of required steps to calculate the metric data.

Table 11: The defined procedure of Metric #1

<ol style="list-style-type: none">1. Use PRTG Network Monitor application's reporting to track daily host uptime percentage of each critical server.2. Calculate the daily average host uptime percentage from the values in step 1.

The defined procedure of Metric 1 is described in Table 10 to give an example to the reader. In total 26 metrics have been employed in the organization; rest of the metric definitions, including the procedures of each metric, is listed in Appendix B.

Following the definition of the security metrics, the security stakeholders have convened to review and discuss the uncertain points in the metric definitions. After discussing and revising some points in the metric definitions, the metric definitions have been finalized. This is the end of the Prepare for Data Collection process.

All of the steps covered in the Prepare for Data Collection process have been realized in the first week of the pilot study. Although the process was challenging and required some overtime work, it was an achievement on the part of the security stakeholders of the organization to complete the process successfully.

Name	Category	State
Host uptime percentage of business-critical systems	Perimeter security	in production
Service uptime percentage of business critical systems	Perimeter security	in production
Percentage of unplanned downtime of business-critical systems	Perimeter security	in production
Total number of not approved open ports on business critical servers	Perimeter security	in production
Incoming Spam detected and filtered in email messages	Perimeter security	in production
Incoming Spam not detected/missed in email messages	Perimeter security	in production
Outgoing viruses and spyware caught at SMTP gateway	Perimeter security	in production
Number of attacks to application servers	Perimeter security	in production
Malicious code detected in client computers	Client Security	in production
Percentage of Client computers covered by antivirus software	Client Security	in production
Percentage of Client computers with current antivirus signatures	Client Security	in production
Total Number of improper shares in client computers	Compliance	in production
Total number of clients having local admin rights in their computers	Client Security	in production
Total number of clients not using any two factor authentication to login thei...	Client Security	in production
Total number of clients successful/failed logins to the computers not register...	Client Security	in production
Percentage of dead or disabled active directory accounts	Client Security	in production
Total number of denied connection attempts from client computers to the lo...	Client Security	in production
Total number of transaction done in online Survey application	Application Security	in production
Total number of researchers using the online Survey application	Application Security	in production
Average number of transactions done by each researcher using the online ...	Application Security	in production
Maximum number of transactions done from a single IP address in the onlin...	Perimeter security	in production
Malicious codes detected on websites browsed by the clients	Compliance	in production
Total number of restricted / banned site access attempts	Compliance	in production

Figure 18: Security metric definitions in the SecMon application

The finalized metric definitions have been defined in the SecMon application, which is installed on a workstation in the organization. The security stakeholders were able to use the application from their own computers to manage the metric definitions. Figure 18 shows a screenshot of the defined security metrics in the SecMon application.

5.1.3 Collect Data

With the definition of the security metrics and the procedures the paper work that the stakeholders are supposed to do for security monitoring is completed. It is the Collect Data process that metric definitions are used to collect data with respect to the defined procedures. During the planning and development of the security metrics, collecting data according to the defined procedures sounds easy, however, developing the required metric data might turn out to be quite challenging from time to time.

Responsible parties should fine-tune the data sources or write scripts (discussed under metric automation) to obtain the metric data in order to transfer the defined procedures of the security metrics to the real life applications. This part needs lots of internet search and trial in the production system from the side of each responsible party. The required steps to calculate the metric data is defined as metric procedure, but procedures don't cover the details of the initial

work done for enabling partial automation. Where implemented, the documentation of the partial and full automation is documented as the “implementation details” for each metric. The steps of implementation details are only implemented once for enabling the partial/full automation of the security metrics. Enabling the implementation details is followed by executing the metric procedures to generate metric data on defined schedules. Nevertheless, all of the metrics’ data collection procedures and implementation details were documented and in production before the end of the second week.

Table 12: The defined implementation details of Metric #1

1. Define business critical servers to the PRTG Network monitor application.
2. Define ping health check for each defined server with the timeout period of 5 seconds.
3. Configure PRTG to report ping downtime of the critical servers on daily bases.

The defined implementation details of Metric #1 are described in Table 11 to give an example to the reader. In total 26 metrics have been employed in the organization, rest of the metric implementation details is listed in Appendix B.

Definition	Source	Time	Value
Host uptime percentage of business-critical systems	PRTG/test server/Ankara	03/11/08	100
Host uptime percentage of business-critical systems	PRTG/test server/Ankara	04/11/08	99,5
Host uptime percentage of business-critical systems	PRTG/test server/Ankara	05/11/08	100
Host uptime percentage of business-critical systems	PRTG/test server/Ankara	06/11/08	99
Host uptime percentage of business-critical systems	PRTG/test server/Ankara	07/11/08	99,8
Host uptime percentage of business-critical systems	PRTG/test server/Ankara	08/11/08	100
Host uptime percentage of business-critical systems	PRTG/test server/Ankara	09/11/08	100
Service uptime percentage of business critical systems	PRTG/test server/Ankara	03/11/08	99
Service uptime percentage of business critical systems	PRTG/test server/Ankara	04/11/08	99
Service uptime percentage of business critical systems	PRTG/test server/Ankara	05/11/08	99
Service uptime percentage of business critical systems	PRTG/test server/Ankara	06/11/08	99
Service uptime percentage of business critical systems	PRTG/test server/Ankara	07/11/08	99
Service uptime percentage of business critical systems	PRTG/test server/Ankara	08/11/08	99
Service uptime percentage of business critical systems	PRTG/test server/Ankara	09/11/08	99
Percentage of unplanned downtime of business-critical syst...	PRTG/test server/Ankara	03/11/08	94
Percentage of unplanned downtime of business-critical syst...	PRTG/test server/Ankara	04/11/08	39
Percentage of unplanned downtime of business-critical syst...	PRTG/test server/Ankara	05/11/08	9
Percentage of unplanned downtime of business-critical syst...	PRTG/test server/Ankara	06/11/08	0
Percentage of unplanned downtime of business-critical syst...	PRTG/test server/Ankara	07/11/08	18
Percentage of unplanned downtime of business-critical syst...	PRTG/test server/Ankara	08/11/08	0
Percentage of unplanned downtime of business-critical syst...	PRTG/test server/Ankara	09/11/08	0
Incoming Spam detected and filtered in email messages	Aladdin eSafe/ns/Ankara	04/11/08	1769
Incoming Spam detected and filtered in email messages	Aladdin eSafe/ns/Ankara	05/11/08	1692

Figure 19: Security metric data stored in the SecMon application

Figure 19 presents a sample screen from the SecMon application that is showing how the metric data stored in the database is presented to the system users.

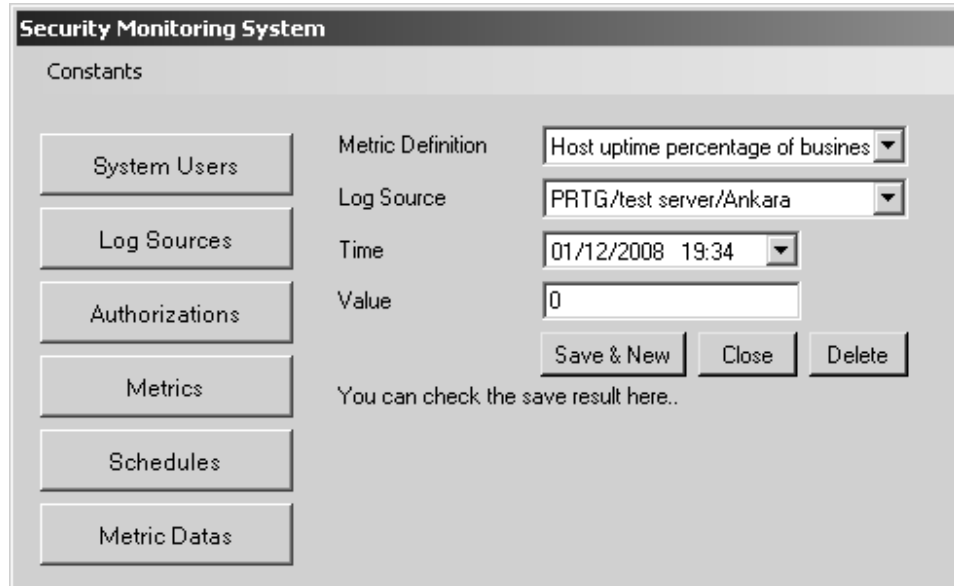


Figure 20: Submitting metric data using the SecMon application

Figure 20 is showing how the system users submit metric data using the GUI of the SecMon application.

The advantages of full automation are discussed in introduction of Chapter 4. As there was not any 3rd party automation software in the organization, implementation of the full automation of the security metrics was not possible. On the other hand, while reviewing the employed security metrics with daily frequency, it has been detected that some of the measures need to be obtained at 00:01 every day due to the limitations in some the system components. Thus, some scripts have been written and scheduled to run in order to collect the requirement measures from the data sources. The following day, the responsible party of the metric has made the required calculation and has obtained the required metric data. The metric data collected from the data sources are submitted to the SecMon application by the responsible parties. By this way, all the metric definitions except the backup metrics are partially automated in the implementation of the CSMF. Partial automation brings the flexibility of calculating the metric data in any time of the day to the responsible parties which increased the effectiveness of the pilot work.

The final point that requires discussion is the tools and programs used for the partial automation. The CSMF recommends to use the resources that are either belong to the organization or that are free of charge for the sustainability of the metric data collection. During the Collect Data phase the data sources for collecting the “Host uptime percentage of mission critical servers” and “Service uptime percentage of mission critical servers” metrics have been discussed intensively. Finally it has been agreed to try a sophisticated enterprise product in the pilot study and to procure the product if it meets the requirements of the organization. Thus, the evaluation version of the PRTG Network Monitor tool has been used in the pilot study. Rest of the tools and scripts employed like Nessus Vulnerability Scanner and Microsoft Security Baseline Analyzer in the pilot work are either open source or free of charge.

With respect to the project plan, at the beginning of the second week, the organization should start collecting the metric data from the specified data sources, however because of the some technical challenges, metric data creation was not possible for some of the metrics in the first few days of the first week. As it was not possible to obtain the missing metric data afterwards, some of the metric data is not available in the security reports.

5.1.4 Security Reporting

The metric data submitted to the SecMon is stored in a database and security stakeholders can use the reporting component of the SecMon to browse the metric reports which are derived from the metric definitions and data sources.

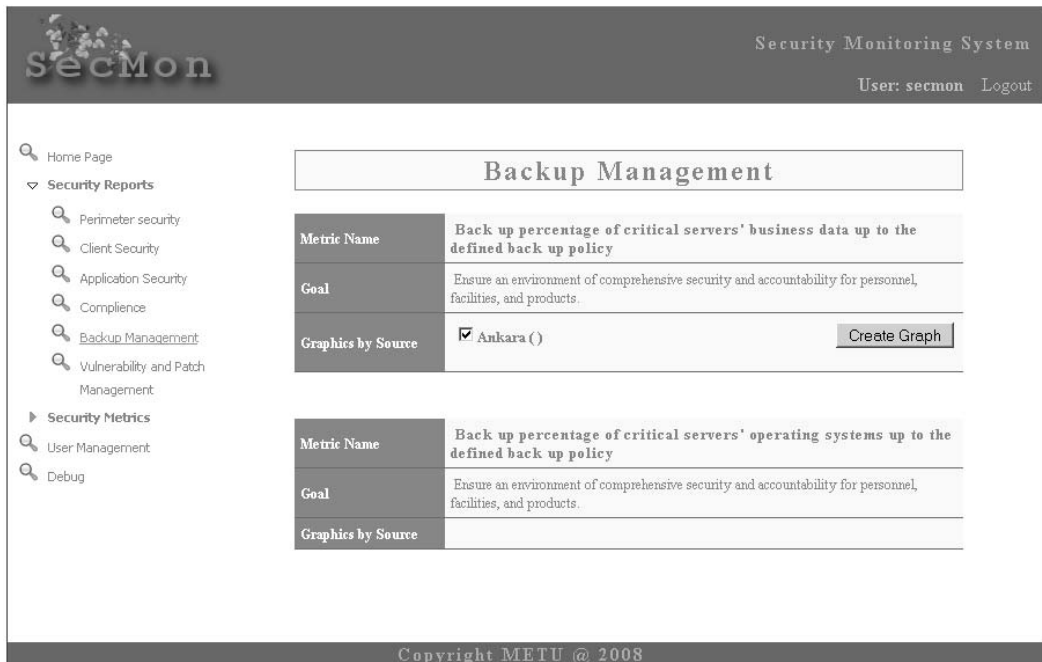


Figure 21: Sample reporting page of the SecMon application

Figure 21 presents a sample reporting page of the SecMon application. Security reports are organized in line with the metric categorization defined by the organization. Security stakeholders browse the metric definitions and draw reports based on the data sources.

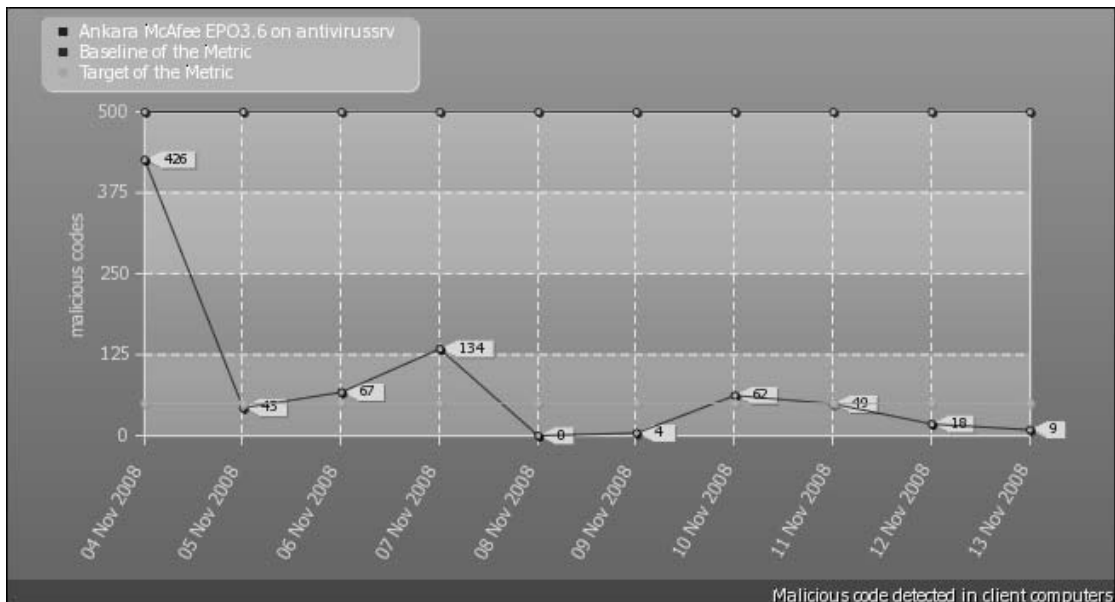


Figure 22: Sample metric report of the SecMon application

Figure 22 presents a sample report of the SecMon application. The reports have headings which contain the metric definitions in the metric template form.

5.1.5 Analyze Results

While discussing the analysis techniques and recommending implementation tips, the CSMF argues that the report analyzing process mainly depends on the security stakeholders. Being one of the analysis techniques of the CSMF, trend analysis is not applicable in the first few rounds of the CSMF implementation since it is not possible to have trend reports from limited number of metric data. On the other hand, the gap analysis method may be used in every stage of the CSMF implementation.

Due to time constraint, it has been decided to hold the review meetings on the first day of each week. These meetings would help the organization to discuss the report findings, to evaluate the security metric reports using gap analysis method and to plan the remediation process for the problematic points. The second week's (as first week was spent on developing the measures) metric reports were containing unexpected problematic points which surprised the security stakeholders of the organization. In addition to metric data collection, during the third and fourth week, security stakeholders have also worked on fixing the problematic issues set forth in the reports.

Although various implementation tips are discussed in the CSMF to facilitate the analysis of the metric reports, due to limited time available only a few of them can be implemented in the reporting component of the SecMon application.



Client Security	
Metric Name	Malicious code detected in client computers
Goal	Ensure an environment of comprehensive security by monitoring the indicators of infection rate on client computers
Type	
Calculation	Total count of malicious codes found in client computers
Target	50
Baseline	500
Unit	malicious codes
Reporting Format	line chart
Metric Reference	inhouse built
Metric State	in production
Select Dates	Start Date: <input type="text" value="2008-11-04"/>  End Date: <input type="text" value="2008-11-14"/>  <div style="text-align: center;"><input type="button" value="Create Graph"/></div>

Figure 23: Sample report’s definition of the SecMon application

After drawing up the security report, the security stakeholder may examine the metric report’s definition at the top of the page. Sample report definition of the SecMon application’s reporting component can be seen in Figure 23. The metric definition helps the user to review what the report is about.

Additionally, user can choose to report on a specific time interval using the “Select Dates” row. If the metric frequency is daily, like in the example metric in Figure 23, by default, system is reporting based on the last two weeks of data. Figure 22 presents the metric report covering the time interval defined in Figure 23.

CHAPTER 6

VALIDATION

It is not possible to prove or to validate directly the continuous security monitoring, the ultimate goal of the thesis. Therefore, the objectives of continuous security monitoring defined in section 1.3 are discussed and evaluated. As each of the defined objectives requires intensive discussion, section 6.1 has been organized with respect to the objectives.

Out of 9 objectives defined at the beginning of the thesis, 8 of them are validated with the proposed CSMF. Although the failed objective is an important objective, it does not affect the ultimate goal directly. Thus, by achieving 8 objectives out of a total of 9, the proposed CSMF has accomplished to validate the ultimate goal; that is to say continuous security monitoring.

6.1 Discussion of the objectives

Obj-1) To create an organizational memory for changing the IT security perception which is currently based on individual memory:

It is a fact that the critical organizational decisions (related to IT Security) are adopted considering the ideas of a few people. In other words, critical decisions are shaped according to the IT security perception of the managers. It is argued that long-term organizational memory changes the IT security perception of the stakeholders in the organization. It is claimed that the proposed framework changes the IT security perception in the organizations by building an organizational memory that is imposing the individual's memories.

To verify this claim, a survey has been held before starting to collect security metrics in the pilot organization. The survey questions were actually parallel with the developed measures and each question has represented a metric definition in the CSMF. The answers of the survey questions can be taken as the individual memory and the finding of the metric can be taken as the organizational memory. If it is possible to show that the stakeholder's IT security perception has changed parallel to the findings in the CSMF, then the claim is verified.

The survey which has been conducted in Turkish can be found in Appendix-C.

Table 13: Survey questions to Employed metric's mapping

Question #	Metric #	Before	After	Change Rate
Question 1	Metric 2	3.75	4	6%
Question 2	Metric 4	3.75	4	6%
Question 3	Metric 6	3.75	4	6%
Question 4	Metric 8	4.75	2.5	-90%
Question 5	Metric 9	2	2.5	20%
Question 6	Metric 11	3.75	3.75	0%
Question 7	Metric 12	1.75	2.25	22%
Question 8	Metric 20	2	2	0%
Question 9	Metric 22	2.75	3.75	27%
Question 10	Metric 23	4.25	4	-6%
Question 11	Metric 26	4	3.25	-23%

The mapping of survey questions to the develop metrics can be found in Table 12. Table 12 also presents the average scores that the survey participants have voted in the survey both before and after the pilot study. The percentages of difference of the average scores between the two surveys are presented in the Change Rate column. Only five of the questions show a difference in the results that deserve real attention. Here is the discussion of each question that leads a change in the survey results.

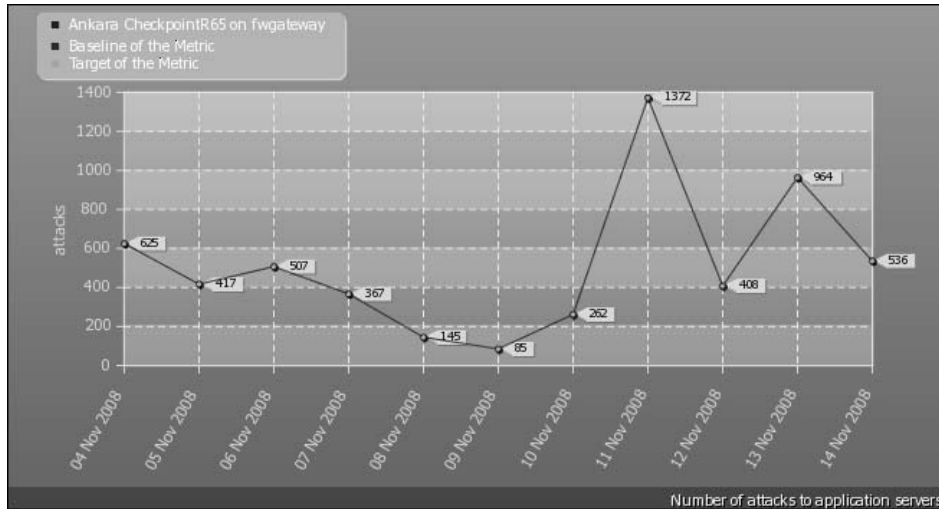


Figure 24: Application level attack statistics to the application servers

Question 4: (Metric 8: Number of detected attacks targeting application servers)

Before the pilot study, participants of the survey gave 4.75 points to the question in which high points means “very rarely” and low points means “very frequently”. After the survey, by analyzing the report presented in Figure 24 in the review meetings, the participants gave 2.5 points to the same question. Decision change of the participants of the survey is consistent with report findings as the daily number of attacks is more than expected by the organization.

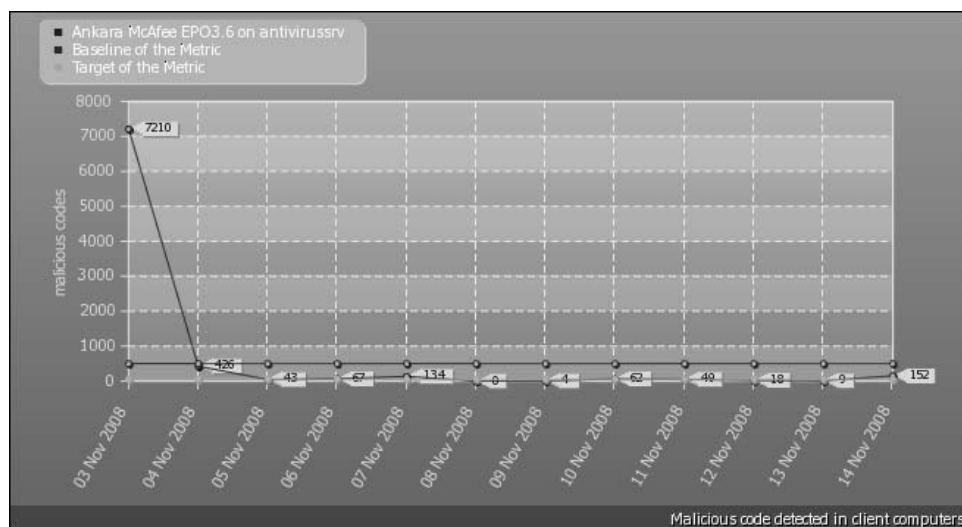


Figure 25: Number of malicious codes detected in client computers

Question 5: (Metric 9: Number of malicious codes detected in client computers)

Before the pilot study, participants of the survey gave 2 points to the question in which high points means “very high” and low points means “very low”. After the survey, by analyzing the report presented in Figure 25 in the review meetings, the participants gave 2.5 points to the same question. Change in the decision of the participants of the survey is consistent with report findings as the number of malicious codes detected on client computers is far more than the target.

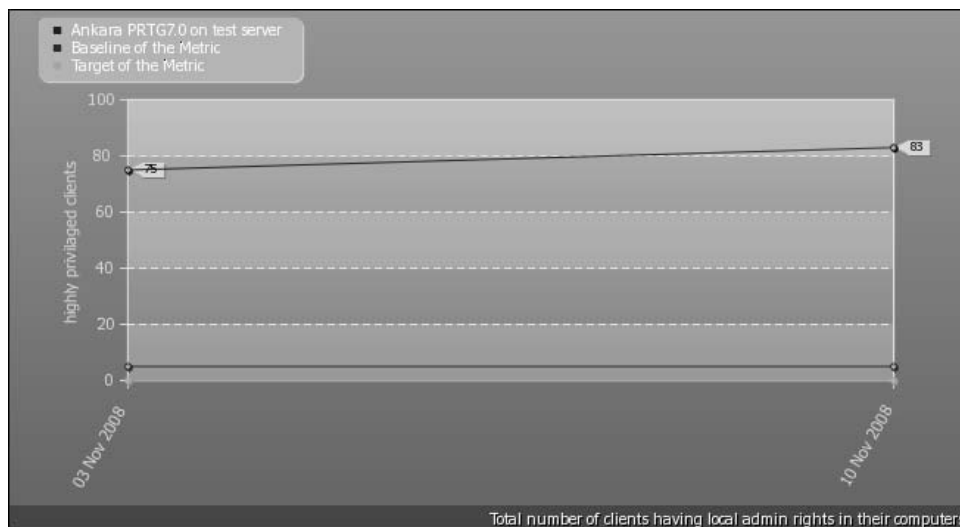


Figure 26: Total number of clients having local admin rights in their computers

Question 7: (Metric 12: Total number of clients having local admin rights in their computers)

Before the pilot study, participants of the survey gave 1.75 points to the question in which high points means “very high” and low points means “very low”. After the survey, by analyzing the report presented in Figure 26 in the review meetings, the participants gave 2.25 points to the same question. Change in the decision of the participants of the survey is consistent with report findings.

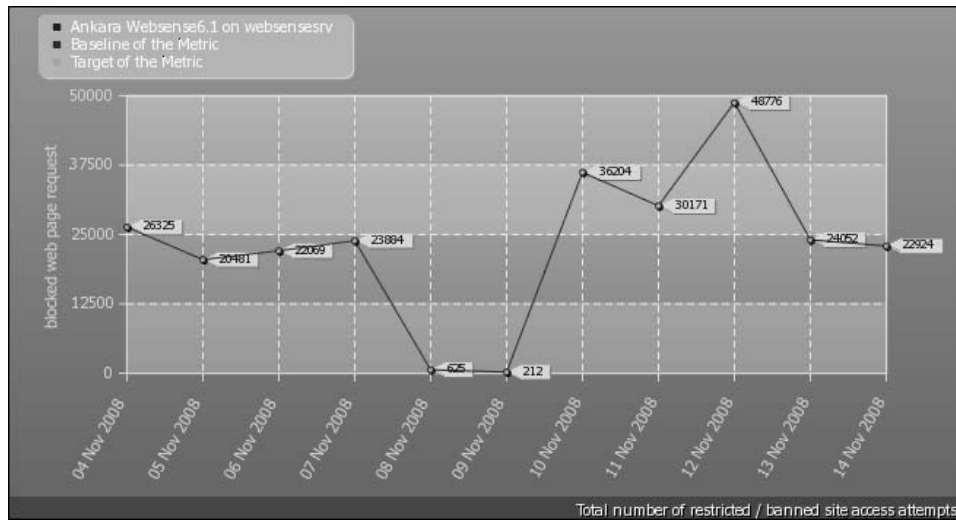


Figure 27: The number of restricted / banned site access attempts

Question 9: (Metric 22: The number of restricted / banned site access attempts)

Before the pilot study, participants of the survey gave 2.75 points to the question in which high points means “high compliance” and low points means “low compliance”. After the survey, by analyzing the report presented in Figure 27 in the review meetings, the participants gave 3.75 points to the same question. Change in the decision of the participants of the survey leads that the 25,000 block page rating’s neighborhood is commented as not bad among the security stakeholders.



Figure 28: Total number of unapplied patches in business-critical servers

Question 11: (Metric 26: Total number of unapplied patches in business-critical servers)

Before the pilot study, participants of the survey gave 4 points to the question in which high points means “at an optimum level” and low points means “at a critical level”. After the survey, by analyzing the report presented in Figure 28 in the review meetings, the participants gave 3.25 points to the same question. Change in the decision of the participants of the survey is consistent with report findings as there are numerous critical vulnerabilities detected on the servers.

When the survey results are considered, it is interesting and impressive that the stakeholder’s IT security perception has changed parallel to the findings in the CSMF, which verifies the claim.

Therefore, the objective is validated.

Obj-2) To assess policy compliance:

Information security measures development process identifies the information security program/approach to develop the measures. Therefore, the employed measures represent a part or whole of the information security program in the organization.

Detailed development of the measures includes the baseline values which are the minimum accepted level for the measure, and target values denote the optimum or expected level for the measure. The metric values over the baseline indicate the policy compliance for that metric and the metric values above the target value of the metric indicate fulfillment of the performance targets for the relevant metric. As proposed by the CSMF, it is possible to build custom reports or even dashboards to report on the compliance level of the organization.

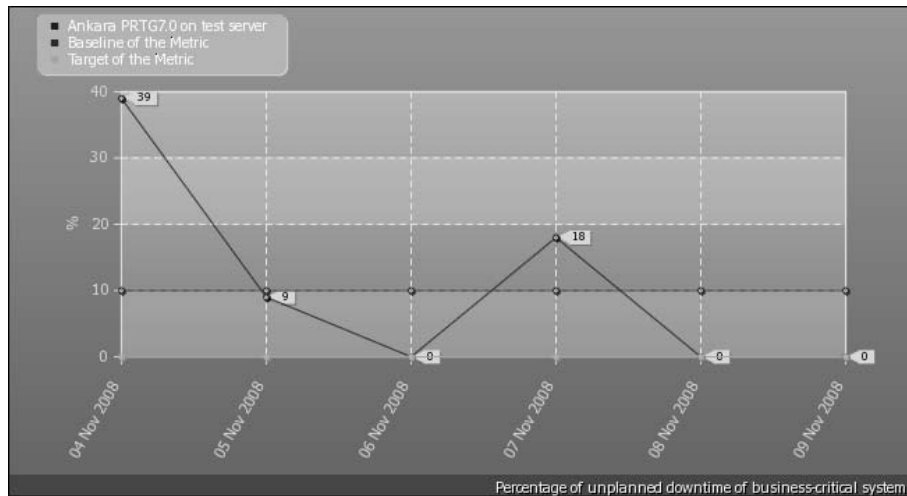


Figure 29: A sample metric report identifying policy compliance/non-compliance level

Figure 29 presents the “Percentage of unplanned downtime of business critical systems” from the pilot study. The red line indicates the baseline, the blue line indicates the metric data and the green line indicates the target values. The values under the baseline show the days that organization has complied with the requirements of the stated metric definition. Being able to report on compliance level and having examples in the pilot work are the valid requirements for validating the objective.

Obj-3) To determine non-compliance:

The validation method of objective 2 and 3 are identical, therefore, same introductory information of objective 2 is valid for objective 3. The metric values below the baseline show policy or performance non-compliance for the relevant metric. In figure 29, the values above the baseline show the days that the organization has not complied with the requirements of the stated metric definition. Being able to report non-compliance and having examples in the pilot study are the valid requirements for validating the objective.

Obj-4) To detect technical problems

CSMF introduces diagnostic reports for the detection and report of technical problems. Diagnostic reports can be defined as the reporting of metrics that lack metric data in the expected time frame. This report will point the problematic situation in a product, collection method or the stakeholder who is responsible for collecting the metric data.

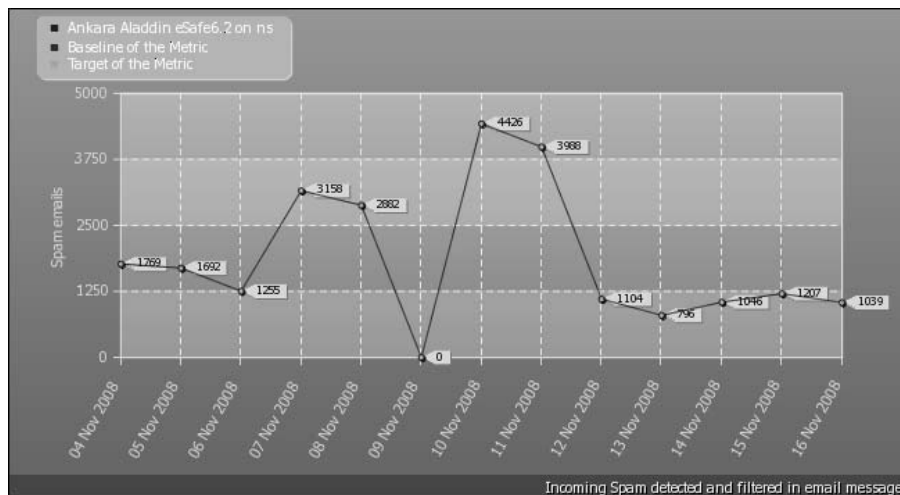


Figure 30: Metric report identifying technical problems Sample-1

An example from the pilot installation might be the “incoming spam detected and filtered in e-mail messages” metric whose report can be seen on Figure 30. Although numerous spam messages are filtered each day, on 9th of November, the detected number of spam e-mail messages is zero. On the other hand, on 9th of November, it has been checked that other system components are healthy. This might mean two things; spam filtering product does not function at all or it functions improperly. The answer turns out to be the first alternative.

CSMF may help the organizations not only to identify shortage of services but also the problems that may arise due to efficiency of the system components. An example of this statement is the patch management system in the pilot organization. During the 3rd week of the pilot study, it has been observed that the non-compliance percentage of hosts dramatically increased, which can be checked from the metric report in Figure 31. Investigating the reasons of the problem, it has been detected out that the patch management system does not effectively distribute the new patches to the client computers. In other words, patch management system is able to distribute the required patches to the clients between 5 to 10 days. As it is not a technical limitation embodied by the product, it has been concluded that either a configuration mistake or a system error caused this problem.

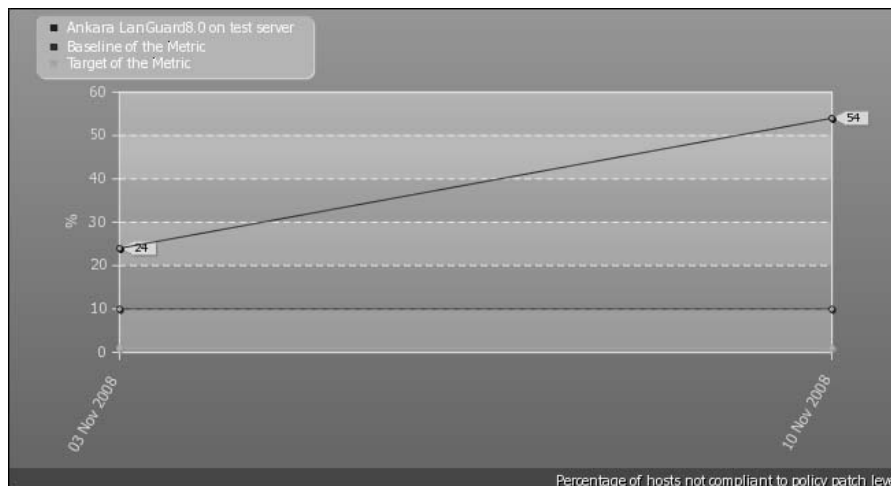


Figure 31: Metric report identifying technical problems Sample-2

Being able to identify shortage of services and problems of the system components are the valid requirements to validate the objective.

Obj-5) To decrease the complexity of security monitoring

Security reporting based on security products’ reporting increase the complexity of security monitoring as discussed during the proposal of the CSMF. Assuming that the implementation of the framework covers a part or whole aspects of the information security program in the organization, the CSMF’s reporting approach decreases the complexity of reporting by:

- Enabling central management and release of the security metric reports
- Providing central access and authorization control/management of the reports
- Providing simple yet powerful design that helps intuitive use of the reporting module
- Providing interactive reports instantly which meet the demands of the users
- Providing dashboard views customizable per user, that is supplying user reporting requirements in one view.

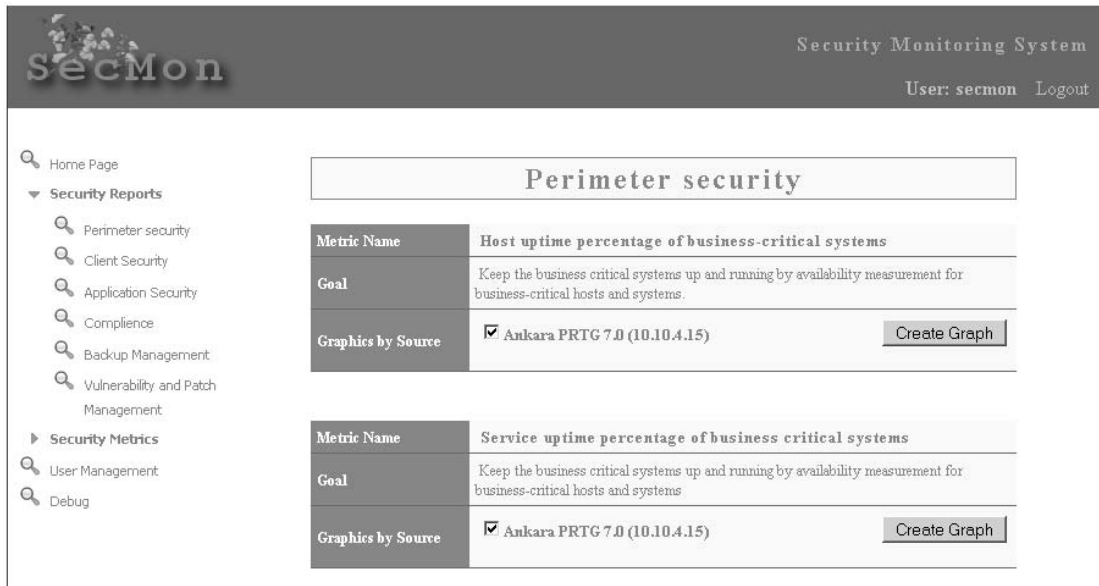


Figure 32: Sample reporting view from SecMon application

Figure 32 presents a sample view of the reporting component of the SecMon application. Current version of the SecMon application meets the first three requirements which can be easily observed from Figure 32. Although interactive reports and dashboards are available in the proposed framework, due to limited time it was not possible to implement these functionalities.

As the CSMF is able to satisfy the requirement of decreasing the complexity of reporting, it can be said that the objective is validated.

Obj-6) To report on the basis of users' needs

CSMF discuss that three levels of reporting is needed in the organizations: executive level reporting (to enable managers to gain an insight into IT systems), administrator level reporting (measuring technical security level of the organization to meet organizational technical objectives) and technical reporting (to identify technical problems). CSMF introduces strategic dashboards, tactical dashboards and operational dashboards to meet the requirements of each level of reporting respectively. In addition to the dashboards, CSMF proposes standard, custom and diagnostic reports to meet the various reporting needs of system users. CSMF offers various types of reports meeting the needs of the users, which is adequate in itself to validate the objective.

Obj-7) To give an idea to the managers and administrators about security trends and current situation IT security in the organization

As discussed in objective 2, information security measures development process identifies the information security program/approach, and the employed measures give a partial or overall picture of the information security program in the organization. The reporting types introduced by the CSMF helps the users (both managers and administrators) to monitor the security trends and to visualize the current situation of IT security in the organization.

The reporting component of the SecMon application may be used to justify this argument with production data from the pilot study.

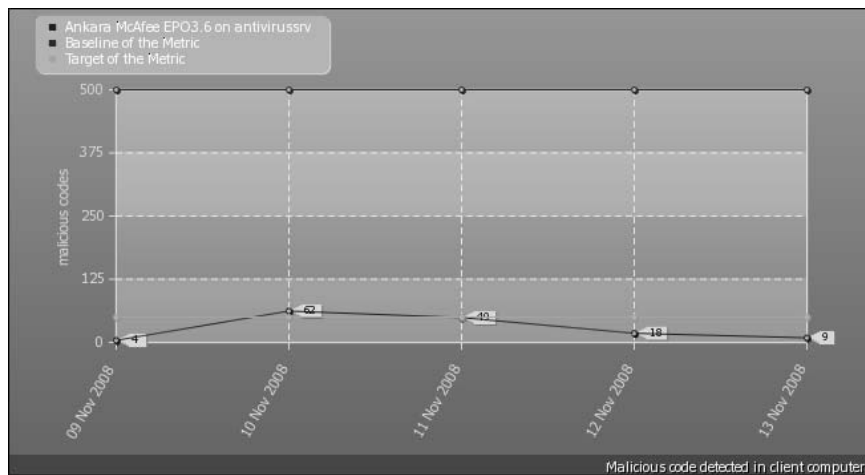


Figure 33: Last 5 days report of the malicious code detected in client computers

Figure 33 is an example of the malicious code detected in client computers over the last 5 days. Considering the metric definition, this metric is defined as technical implementation metric which is mainly used by the security administrators. Managers may browse the efficiency/effectiveness and impact metrics to obtain executive level reports.

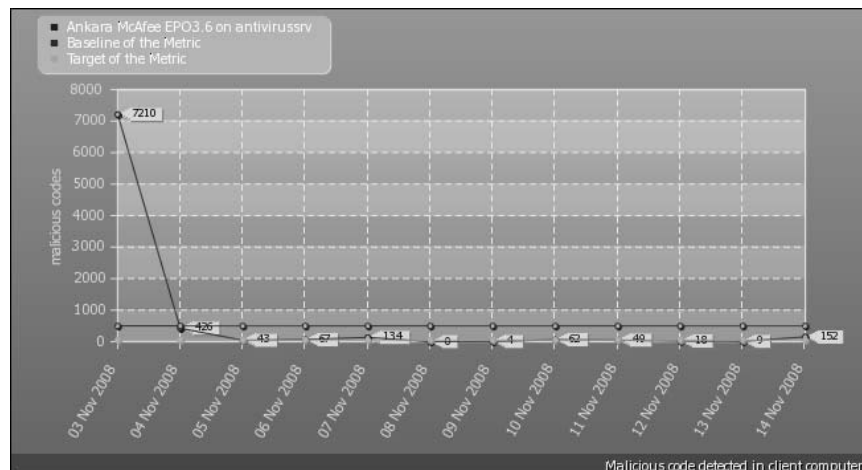


Figure 34: Last 2 weeks report of malicious code detected in client computers

Trend based reporting is also supported by the SecMon application. Having a flexible architecture, system users query the SecMon application to generate reports spanning large time intervals. Due to limited data available in the pilot system, Figure 34 reports only the last 2 weeks malicious code detected in client computers metric, which can be regarded as the trend report. Therefore, reporting capabilities of the CSMF make the framework adequate to validate the objective.

Obj-8) To improve the security level of the organization in the course of time

Effective management of continuous security monitoring using CSMF offers prospects for the achievement of various improvements in the security level of the organization. This objective is validated via many examples during the pilot study.

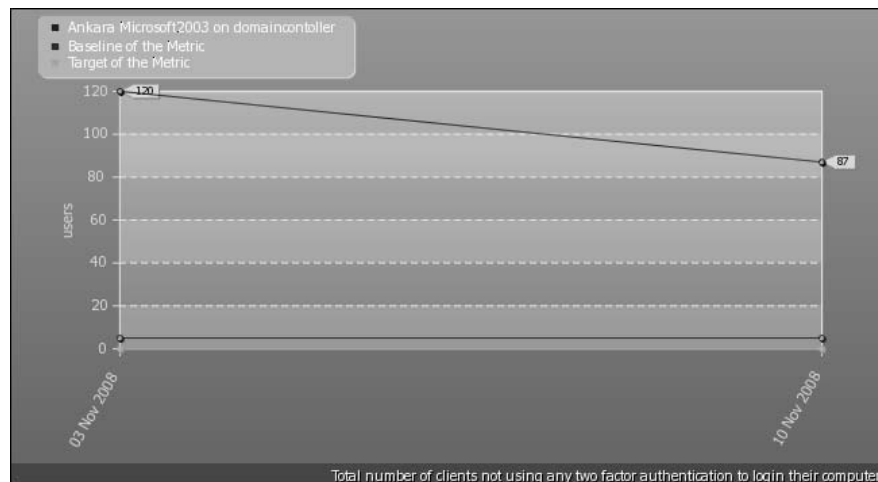


Figure 35: Metric report for the total number of clients not using any 2-factor authentication

Figure 35 represents the last 2 weeks reporting of the total number of clients not using any two factor authentication to login their computers metric. The measurement made in the 1st week of November reveals that there are 120 non-compliant users who do not use any two factor authentication. During the review meeting, it has been discussed that this number exceeds the expected number of privileged users in the system and the review process is planned. The measurement made in the 2nd week of November reveals that the metric value has dropped to 87. This indicates that 28% of the privileged users did not comply with the security policy.

Therefore, the continuous security monitoring lifecycle proposed by the CSMF makes the framework adequate to validate the objective.

Obj-9) Provide Benchmarking

Objective of this item is the use of the CSMF for benchmarking. With the accumulated metric data it is possible for the organizations to compare their security level with respect to the other organizations. Although methodologies for benchmarking surveyed during the literature survey, it was not possible to propose a benchmarking methodology.

Therefore, the proposed CSMF failed to satisfy this objective.

CHAPTER 7

SUMMARY AND CONCLUSION

The CSMF is proposed to monitor the organizational security in line with the needs and requirements of the organizations. As security monitoring is affected by various components (like size of the IT systems, management approach, system administrators/operators, business sector, size of the organization, maturity of the IT systems etc.) this makes the security monitoring requirements and implementation unique for each organization. That is to say, a security monitoring implementation which is successful in organization A does not necessarily work for organization B.

Seeing continuous security monitoring as a life cycle, likewise PDCA cycle, is the most critical feature of the CSMF. In addition to the goals and expected gains of the framework, NIST's guide discusses the side effects of employing the framework as: "Measures that are ultimately selected for implementation will be useful not only for measuring performance, identifying causes of unsatisfactory performance, and pinpointing improvement areas, but also for facilitating consistent policy implementation, affecting information security policy changes, redefining goals and objectives, and supporting continuous improvement."

Although the proposed CSMF is discussed in details, it is for sure that some aspects in relation to the implementation of CSMF may be unclear for the reader. As the implementation chapter covers the application of the CSMF to an organization and validation chapter includes the results and findings of the implementation of the CSMF, it is expected that the unclear points will be clarified throughout these chapters.

7.1 Results

After an overview of the continuous security monitoring concept and related technologies, a continuous security monitoring framework based on security metrics is proposed. Utilizing the security metrics concept is the one of the milestones of the thesis since security metrics concept already includes the measures development, collection, storage and reporting steps in its architecture. The NIST Special Publication 800-55 Revision-1 “Performance Measurement Guide for Information Security” is found to be the most applicable guide. While sticking to the governing ideas, the guide is adopted for security monitoring.

A proposal on the CSMF is followed by designing and developing a proof of concept software application, SecMon, which facilitates the implementation of the framework in the organizations. The proposed framework with the support of the SecMon application is tested in a medium-sized public organization in Turkey. It is a pleasure to see that the proposed framework meets the goals and most of the defined objectives of the thesis, thus the framework is evaluated as successful.

The major advantages brought by the approach presented in this thesis are:

- The creation of organizational memory which enhances the IT security perception
- The idea given to the stakeholders about the security trends in the organization
- The decrease in the complexity of security monitoring
- The improvement in the security level of the organization in the course of time
- The simplified assessment of the policy compliance and non-compliance

These contributions can be ensured by the organizations by only utilizing the organizational dynamics without any additional investment. This statement should not confuse the reader as the proposed framework is not a plug and play tool. In addition to making some configuration changes in the system devices, organizations need to provide human resources and ensure participation of the management for the success of the implementation. The statement underlines that just by making use of existent resources in the organization one can ensure the above mentioned contributions without buying any additional service or product. It should be noted that the use of organizational resources for the implementation of the CSMF has a cost, which needs to be taken into consideration.

The use of the proposed framework has the following additional advantages:

- Evaluate and enhance the efficiency of the products in the organization.
- Identify technical problems.
- Decrease detection and response time to the incidents.

Although being minor issues, the proposed framework can be improved by means of the followings as discussed during the implementation process:

- Adding metric procedure and metric implementation details to the metric definition
- A way to link the metric data to the raw event and logs can be introduced for enhancing the performance of the framework for the administrators.
- Report explanations in the metric definition or report template can be introduced to support the system users while analyzing the reports.
- Measurement selection can also be introduced for the pre-selection of the IT Security categories.

Having a few prerequisites, CSMF can be easily implemented in any organization. The sustainability of the implementation is one of the main requirements of the process. Taking this point into account, organizations can decide on the implementation cost and burden in line with their available resources.

Proposing a systematical approach to continuous security monitoring, continuous security monitoring framework is a powerful tool for monitoring the IT security in the organizations.

7.2 Future Work

There are many areas in which the proposed framework can be extended as a future work. Here is the list of items that can be discussed as future work:

- Introducing a risk analysis approach, including asset management and categorization, will enhance the type and content of the reports. Therefore, the framework can be named continuous risk monitoring, which will contribute the adjustment of IT systems to the business needs.

- The missing objective security benchmarking is left as a future work. Benchmarking reports is an important tool for the organizations to see how they are performing in their sector and compare their IT security level with the security best practices.
- A cost benefit analysis discussion can be a future work that is important for the organizations to analyze the Return on Investment of the CSMF.

For the SecMon application, the future work items can be as follows:

- The Preprocessor's can be developed for the automatic metric collection including wide number of application support.
- Implementation of the custom reports and dashboards is an important point missing in the application. These additional components contribute significantly to reporting performance.
- Introducing an auto response for the user-configured cases (sending email, command injection etc.) will decrease the response time to the threats and increase the effectiveness of the system.

REFERENCES

Bejtlich, R. (2004). *The Tao of Network Security Monitoring: Beyond Intrusion Detection*, Addison-Wesley Professional.

Chew, E., M. Swanson, et al. (2008). *Performance measurement guide for information security*, NIST.

Denning, D. E. (1987). "An Intrusion-Detection Model." *IEEE Transactions on Software Engineering* SE-13(2): 11.

DeRodeff, C. (2002). *Got correlation? Not without normalization*, Arcsight.

El-Hassan, F., A. Matrawy, et al. (2008). *Quantitative Evaluation of Network Security: A Case Study of Intrusion Detection Metrics*. Carleton university technical report - sce-08-05. Carleton university.

FFIEC (2006). "Information Systems IT Examinations Handbook." 138.

Hinson, G. (2006). "Seven myths about information security metrics." ISSA.

ISF (2006). *Information Security Metrics Report*. Information Security Forum. 48.

Jaquith, A. (2007). *Security Metrics: Replacing Fear, Uncertainty, and Doubt*, Addison-Wesley Professional.

Kahraman, E. (2005). *Evaluating IT security performance with quantifiable metrics*. Dept. of Computer and Systems Sciences, Stockholm University. MS: 55.

Kelly, L. (2007). "IT security spending on the increase" from <http://www.computing.co.uk/computing/news/2194221/security-spending-increase>.

Kuperman, B. A. (2004). A categorization of computer security monitoring systems and the impact on the design of audit sources, Purdue University: 151.

Lennon, E. B. (2003) IT security metrics. National Institute of Standards and Technology, Computer Security Resource Center.
<http://csrc.nist.gov/publications/nistbul/bulletin08-03.pdf>

Lowans, P. W. (2002). Implementing a Network Security Metrics Program. SANS.

Mukosaka S., Koike H. 2007 Integrated Visualization System for Monitoring Security in Large-Scale Local Area Network, Asia-Pacific Symposium on Visualization 2007

Nichols, E. A. and G. Peterson (2007). "A Metrics Framework to Drive Application Security Improvement." IEEE Security and Privacy 5(2): 88-91.

Nichols, E. A. (2008). Metrics Center: Technical Note
http://www.plexlogic.com/images/Metrics_Center_Note-1_v4.pdf

Opacki D. 2005 Security Metrics: Building Business Unit Scorecards.
http://www.adotout.com/BU_Scorecards.pdf

Payne, S. C. (2006). A Guide to Security Metrics. SANS.
http://www.sans.org/reading_room/whitepapers/auditing/55.php

Ranavel, P. (2006). "Effective Operational Security Metrics." Infosectoday.

Rayford B. Vaughn, J., R. Henning, et al. (2003). Information Assurance Measures and Metrics " State of Practice and Proposed Taxonomy. Proceedings of the 36th Annual Hawaii International Conference on System Sciences (HICSS'03) - Track 9 - Volume 9, IEEE Computer Society.

Robinson, C. (2005) Collecting Effective Security Metrics. CSO Online, Data Protection.
http://www.csoonline.com/article/219182/Collecting_Effective_Security_Metrics

Ross, R., S. Katzke, et al. (2007). Recommended Security Controls for Federal Information Systems.

Sademies, A. (2004) Process approach to information security metrics in Finnish industry and state institutions.

Savola, R. (2007). Towards a Security Metrics Taxonomy for the Information and Communication Technology Industry. ICSEA: 60.

Schneier, B. (2001). "Managed security monitoring: network security for the 21st century." Computers and Security 20(6): 13.

Security Metrics Catalog, by PlexLogic (n.d.). Retrieved October 10, 2008, from <http://www.metricscenter.org/index.php/plexlogicmetricviewer>

Seddigh, N., P. Pieda, et al. (2004). Current Trends and Advances in Information Assurance Metrics. Proceeding of the Second Annual Conference on Privacy.

Swanson, M., N. Bartol, et al. (2003). Security Metrics Guide for Information Technology Systems, NIST: 99.

Villarrubia, C., E. Fern´andez-Medina, et al. (2004) Analysis of ISO/IEC 17799:2000 to be used in Security Metrics.

Wieggers, K. E. (1997). Software Metrics: Ten Traps To Avoid. Software Development.

WISSSR (2001). Information System Security Attribute Quantification or Ordering Workshop Proceedings S. S. S. a. R. workshop on Information.

APPENDICES

APPENDIX A: List of Candidate Measures

Table 14: Organized Long List of Candidate Measures

Note: Each metrics' reference is stated in Appendix B.

- 1) Perimeter security
 - i) Inbound connections/sessions to Internet-facing servers
 - ii) Average utilization of the ISP lines
 - iii) Host uptime percentage of mission critical servers
 - iv) Service uptime percentage of mission critical servers
 - v) Unplanned downtime of mission critical servers
 - vi) Percentage of systems with monitored event and activity logs
 - vii) Percentage of systems with an established contingency plan
 - viii) Number of not approved open ports on mission critical servers
 - ix) Percentage of business-critical systems under active monitoring
 - x) Percentage of critical assets/functions with cost of compromise estimated
 - xi) Number of incoming Spam detected and filtered in email messages
 - xii) Number of incoming Spam not detected/missed in email messages
 - xiii) Number of viruses and spyware detected in e-mail messages

Table 13: (Cont.)

<p>xiv) Number of outgoing viruses and spyware caught at gateway</p> <p>xv) Number of successful attacks</p> <p>xvi) Number of detected attacks targeting application servers</p> <p>2) Client security</p> <p>i) Number of malicious codes detected in client computers</p> <p>ii) Number of malicious code incidents requiring manual cleanup</p> <p>iii) Malicious code incidents' cleanup cost</p> <p>iv) Percentage of client computers covered by antivirus software</p> <p>v) Percentage of client computers with current antivirus signatures</p> <p>vi) Total Number of improper shares per end point devices</p> <p>vii) Number of not approved open ports on workstations</p> <p>viii) Number of accounts with default passwords still being used</p> <p>ix) Number of active user IDs assigned to only one person</p> <p>x) Percentage of users with authorized system access</p> <p>xi) Percentage of highly privileged employees whose privileges reviewed this period</p> <p>xii) Total number of clients having local admin rights in their computers</p> <p>xiii) Total number of clients not using any two factor authentication</p> <p>xiv) Total number of clients' failed logins to the computers</p> <p>xv) Percentage of directory accounts dead or disabled</p> <p>xvi) Cycle time to remove terminated or inactive users</p> <p>xvii) Percentage of inactive/terminated user accounts disabled per policy</p> <p>xviii) Total number of denied connection attempts from client computers to the low ports of the servers located in the server segment.</p> <p>3) Application Security</p> <p>i) Cost of security for revenue-generating systems</p> <p>ii) Cycle time to grant customer/partner access to company systems</p>

Table 13: (Cont.)

<ul style="list-style-type: none">iii) Number of unauthorized customer/partner transactions, by applicationiv) The number of users with access to secure software and applications without being security administratorsv) Number of pending audit items, and estimated time to completevi) Total number of transaction done in the application serversvii) Total number of researchers using the application serversviii) Average number of transactions done by each researcher using application serversix) Maximum number of transactions done from a single IP address using the application servers <p>4) Compliance</p> <ul style="list-style-type: none">i) Malicious codes detected on websitesii) What is the number of restricted / banned site access attempts <p>5) Backup management</p> <ul style="list-style-type: none">i) Percentage of backup media stored with third partiesii) Percentage of critical data that is frequently backed upiii) Percentage of systems with critical information assets or functions that have been backed up in accordance with policy [exchange]iv) Percentage of backup media stored offsite in secure storage.[exchange] <p>6) Vulnerability and Patch management</p> <ul style="list-style-type: none">i) Percentage of hosts not compliant to policy patch levelii) Total number of unapplied patches in business-critical serversiii) Unapplied patch ratioiv) Unapplied patch latency (age of missing patch, per node)v) Vulnerability identification latencyvi) Vulnerability scanner coveragevii) Monthly vulnerability counts
--

APPENDIX B: Security Metrics Employed

Table 15: Definition of Metric #1

Field	Description
Metric Definition	Host uptime percentage of business-critical servers
Goal	Keep the business critical systems up and running by availability measurement for business-critical hosts and systems
Value	between 0 and 100
Unit	%
Type	Implementation/technical
How to Calculate	Average of host uptime percentage of each business critical server
Target	99.9
Baseline	99
Frequency	Daily
Responsible parties	Network Responsible
Data sources	PRTG Network Monitor
Reporting format	line graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value < Baseline → email alert
Alert	email to Network Responsible

Procedure:

1. Use PRTG Network Monitor application's reporting to track daily host uptime percentage of each critical server.
2. Calculate the daily average host uptime percentage from the values in step 1.

Implementation details:

1. Define business critical servers to the PRTG Network monitor application.
2. Define ping health check for each defined server with the timeout period of 5 seconds.
3. Configure PRTG to report ping downtime of the critical servers on daily bases.

Table 16: Definition of Metric #2

Field	Description
Metric Definition	Service uptime percentage of business-critical systems
Goal	Keep the business critical systems up and running by availability measurement for business-critical hosts and systems
Value	between 0 and 100
Unit	%
Type	implementation
How to Calculate	Average of service uptime percentage of each business critical server
Target	99.5
Baseline	98
Frequency	Daily
Responsible parties	Network Responsible
Data sources	PRTG Network Monitor
Reporting format	line graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value < Baseline → email alert
Alert	email to System administrator

Procedure:

1. Use PRTG Network Monitor application's reporting to track daily service uptime percentage of each critical server.
2. If more than one service is running on the same server, while reporting, take the service that has the least uptime.
3. Calculate the daily average service uptime percentage from the values in step 1.

Implementation details:

1. Define the applications running on the business critical servers to the PRTG Network monitor application.
2. Define service health check for each defined service with the timeout period of 5 seconds.
3. Configure PRTG to report service downtime of the critical servers on daily bases.

Table 17: Definition of Metric #3

Field	Description
Metric Definition	Percentage of unplanned service downtime of business-critical systems to the total downtime.
Goal	Keep the business critical systems up and running by monitoring the amount of change control process variance
Value	between 0 and 100
Unit	%
Type	effectiveness/efficiency
How to Calculate	Average of unplanned downtime percentage of each business critical server
Target	0.1
Baseline	1
Frequency	Daily
Responsible parties	Network Responsible
Data sources	PRTG Network Monitor
Reporting format	bar graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value > Baseline → email alert
Alert	email to System administrator

Procedure:

1. List the SERVICE downtime date and duration for each critical server.
2. Communicate to the critical servers' responsible staff to figure out if the downtime is a planned one.
3. Calculate daily unplanned downtime of the critical servers by removing the planned downtimes from the list.
4. Using the values in step 3, calculate the "average unplanned service downtime" of the critical servers.
5. Using the average service uptime values found in metric 2, calculate the "average service downtime" of the critical servers.
6. Find the required metric by taking the percentage of the "average unplanned service downtime" to the "average service downtime" using the values found in step 4 and 5.

Implementation details:

N/A

Table 18: Definition of Metric #4

Field	Description
Metric Definition	Total number of not approved open ports on business critical servers
Goal	Ensure an environment of comprehensive security by monitoring and identifying malicious activities.
Value	$0 < x < 100,000$
Unit	open ports
Type	Implementation
How to Calculate	Sum up the number of open ports detected on each business critical server
Target	0
Baseline	5
Frequency	weekly
Responsible parties	OS Responsible
Data sources	Nessus network vulnerability scanner
Reporting format	bar chart
Reference	in house developed
State	Reviewed
Alert Criteria	metric value > Baseline → email alert
Alert	email to System administrator

Procedure:

1. Use Nessus Vulnerability Scanner application with port_scanner policy to scan the TCP and UDP ports of the critical servers.
2. List the open ports for each critical server.
3. Communicate to the critical servers' responsible staff to figure out if the open ports are used by the authorized services. This will give the number of unapproved open ports on each critical server.
4. Find the required metric by summing up the number of unapproved ports in each server.

Implementation details:

1. Define the port_scanner policy on the Nessus Vulnerability Scanner application having:
 - a. All plug-ins disabled.
 - b. With “Nessus TCP scanner”, “netstat portscanner” (both SSH and WMI) enabled only.
2. For easier management of the policies in Nessus, Nessgui application is used.

Table 19: Definition of Metric #5

Field	Description
Metric Definition	Number of incoming Spam detected and filtered in email messages
Goal	Ensure an environment of comprehensive security by filtering spam email messages
Value	$0 \leq x < 100,000,000$
Unit	spam email messages
Type	implementation
How to Calculate	Total count of incoming email messages blocked as spam in the antispam gateway
Target	-
Baseline	-
Frequency	daily
Responsible parties	Security Responsible
Data sources	Gateway antispam system
Reporting format	bar chart
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value = 0 → email alert
Alert	email to System administrator

Procedure:

1. Get the total number of spam emails filtered from daily statistics report
2. Get the total number of spam emails filtered from previous day's report
3. Subtract the current day's spam value from the previous day's spam value to calculate the required metric data.

Implementation details:

1. Write a script to take a copy of the statistics file of the antispam gateway system.
2. Schedule via crontab configuration to run the script everyday at 23:59.

By this way, for each day a distinct statistics file will be created, that will be used by the defined procedure.

Table 20: Definition of Metric #6

Field	Description
Metric Definition	Number of incoming Spam not detected/missed in email messages
Goal	Ensure an environment of comprehensive security by filtering spam email messages
Value	$0 \leq x < 100,000,000$
Unit	spam email messages
Type	implementation
How to Calculate	Total count of incoming email messages blocked as spam in the email server
Target	400 (max 1 spam emails per mail account)
Baseline	-
Frequency	daily
Responsible parties	Security Responsible
Data sources	eMail server antispam software
Reporting format	line chart
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	
Alert	

Procedure:

1. Browse the McAfee Groupshield reports: Detected Items→Spam
2. Query the spam report for the required day.
3. Total count of spam email in the report is the required metric data.

Implementation details:

N/A

Table 21: Definition of Metric #7

Field	Description
Metric Definition	Number of outgoing email viruses and spywares caught at gateway
Goal	Ensure an environment of comprehensive security by monitoring the indicators of internal infections
Value	$0 \leq x < 100,000,000$
Unit	malicious email messages
Type	implementation
How to Calculate	Total count of email messages blocked as spam in the email server
Target	0
Baseline	100
Frequency	daily
Responsible parties	Security Responsible
Data sources	Gateway antivirus/antispam system
Reporting format	line chart
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value > baseline → email alert
Alert	email to System administrator

Procedure:

1. Get the total number of outgoing malicious code filtered from daily statistics report
2. Get the total number of malicious code filtered from previous day's report
3. Subtract the current day's spam value from the previous day's malicious code value to calculate the required metric data.

Implementation details:

1. Write a script to take a copy of the statistics file of the gateway antivirus/antispam system.
2. Schedule via crontab configuration to run the script everyday at 23:59.
By this way, for each day a distinct statistics file will be created, that will be used by the defined procedure.

Table 22: Definition of Metric #8

Field	Description
Metric Definition	Number of detected attacks targeting application servers
Goal	Ensure an environment of comprehensive security by monitoring the indicators of malicious activity
Value	$0 \leq x < 100,000,000$
Unit	attacks
Type	implementation
How to Calculate	Total count of application level attack logs/alarms
Target	
Baseline	
Frequency	daily
Responsible parties	Security Responsible
Data sources	Firewall's IPS module's logs
Reporting format	line chart
Reference	in house built
State	Reviewed
Alert Criteria	
Alert	

Procedure:

1. Open Smartview Tracker application of Check Point Firewall management to monitor the logs.
2. Filter the logs up to the below criteria:
 - a) Destination address: web servers
 - b) Service: Http
 - c) Product: Smart Defense
 - d) Date: Specify the date
3. Count the total number of attacks using the “get number of filtered records” button which gives the required metric data.

Implementation details:

1. Update the server configuration in Check Point firewall to define the web server and application engine details of the web servers in the organization.
2. Configure the Web-Intelligence module of the Check Point firewall to monitor the incoming traffic to the defined servers.

3. Configure Web Intelligence module to block the cross-site scripting, LDAP injection, command injection and directory traversal attacks in addition to error concealment protection.

Table 23: Definition of Metric #9

Field	Description
Metric Definition	Number of malicious codes detected in client computers
Goal	Ensure an environment of comprehensive security by monitoring the indicators of infection rate on client computers
Value	
Unit	malicious codes
Type	implementation
How to Calculate	Total count of malicious codes found in client computers
Target	50
Baseline	500
Frequency	daily
Responsible parties	Security Responsible
Data sources	antivirus management system
Reporting format	line graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value > baseline → email alert
Alert	email to System administrator

Procedure:

1. Browse the McAfee ePolicy Orchestrator reports: Reporting →... → Antivirus → Detection → Detection History
2. Query the detection history report for the required day with excluding the Anti Spam statistics.
3. Total count of detected malicious codes in the report is the required metric data.

Implementation details:

N/A

Table 24: Definition of Metric #10

Field	Description
Metric Definition	Percentage of Client computers covered by antivirus software
Goal	Ensure an environment of comprehensive security by monitoring the coverage of antivirus software
Value	$0 < x < 100$
Unit	%
Type	implementation
How to Calculate	Ratio of number of Client computers covered by antivirus software to the total number of Client computers
Target	100
Baseline	95
Frequency	weekly
Responsible parties	Security Responsible
Data sources	antivirus management system
Reporting format	line graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Browse the McAfee ePolicy Orchestrator reports: Reporting →... → Antivirus → Coverage → Agent to Server Connection info
2. Query the agent to server communications in the last 5 business days
3. Addition of “live” number of agents to the “late” number of agents from the report statistics gives the total number of client computers covered by antivirus software
4. The percentage of “number of Client computers covered by antivirus software” to “the total number of Client computers” gives the required metric data.

Implementation details:

How to calculate the number of client computers in the organization:

Although there is an asset management system in the organization, it is not possible to figure out the total number of computers in production from the asset records. Thus it is decided to use two different ways to track the number of computers in the organization:

1. Track the total number of live Active Directory accounts. Knowing each user is using only one computer (with known 12 exceptions) in the organization, from the live account number it is possible to figure out the number of computers in the system. For this reason a script (namely, LastLogon.vbs) from Richard L. Mueller's web site is used.
2. The freeware application Look@Lan which is developed by Carlo Medas is used to track the number of live computers with ping control. The application can be configured to do a client check every 10 minutes and keep the discovered hosts in its repository. Although the computers in the organization are controlled by the group policy which disables the client firewall applications in the client computers, it is known that, this application may not give the total number of client computers. But it is used to double check the number that is found from the first option.

Another method that is discussed is checking the firewall logs for counting the unique number of IP addresses. Due to the topology of the organization, firewall is receiving all the broadcast traffic of the clients thus this is a more guaranteed way of counting client computers. Due to calculation complexity, it is decided to try the first and second methods first of all. In case they fail, this method will be implemented.

Table 25: Definition of Metric #11

Field	Description
Metric Definition	Percentage of Client computers with current antivirus signatures
Goal	Ensure an environment of comprehensive security by monitoring the up-to-datedness of antivirus software
Value	$0 < x < 100$
Unit	%
Type	effectiveness
How to Calculate	
Target	100
Baseline	95
Frequency	weekly
Responsible parties	Security Responsible
Data sources	antivirus management system
Reporting format	line graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Browse the McAfee ePolicy Orchestrator reports: Reporting →... → Antivirus → Coverage → DAT/Definition deployment summary
2. Query the DAT/Definition deployment summary for the last 4 versions.
3. Addition of number of client having current or max 4 out of date versions of antivirus signatures gives the total number of client computers with current antivirus signatures.
4. The total number of client computers covered by antivirus software can be used from Metric 10.
5. The percentage of total number of client computers with current antivirus signatures to the total number of client computers covered by antivirus software gives the required metric data.

Implementation details:

N/A

Table 26: Definition of Metric #12

Field	Description
Metric Definition	Total number of clients having local admin rights in their computers
Goal	Ensure an environment of comprehensive security by reviewing highly privileged client computers.
Value	$0 < x < 100,000$
Unit	highly privileged clients
Type	implementation
How to Calculate	Total count of undocumented users having admin rights in each client computer.
Target	0
Baseline	5
Frequency	weekly
Responsible parties	Hardware Sec. Manager
Data sources	Network Scanner
Reporting format	line graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Define the IP address block of the clients that will be scanned to the Microsoft Baseline Security Analyzer application.
2. Run the scanner two different days of the week, considering the probability of the client computers uptime.
3. Check the Windows scan results → Administrative Vulnerabilities → Administrators if any other user/user-group other than help desk is defined.
4. List the name of the computers that are not compliant with the control in step 3 in each list.
5. Merge the two list results to find the list of clients having local admin rights in their computers.
6. The count of computers in the list is the required metric data.

Implementation details:

N/A

Table 27: Definition of Metric #13

Field	Description
Metric Definition	Total number of clients not using any two factor authentication
Goal	Ensure an environment of comprehensive security by reviewing/monitoring usage of weak authentication schemas
Value	$0 < x < 1,000$
Unit	users
Type	implementation
How to Calculate	Total count of users not using smartcard logon.
Target	0
Baseline	5
Frequency	weekly
Responsible parties	OS Responsible
Data sources	Active Directory
Reporting format	line graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Count the total number of users in the Active Directory, whose accounts are not enforced to use smart card login, via the defined query “UsersWithoutSmartCard ”.
2. Count the total number of users in the Active Directory, whose accounts are not enforced to use smart card login AND disabled: Use the query “DisabledUsers” and “UsersWithoutSmartCard” to find the Disabled users without Smart card forced.
3. Count the total number of users in the Active Directory, whose accounts are not enforced to use smart card login AND expired: Use the query “ExpiredUsers” and “UsersWithoutSmartCard” to find the Expired users without Smart card forced.
4. Subtract “Disabled users without Smart card forced” and “Expired users without Smart card forced” from “total number of UsersWithoutSmartCard” gives the required metric data.

Implementation details:

1. Open the Active Directory Users and Computers MMC.
2. On the Saved Queries folder, right click and New→Query.

3. Define
 - a. Name: UsersWithoutSmartCard
 - b. Define Name: Custom Search → Advanced →
“(&(objectCategory=person)(objectClass=user)(!useraccountcontrol:1.2.840.113556.1.4.803:=262144))”
4. On the Saved Queries folder, right click and New→Query.
5. Define
 - a. Name: DisabledUsers
 - b. Define Name: Custom Search → Advanced →
“(&(objectCategory=person)(objectClass=user)(userAccountControl:1.2.840.113556.1.4.803:=2))”
6. On the Saved Queries folder, right click and New→Query.
7. Define
 - a. Name: ExpiredUsers
 - b. Define Name: Custom Search → Advanced →
“userAccountControl:1.2.840.113556.1.4.803:=8388608”

Table 28: Definition of Metric #14

Field	Description
Metric Definition	Total number of clients' failed logins to the computers
Goal	Ensure an environment of comprehensive security by reviewing/monitoring malicious client activities
Value	$0 < x < 10,000$
Unit	users
Type	implementation
How to Calculate	Count the number of logon failure from event logs of the DC.
Target	0
Baseline	5
Frequency	daily
Responsible parties	OS Responsible
Data sources	Active Directory
Reporting format	line graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Open Event Viewer application in the Domain Controller.
2. Right clicking on the Security logs, choose View → Filter. Define
 - a. Event ID : 675 (Authentication failure with password incorrect)
 - b. Define the date to query using the “From” and “To” parameters.
3. The total count of the events is the required metric data.

Implementation details:

1. Audit Failure is disabled by default and needs to be opened from Group Policy Management. Open the group policy manager.
2. Browse the domain controllers and edit Default Domain Controllers Policy
3. From Group Policy Object Editor browse:
 - Computer Configuration → Windows Settings → Security Settings → Local Policies → Audit Policy Audit Account Logon Events: Failure & Success
 - Audit Logon Events: Failure & Success
4. Start → Run → “gpupdate /force”

Table 29: Definition of Metric #15

Field	Description
Metric Definition	Percentage of dead or disabled active directory accounts
Goal	Ensure an environment of comprehensive security by hardening user database
Value	$0 < x < 100$
Unit	%
Type	implementation
How to Calculate	10
Target	0
Baseline	5
Frequency	weekly
Responsible parties	OS Responsible
Data sources	Active Directory
Reporting format	line graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Count the number of accounts that is not used for computer logon in the last 14 days. (As discussed in Metric 10, implementation details 1)
2. Count the number of accounts in the Active Directory that is identified as late logon AND disabled: Use the query “DisabledUsers” and Step 1 to find the late logon accounts because of disabled account.
3. Count the number of accounts in the Active Directory that is identified as late logon AND expired: Use the query “ExpiredUsers” and Step 1 to find the late logon accounts because of expired account.
4. Count the number of accounts in the Active Directory that is identified as late logon AND service account: List the service accounts and compare the list with Step 1 to find the late logon accounts because of service usage only.
5. Subtract Value (step2), Value (step3) and Value (step4) from Value (step1) gives the number of dead accounts in the AD.

6. The percentage of dead accounts to the total number of accounts gives the required metric data.

Implementation details:

N/A

Table 30: Definition of Metric #16

Field	Description
Metric Definition	Total number of denied connection attempts from client computers to the low ports of the servers located in the server segment.
Goal	Ensure an environment of comprehensive security by reviewing/monitoring malicious client activities
Value	$0 < x < 100,000$
Unit	denied connection attempts
Type	Implementation
How to Calculate	Count of Drop logs from client computers to the server pool from low ports.
Target	
Baseline	
Frequency	daily
Responsible parties	Hardware Sec. Manager
Data sources	Firewall
Reporting format	line graph
Reference	in house built
State	Reviewed
Alert Criteria	
Alert	

Procedure:

1. Open Smartview Tracker application of Check Point Firewall management to monitor the logs.
2. Filter the logs up to the below criteria:
 - e) Source address: Client networks
 - f) Destination address: Server NET
 - g) Service: TCP and UDP low ports
 - h) Action: Drop
 - i) Date: Specify the date
3. Count the total number of drop packets using the “get number of filtered records” button which gives the required metric data.

Implementation details:

N/A

Table 31: Definition of Metric #17

Field	Description
Metric Definition	Total number of transaction done in the application servers
Goal	Ensure business application security by monitoring usage trends and behaviors
Value	$0 < x < 100,000$
Unit	transactions
Type	implementation
How to Calculate	Count total number of transactions from application server logs
Target	
Baseline	
Frequency	daily
Responsible parties	Software Sec. Manager
Data sources	application server logs
Reporting format	bar graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value=0 → email alert
Alert	email to Application administrator

Procedure:

1. Application logs are stored in the DB. Execute the following SQL statement in the DB to find the required metric data:

```
Select count (*) from APPLOGS where to_char (searchtime,'dd.mm.yyyy') = '04.11.2008'
```

Note: Table name is altered for security reasons.

Implementation details:

N/A

Table 32: Definition of Metric #18

Field	Description
Metric Definition	Total number of researchers using the application servers
Goal	Ensure business application security by monitoring usage trends and behaviors
Value	$0 < x < 100,000$
Unit	researchers
Type	implementation
How to Calculate	Total count of distinct ip addresses from application server logs
Target	
Baseline	
Frequency	daily
Responsible parties	Software Sec. Manager
Data sources	application server logs
Reporting format	bar graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value=0 → email alert
Alert	email to Application administrator

Procedure:

1. Application logs are stored in the DB. Execute the following SQL statement in the DB to find the required metric data:

```
Select count (*) from APPLOGS where to_char (searchtime,'dd.mm.yyyy') = '04.11.2008' group by researcher
```

Note: Table name is altered for security reasons.

Implementation details:

N/A

Table 33: Definition of Metric #19

Field	Description
Metric Definition	Average number of transactions done by each researcher using application servers
Goal	Ensure business application security by monitoring usage trends and behaviors
Value	$0 < x < 100,000$
Unit	transactions
Type	effectiveness
How to Calculate	Divide “Total number of transaction done in application servers” by “Total number of researchers using application servers”
Target	
Baseline	
Frequency	daily
Responsible parties	Software Sec. Manager
Data sources	application server logs
Reporting format	line graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value=0 → email alert
Alert	email to Application administrator

Procedure:

1. Divide Metric 17 to Metric 18 to calculate the required metric data.

Implementation details:

N/A

Table 34: Definition of Metric #20

Field	Description
Metric Definition	Maximum number of transactions done from a single IP address using the application servers
Goal	Ensure business application security by monitoring usage trends and behaviors
Value	$0 < x < 100,000$
Unit	transactions
Type	implementation
How to Calculate	max(total number of transactions done from distinct IP addresses) from application server logs
Target	
Baseline	
Frequency	daily
Responsible parties	Software Sec. Manager
Data sources	application server logs
Reporting format	bar graph
Reference	in house built
State	Reviewed
Alert Criteria	metric value=0 → email alert
Alert	email to Application administrator

Procedure:

1. Application logs are stored in the DB. Execute the following SQL statement in the DB to find the required metric data:
Select max (count (*)) from APPLOGS where to_char (searchtime,'dd.mm.yyyy') = '04.11.2008' group by researcher
Note: Table name is altered for security reasons.

Implementation details:

N/A

Table 35: Definition of Metric #21

Field	Description
Metric Definition	Malicious codes detected on websites browsed by the clients
Goal	Ensure an environment of comprehensive security by reviewing/monitoring malicious client activities
Value	$0 < x < 100,000$
Unit	Malicious codes
Type	implementation
How to Calculate	Count of HTTP/FTP based malicious code detection logs in the gateway antivirus system.
Target	
Baseline	
Frequency	daily
Responsible parties	Security Responsible
Data sources	gateway antivirus system
Reporting format	line graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	
Alert	

Procedure:

1. Get the total number of Malicious codes detected from daily statistics report
2. Get the total number of Malicious codes detected from previous day's report
3. Subtract the current day's Malicious codes detection value from the previous day's Malicious codes detection value to calculate the required metric data.

Implementation details:

1. Write a script to take a copy of the statistics file of the gateway antivirus system.
2. Schedule via crontab configuration to run the script everyday at 23:59.

By this way, for each day a distinct statistics file will be created, that will be used by the defined procedure.

Table 36: Definition of Metric #22

Field	Description
Metric Definition	The number of restricted / banned site access attempts
Goal	Ensure an environment of comprehensive security by reviewing/monitoring malicious client activities
Value	$0 < x < 100,000$
Unit	blocked web page request
Type	implementation
How to Calculate	Count the total number of blocked web page request from Url filtering system logs/reports
Target	
Baseline	
Frequency	daily
Responsible parties	Hardware Sec. Manager
Data sources	Url Filtering System
Reporting format	Bar Graph
Reference	Kahraman (2005)
State	Reviewed
Alert Criteria	
Alert	

Procedure:

1. Browse the Websense Enterprise Explorer reports: Reporting → Disposition
2. Refine the query by defining the date
3. The number of occurrences in “Category Block” is the required metric data.

Implementation details:

N/A

Table 37: Definition of Metric #23

Field	Description
Metric Definition	Back up percentage of critical servers' business data up to the defined backup policy
Goal	Ensure an environment of comprehensive security and accountability for personnel, facilities, and products.
Value	%
Unit	$0 < x < 100$
Type	implementation
How to Calculate	Percentage of “Total number of critical servers compliant to the data backup policy” to “Total number of critical servers”
Target	100
Baseline	95
Frequency	weekly
Responsible parties	Hardware Sec. Manager
Data sources	Data protector
Reporting format	bar graph
Reference	Kahraman (2005)
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Communicate to the critical servers’ responsible staff to figure out the compliance with the defined data backup policy for each server.
2. Percentage of “Total number of critical servers compliant to the backup policy” to “Total number of critical servers” is the required metric data.

Implementation details:

N/A

Table 38: Definition of Metric #24

Field	Description
Metric Definition	Back up percentage of critical servers' operating systems up to the defined backup policy
Goal	Ensure an environment of comprehensive security and accountability for personnel, facilities, and products.
Value	%
Unit	0<x<100
Type	implementation
How to Calculate	Percentage of “Total number of critical servers compliant to the OS backup policy” to “Total number of critical servers”
Target	100
Baseline	95
Frequency	weekly
Responsible parties	Hardware Sec. Manager
Data sources	Acronis
Reporting format	bar graph
Reference	Nichols, E. A. (2008) Metrics Center
State	Reviewed
Alert Criteria	metric value < baseline → email alert
Alert	email to System administrator

Procedure:

1. Communicate to the critical servers' responsible staff to figure out the compliance with the defined Operating System backup policy for each server.
2. Percentage of “Total number of critical servers compliant to the OS backup policy” to “Total number of critical servers” is the required metric data.

Implementation details:

N/A

Table 39: Definition of Metric #25

Field	Description
Metric Definition	Percentage of hosts not compliant to policy patch level
Goal	Ensure an environment of comprehensive security and accountability for personnel, facilities, and products.
Value	%
Unit	$0 < x < 100$
Type	implementation
How to Calculate	Count the number of hosts not meeting the patch requirements of the policy/ Total number of clients * 100
Target	1
Baseline	10
Frequency	weekly
Responsible parties	OS Responsible
Data sources	network scanner
Reporting format	bar graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value > baseline → email alert
Alert	email to System administrator

Procedure:

1. Define the IP address block of the clients that will be scanned to the Microsoft Baseline Security Analyzer application.
2. Run the scanner two different days of the week, considering the probability of the client computers uptime. (Or the same scan result from Metric 12 can be used)
3. Check the Windows scan results → Security Update Scan Result → Windows Security Updates for the number of “Critical” and “Important” missing security updates.
4. List the name of the computers that have more than 5 “Critical” and “Important” missing security updates in each list.
5. Merge the two list results to find the list of clients.
6. The percentage of “number of Client computers not compliant to policy patch level” to “the total number of Client computers” gives the required metric data. (Refer implementation detail of Metric 10 for further details.)

Implementation details:

N/A

Table 40: Definition of Metric #26

Field	Description
Metric Definition	Total number of unapplied critical patches in business-critical servers
Goal	Ensure an environment of comprehensive security and accountability for personnel, facilities, and products.
Value	unapplied patches
Unit	$0 < x < 10,000$
Type	implementation
How to Calculate	Sum of the number of unapplied patches in each business-critical server identified with network scanner.
Target	0
Baseline	30
Frequency	weekly
Responsible parties	OS Responsible
Data sources	network scanner
Reporting format	bar graph
Reference	Jaquith 2007
State	Reviewed
Alert Criteria	metric value > baseline → email alert
Alert	email to System administrator

Procedure:

1. Run the predefined Nessus sessions.
2. Sum the number of “High” vulnerabilities identified by Nessus in each server to calculate the required metric.

Implementation details:

1. Scan windows servers with the following scan policy:
 - a. Credentials → Windows credentials: Define administrator credentials
 - b. Enable the following plug-ins: Backdoors, DoS, FTP, General, P2P, RPC, Remote file access, SMTP problems, SNMP, Service detection, Settings, Useless services, Web Servers, Windows, Microsoft Bulletins and User management.
2. Scan Linux servers with the following scan policy:
 - a. Credentials → SSH settings: Define root credentials

- b. Enable the following plug-ins: Backdoors, CGI abuses, CGI abuses: Xss, Databases (Oracle), Default Unix accounts, DoS, FTP, Finger abuses, Gain shell remotely, Gain root remotely, General, HP-UX Local security checks, Misc, Remote file access, SNMP, Service detection, Settings, Useless services, Web servers.
3. Define the IP addresses of the critical servers as the target hosts by grouping windows and Linux servers as different sessions.

APPENDIX C: Organizational IT Security Perception Survey

Kurumsal Güvenlik Algısı Anketi

Kurumsal güvenlik dediğimizde öne çıkan noktalarda kurumunuzun ne kadar başarılı olduğunu düşünüyorsunuz? Bu anketi doldurarak kurumsal güvenlik puanınızı belirlemiş olacaksınız.

Sorulan sorulara kurumunuzun bulunduğu duruma göre 1 ile 5 arası puanlama yapmanız beklenmektedir. Her sorunun altında puanlama ile ilgili bilgi bulunmaktadır.

Her soruyu cevaplama zorunluluğu yoktur. Cevabını bilmediğiniz veya sizinle ilgisiz olduğunu düşündüğünüz soruları lütfen cevaplamayınız.

* Required

Adınız Soyadınız: *

Göreviniz: *

1. Kurumsal sunucularınız tarafından verilmekte olan hizmetin kesintisizliğini, yaşadığımız sorunlara ve aldığımız/duyduğunuz şikayetlere bağlı olarak değerlendirir misiniz?

1 2 3 4 5

çok düşük çok iyi

2. Kurumsal sunucularınız iç ve dış tehditlere karşı maruz kaldığı güvenlik risklerinin azaltılması için sizce ne kadar sıkılaştırılmıştır? Sıkılaştırmaya, kullanılmayan servisler kapatılması ve erişim denetim listelerinin oluşturulması gibi örnekler verilebilir.

1 2 3 4 5

çok düşük çok iyi

3. Kurumunuzda mevcutta kullanılmakta olan spam eposta önleme sisteminin, spam eposta yakalamada ne kadar başarılı çalıştığını düşünüyorsunuz?

1 2 3 4 5

çok kötü çok iyi

4. Kurumunuzda dışarıya hizmet veren servislerin üzerinde çalıştığı sunucular ne sıklıkla saldırıya maruz kalmaktadır?

1 2 3 4 5

çok sık çok nadir

5. Kurumsal bilgilerin bulunduğu istemci bilgisayarları, virüs ve zararlı kod tehditlerinden ne kadar etkilenmektedir? İstemci bilgisayarlarında bulunan virüs ve zararlı kod miktarı bu tehditlerin bir göstergesi olabilir.

1 2 3 4 5

çok az çok fazla

6. İstemci bilgisayarlarında hali hazırda kullanılmakta olan McAfee virüs koruma yazılımı, sizce zararlı kodların oluşturduğu tehditlere karşı korumayı sağlamakta başarılı mıdır?

1 2 3 4 5

çok başarısız çok başarılı

7. Kurumsal kullanıcıların neden olduğu yetki aşımı sizce ne seviyededir? Yetki aşımı olarak, kurumsal bilgisayarlara izinsiz yazılım kurma, kişiye zimmetlenenin haricindeki kurumsal bilgisayarları kullanma, smartcard'sız oturum açma gibi örnekler verilebilir.

1 2 3 4 5

çok düşük çok yüksek

8. Kurumsal uygulamalardan A (kurumun güvenliği için gizlenmiştir) uygulaması dış kullanıcılar tarafından, sizce amacı dışında kötü niyetle kullanılmakta mıdır?

1 2 3 4 5

asla kesinlikle

9. Kurum çalışanlarının, yayınlanan kurumsal güvenlik politikasına dikkat edip, uyum sağlama düzeyleri sizce nedir?

1 2 3 4 5

çok düşük çok yüksek

10. Kurumunuzda kritik sunucularda uygulanan veri yedekleme sistemi sizce yeterli midir?

1 2 3 4 5

çok yetersiz çok iyi

11. Kurumunuzda yama ve zafiyet yönetimi sizce yeterli seviyede midir?

1 2 3 4 5

çok yetersiz çok iyi

APPENDIX D: Use Case Diagrams

Table 41: Use Case #1

Use Case	UC1: Submit metric definitions to the system
Description	Inputting security metric definitions developed in the Information Security Measures Development process.
Actors	Security Stakeholder assigned responsible of the metric definition.
Success Condition	Metric definition received by the system is saved.
Assumptions	Metric definition is developed in the Information Security Measures Development process.
Steps	<ol style="list-style-type: none"> 1. User inputs the metric definition to the system. 2. System does the data validation controls. 3. System saves the metric definition.
Variations	<p>#2.1 Authentication/Authorization Fails: System ignores the input</p> <p>#2.2 Data validation fails: System does not save input and reports the error condition to the user.</p> <p>#2.3 System cannot save the metric definition: System reports the error condition to the user.</p>

Table 42: Use Case #2

Use Case	UC2: Manage (query/update/delete) metric definitions
Description	Defined security metric definitions in the Information Security Measures Development process may require preview, update or deletion while performing the latter processes of the framework.
Actors	Security Stakeholder assigned responsible of the metric definition.
Success Condition	<p>The query performed is displayed by the system.</p> <p>The updated metric definition is saved by the system.</p> <p>The deleted metric successfully removed from the system.</p>
Assumptions	There are metric definitions defined in the system.
Steps	<ol style="list-style-type: none"> 1. User query/update/delete metric definition 2. System performs the query/update/delete command
Variations	<p>#2.1 Authentication/Authorization Fails: System ignores the command.</p> <p>#2.2 Updated metric definition validation fails: System does not save input and reports the error condition to the user.</p> <p>#2.3 System cannot save/delete the metric definition: System reports the error condition to the user.</p>

Table 43: Use Case #3

Use Case	UC3: Manage (define/update) users
Description	System administrators define /update security stakeholders or managers to the system.
Actors	Security Stakeholders accessing or requiring access to the system.
Success Condition	User is successfully defined to the system. User details are successfully updated in the system.
Assumptions	-
Steps	<ol style="list-style-type: none">1. User define/update the requested user details2. System performs the input validation control.3. System updates the records about updated/defined user.
Variations	#2.1 Authentication/Authorization Fails: System ignores the input #2.2 Data validation fails: System does not save input and reports the error condition to the user. #2.3 System cannot save the user details: System reports the error condition to the user.

Table 44: Use Case #4

Use Case	UC4: Delete users
Description	System administrators delete security stakeholders or managers from the system.
Actors	Security Stakeholders performing the user management of the system.
Success Condition	System user is successfully removed from the system.
Assumptions	-
Steps	<ol style="list-style-type: none">1. User queries the user who will be deleted.2. System responds with the answer of the query.3. User deletes the listed user.4. System validates if the user is linked to any metric definition or data source.5. Validated users are deleted from the system.
Variations	#2.1 Authentication/Authorization Fails: System ignores the input #4.1 User is linked to other sources: System rejects the command returning the error.

Table 45: Use Case #5

Use Case	UC5: Define log sources
Description	Define the log sources that metric data will be collected from
Actors	Security Stakeholder assigned responsible of the metric definition.
Success Condition	Log sources are successfully defined to the system.
Assumptions	-
Steps	<ol style="list-style-type: none"> 1. User defines the log source to the system. 2. System does the data validation controls. 3. System saves the log source information.
Variations	<p>#2.1 Authentication/Authorization Fails: System ignores the input</p> <p>#2.2 Data validation fails: System does not save input and reports the error condition to the user.</p> <p>#2.3 System cannot save the log source information: System reports the error condition to the user.</p>

Table 46: Use Case #6

Use Case	UC6: Define system authorization rights
Description	Defining the system users' rights for the management of the log source definitions and reporting.
Actors	Security Stakeholders performing the user management of the system.
Success Condition	System authorization right definition is saved.
Assumptions	-
Steps	<ol style="list-style-type: none"> 1. Security Stakeholders performing the user management, query the current rights of the user. 2. System responds with the answer of the query. 3. User defines/updates system authorization rights of the requested user 4. System performs the input validation control. 5. System updates the records about updated/defined user.
Variations	<p>#2.1 Authentication/Authorization Fails: System ignores the input</p> <p>#4.1 Data validation fails: System does not save input and reports the error condition to the user.</p> <p>#5.1 System cannot save the system authorization rights: System reports the error condition to the user.</p>

Table 47: Use Case #7

Use Case	UC7: Define schedules for metric data collection
Description	Define the time period that specified metric definition will be in production for the defined log source.
Actors	Security Stakeholder assigned responsible of the metric definition.
Success Condition	Metric schedule is successfully defined to the system.
Assumptions	The metric definition and log source is specified by the responsible security stakeholder
Steps	<ol style="list-style-type: none">1. User defines the metric schedule to the system.2. System does the data validation controls.3. System saves the metric schedule information.
Variations	<p>#2.1 Authentication/Authorization Fails: System ignores the input</p> <p>#2.2 Data validation fails: System does not save input and reports the error condition to the user.</p> <p>#2.3 System cannot save the metric schedule information: System reports the error condition to the user.</p>

Table 48: Use Case #8

Use Case	UC8: Submit metric data manually
Description	Responsible security stakeholder submits the collected metric data.
Actors	Security Stakeholder assigned responsible of the metric definition.
Success Condition	Metric data is successfully accepted by the system.
Assumptions	System User is authenticated and authorized Security Metric definition is defined in the system
Steps	<ol style="list-style-type: none">1. User chooses the security metric definition he/she will submit the metric data for.2. User chooses the log source he/she will submit the metric data for.3. User submits the metric data to the system.4. System saves the metric data.
Variations	<p>#3.1 Data validation fails: System does not save input and reports the error condition to the user.</p> <p>#4.1 System cannot save the metric data: System reports the error condition to the user.</p>

Table 49: Use Case #9

Use Case	UC9: Submit metric data manually automatically
Description	System device's metric data is calculated and submitted to the system
Actors	System device
Success Condition	Metric data send to system is saved
Assumptions	-
Steps	<ol style="list-style-type: none">1. System device pushes a Metric Data to system2. System saves the Metric Data
Variations	<p>#2.1 Authentication Fails: System ignores the message</p> <p>#2.2 Data validation fails: System does not save message and sends system device the validation error back</p> <p>#2.3 System cannot save the metric data : System sends system device the validation error back</p>

Table 50: Use Case #10

Use Case	UC10: Browse metric categories/definitions
Description	Security stakeholder browses the metric definitions grouped up to metric categories
Actors	Security Stakeholders
Success Condition	Requested metric definitions are displayed to the user
Assumptions	Metric definitions and categories are available in the system
Steps	<ol style="list-style-type: none">1. User query metric definitions and categories2. System displays the queried metric definitions
Variations	<p>#2.1 Authentication/Authorization Fails: System ignores the command.</p> <p>#2.2 System cannot query the metric definition: System reports the error condition to the user.</p>

Table 51: Use Case #11

Use Case	UC11: Generate report based on metric definition
Description	Security stakeholder generate report by choosing the metric definition
Actors	Security Stakeholders
Success Condition	Requested report is displayed to the user
Assumptions	Metric definitions are available in the system User is authenticated and authorized
Steps	<ol style="list-style-type: none">1. User chooses the metric definition for reporting.2. User requests the report.3. System generates and displays the metric report to the user.
Variations	#3.1 System cannot generate the report: System reports the error condition to the user. #3.2 Chosen metric definition doesn't contain any metric data: System reports the error condition to the user.

Table 52: Use Case #12

Use Case	UC12: Browse interactive reports
Description	Security stakeholder fine-tunes the interactive reports up to the requirements.
Actors	Security Stakeholders
Success Condition	Reports are customized up to the user needs.
Assumptions	Metric definitions are available in the system User is authenticated and authorized
Steps	<ol style="list-style-type: none">1. User choose the metric definition for reporting2. User request the report3. System generates and displays the report to the user.4. User updates the reporting parameters.5. System generates and displays the report up to the changed parameters.
Variations	#3.1 System cannot generate the report: System reports the error condition to the user. #3.2 Chosen metric definition doesn't contain any metric data: System reports the error condition to the user. #5.1 System cannot generate the report: System reports the error condition to the user. #5.2 System receives wrong parameters: System reports the error condition to the user.

Table 53: Use Case #13

Use Case	UC13: Customize home page
Description	System users update their homepages with their favorite reports.
Actors	Security Stakeholders
Success Condition	User updates his/her homepage
Assumptions	Metric definitions are available in the system User is authenticated and authorized
Steps	<ol style="list-style-type: none"> 1. User displays his/her favorite report. 2. User requests the displayed report to be his/her homepage report. 3. System updates the user's homepage.
Variations	#3.1 System cannot update the user's homepage: System reports the error condition to the user.

Table 54: Use Case #14

Use Case	UC14: Ask/Answer questions
Description	System users ask/answer questions that may rise while browsing the reports.
Actors	Security Stakeholders
Success Condition	User submits the question/answer to the system.
Assumptions	User is authenticated and authorized
Steps	<ol style="list-style-type: none"> 1. User browses the security report. 2. User submits the question/answer for the report. 3. System receives and publishes the question/answer for the related report.
Variations	#3.1 System cannot receive/publish the user's question/answer: System reports the error condition to the user.

Table 55: Use Case #15

Use Case	UC15: Make/Request comments
Description	System users make/request comments that may rise while browsing the reports.
Actors	Security Stakeholders
Success Condition	User submits the request for comment/comment to the system.
Assumptions	User is authenticated and authorized
Steps	<ol style="list-style-type: none"> 1. User browses the security report. 2. User submits the request for comment/comment for the report. 3. System receives and publishes the request for comment/comment for the related report.
Variations	#3.1 System cannot receive/publish the user's request for comment/comment: System reports the error condition to the user.

Table 56: Use Case #16

Use Case	UC16: Manage report templates
Description	System users customize report templates up to their reporting needs.
Actors	Security Stakeholders
Success Condition	System saves the updated report templates up to the needs of the users.
Assumptions	User is authenticated and authorized There are defined report templates in the system
Steps	<ol style="list-style-type: none"> 1. User browses the available report templates. 2. User submits the request for changes for the report templates. 3. System saves the additional reports to the available reports.
Variations	<p>#1.1 System cannot display the report templates: System reports the error condition to the user.</p> <p>#2.1 System cannot receive the user's request for changes: System reports the error condition to the user.</p> <p>#3.1 System cannot save the additional report definition: System reports the error condition to the user.</p>