Assessment of Six E-Mail Encryption Solutions Using an Utility Value Analysis

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Abstract

E-mail is one of the most frequently used form of communication. Confidentiality, integrity and authenticity are often indispensable in e-mail communication, especially in business use. However, these security objectives can only be guaranteed with the help of additional encryption solutions. Today, there are a variety of client, gateway and software-as-a-service solutions for e-mail encryption. Companies are faced with the challenge of finding the most suitable solution for them. Our research work presents findings from a utility value analysis which provides a comprehensive process for assessing and selecting an appropriate solution for securing e-mail traffic. We present the basic principles behind the utility value analysis and how it is used for the evaluation process of e-mail encryption solutions. In addition, we document how our methodology was applied in a practice-based project to make a selection decision between six existing e-mail encryption solutions.

1. Introduction

Since Ray Tomlinson's first e-mail in 1971 [1] this asynchronous communication issue has evolved to a mass phenomenon with strong effects to all personal and business spheres. The total number of business and consumer e-mails sent and received per day will reach in 2017 269 billion and is expected to continue to grow to 319.6 billion by the end of 2021 [2]. Especially the impact in business communication is enormous. But in this case, it is essential to ensure that e-mail content remains confidential between the sender and the receiver, especially if the e-mail includes sensitive information like HR data, payment related data, financial records or intellectual property [3]. The main solution is encrypting the e-mail. The reality in practice very often looks quite different. According to a study of Ponemon Institute, 61% of the respondents said that employees sent sensitive data unencrypted through e-mail [4]. Another survey conducted by Osterman Research indicates that e-mail encryption is used "extensively" by only 40 percent of organizations [5]. On the other hand, there is a wide

world of e-mail encryption solutions available [6]. This variety of solutions shows that the main problem has changed from looking for a method of e-mail encryption to selecting the most suitable encryption solution.

The objective of our work is to derive a methodology for the selection of a suitable e-mail encryption solution based on the utility value approach. Furthermore, the applicability of the methodology should be presented in a practice-based project.

The paper is organized as follows: In the next section we define important terms in the context of the paper and provide a summary of related work. In section 3 we give an overview of the utility value analysis and describe how it can be used to assess and select an e-mail encryption solution. Finally, we conclude the paper with a brief summary and an outlook of future research.

2. Related work

E-mail encryption solutions in this paper are all products that use cryptographic methods to improve the confidentiality, integrity or authenticity of e-mail communications [7, 8]. Based on [9] we distinguish between three different types of products:

- client solutions: cryptographic methods are used directly on the clients of the senders and receivers of e-mails,
- gateway (or server-based) solutions: central, organization-internal systems provide the functions for securing e-mail communication,
- and software-as-a-service (or cloud-based) solutions: organization-external providers enable encryption, decryption, signing and verification of e-mails.

There are a large number of alternatives for all three types of e-mail encryption solutions. Schneider et al. identify a total of 89 e-mail encryption solutions as part of a worldwide survey on encryption hardware and software products [6]. Various market studies

assume that the offered amount of solutions will continue to grow and predict a strong growth of the global e-mail encryption market over the next few years [10, 11].

There is certainly literature that contains criteria and recommendations for selecting e-mail encryption solutions. The National Institute of Standards and Technology (NIST) publishes guidelines on the security of electronic messages to help organizations develop, set up and operate their e-mail systems [12]. Requirements and comparison criteria for e-mail encryption solutions can be derived from this, for example. Moecke and Volkamer identify evaluation criteria covering security, usability, and interoperability aspects of e-mail security, and to apply them to existing solutions [13]. Fox describes requirements for e-mail security solutions, specifies important evaluation criteria and gives an overview of the most important standards for e-mail security [14]. On this basis he develops exemplary decision-making aids and makes recommendations for the selection of suitable solutions. Without evaluating specific products, other authors also compare the different types of e-mail encryption solutions (client, gateway, SaaS), discuss their advantages and disadvantages and derive typical applications and recommendations from them [9].

A systematic and yet flexible methodology for selecting e-mail encryption solutions is currently missing.

3. Methodical approach and results

We use the utility value analysis (UVA) as a basic methodical guideline for structuring and justifying the selection process. The UVA provides a set of complex action alternatives with the purpose of arranging the elements of this set according to the decision-maker's preferences regarding a multi-dimensional target system [15].

Generally, the UVA is structured in following five steps:

1. Define target system
2. Determine target returns
3. Determine target values
4. Determine weighting of target criteria
5. Perform value synthesis [16].

In the following sections we will explain, how we had applied this methodology to support the selection process for an appropriate encryption solution in a practice-based project. In this project, we evaluated six solutions (two client, two gateway, and two software-as-a-service solutions) that were preselected by our practice partner. The selection was oriented on current comparison tests of practical IT-journals [17, 18]. Following six e-mail encryption solutions were selected:

- Mailvelope v1.3.6,
- Gpg4win v2.3.1,
- SEPPMail Gateway 500,
- Z1 SecureMail Gateway,
- Mailbox.org,
- StartMail.com.

The approach, selecting the software solutions by referring to practically relevant IT-journals ensures that the considered alternatives are current and practically relevant.

3.1. Define target system

There is no generally applicable approach for defining the target system. However, it makes sense to aim for a minimization of the targets with simultaneous completeness and redundancy free [8]. We performed a literature analysis to identify the main targets. We queried ACM Digital Library, AISeL, EBSCOhost, IEEE Xplore, ScienceDirect, Springer-Link, Google Scholar and a previous selected set of specialized journals with the following terms: “e-mail, encryption, software, solution” combined with “criteria, compar*, evaluation, select*, choose”. As a result, we were able to compile the functional and non-functional targets shown in Table 1.

Table 1. Compiled Target System

Functional Targets	Non-Functional Targets
High confidentiality of message exchange (VN)	Low installation effort (IA)
High integrity assurance during message exchange (IN)	Low acquisition costs (AK)
High identity assurance of the communication partners (IK)	Low operating costs (BK)
Ensure high availability (VB)	Ease of operation (EB)
Large scope of services (LU)	Good support (SU)
	High trustworthiness of the manufacturer/provider (HV)
	High system/product maturity (SR)
	Good integrability (IB)

In order to operationalize the target system, we defined suitable target criteria for all targets, with the help of the previous selected literature. For this purpose, the targets were broken down into sub-targets (target criteria). Table 2 shows the result of this top-down procedure.

For each target criterion, we defined possible criterion values and determined how they can contribute to the achievement of the target. This is briefly outlined below using the target criteria VN2 and VN3 as an example.

The target criterion VN2 “Place of encryption” states, where or rather on which system the encryption and decryption of e-mail takes place. We distinguish three possible criteria values: client, gateway and external.

Table 2. Target criteria

Targets / Target criteria	
High confidentiality of message exchange (VN)	
VN1	Content encryption procedure
VN2	Place of encryption
VN3	Encrypting e-mail attachments
VN4	Transport encryption procedure
VN5	Enhancements to transport encryption
High integrity assurance during message exchange (IN)	
IN1	Signature creation and verification possible
High identity assurance of the communication partners (IK)	
IK1	Creation of certificates possible
IK2	Signature creation and verification possible
Ensure high availability (VB)	
VB1	Dependence on the manufacturer/provider
Large scope of services (LU)	
LU1	Spam and malware filtering
LU2	Secure communication with non-PGP and -S/MIME users
LU3	Data Loss Prevention (DLP)
LU4	Sending large files
LU5	Subsequent encryption of incoming e-mail
Low installation effort (IA)	
IA1	Creation of key pairs by the end user
IA2	Certification of the public keys for each end user, if necessary
IA3	Publishing of the public keys to all communication partners by end users
IA4	Collection of public keys from all communication partners by end users
IA5	Installation and configuration of software on all client PCs, if necessary
IA6	Installation and configuration of central software, if necessary
Low acquisition costs (AK)	
AK1	One-time costs
Low operating costs (BK)	
BK1	Regular (monthly) costs
Ease of operation (EB)	
EB1	Additional user actions required when sending / receiving
EB2	Knowledge of encryption and signing required
Good support (SU)	
SU1	Help function on homepage, e. g. FAQ, documentation, interactive e-mail support
SU2	Hotline

SU3	On-site service
High trustworthiness of the manufacturer/provider (HV)	
HV1	Data protection, legal regulations in the country of origin
HV2	Awards
HV3	Known vulnerabilities, backdoors
HV4	Source code viewable
HV5	Experience in the fields of encryption, secure digital communication, etc.
HV6	References
High system/product maturity (SR)	
SR1	Period since the first product generation appeared
Good integrability (IB)	
IB1	Secure e-mail communication from mobile devices possible
IB2	Availability/compatibility with desktop operating systems
IB3	Compatibility with e-mail clients

The confidentiality of message exchange is even better, the closer the content encryption/ decryption process is located to the sender and receiver systems. The highest level of target achievement is possible if encryption or decryption takes place directly on the client systems of the communication partners and e-mails are thus transmitted in encrypted form on the entire transmission path (end-to-end). Encryption using in-house gateways at least ensures that the e-mails are encrypted from or to the company boundary. It is assumed that this is less confidential than end-to-end encryption. If the encryption/decryption is carried out by an external service provider, a further reduction in confidentiality can be assumed. The target criterion VN3 “Encryption of e-mail attachments” can be used to check whether only the e-mail messages themselves or their attachments are encrypted. Greater confidentiality of message exchange can be achieved if both e-mail messages and attachments are transmitted in encrypted form.

3.2. Determine target returns

In the second step, for each alternative (evaluated e-mail encryption solutions) the target returns are determined for each target criterion.

For this, we analysed the datasheets, product descriptions, whitepapers, manuals and similar documents. This approach ensures, that the target returns are compiled objective and are not attached by the user's subjective cognition. In case that the target returns cannot be determined this way, we contacted or interviewed the manufacturer's support.

Table 3 shows a cutout of the complex matrix for the first target and its target criteria. The complete table with the determination of all target criteria for all six analysed solutions can be found at Appendix 1.

Table 3. Cutout of the Target Returns Matrix

Target: High confidentiality of message exchange (VN) Target criteria: Content encryption procedure (VN1) Place of encryption (VN2) Encrypting e-mail attachments (VN3) Transport encryption procedure (VN4) Enhancements to Transport Encryption (VN5)				
	Alternative Solutions			
	Mailvelope	Z1 SecureMail Gateway	StartMail.com	...
VN1	OpenPGP	OpenPGP, S/MIME	OpenPGP	
VN2	Client-PC	Gateway (intern)	StartMail Server (extern)	
VN3	No	Yes	No	
VN4	TLS 1.2	TLS 1.2	TLS 1.2	
VN5	PFS, DANE via add-ons	PFS	PFS	
...				

3.3. Determine target values

The relatively freely formulated alphanumeric target returns cannot be compared properly with each other. Therefore, they are transformed into non-dimensional quantities and represented in so-called target values. In our case, the target returns are transformed into target values according to a five-level nominal scale (1 – insufficient ... 5 – very good). In Table 4 we show the same matrix cutout with its target values. The full target value matrix can also be found at Appendix 2.

Table 4. Cutout of the Target Value Matrix

	Alternative Solutions			
	Mailvelope	Z1 SecureMail Gateway	StartMail.com	...
VN1	3	5	3	
VN2	5	4	1	
VN3	1	5	1	
VN4	5	5	5	
VN5	5	4	4	
...				

3.4. Determine weighting of target criteria

In order to take into account, the individual application context of the encryption solution, which expresses itself through individual requirements, a weighting of the target criteria is necessary. For example, acquisition costs can have a different weighting depending on the amount of financial resources allocated. In our practice-based project, weights were used on the target level and not on the target criteria level. Furthermore, these weights were collected through a survey where security and IT

specialists were interviewed with the help of questionnaires. The weights of the targets have been passed on to their criteria. Table 5 shows the target weights for our practice-based project.

Table 5. Average Weighted targets

Functional Targets							
VN	IN	IK	VB	LU			
3.8	3.6	3.8	3.2	2.4			
Non-Functional Targets							
IA	AK	BK	EB	SU	HV	SR	IB
2.6	3.0	3.4	2.8	2.8	3.2	2.6	3.6

(4 – important ... 1 – not important; abbreviations see Table 1)

3.5. Perform value synthesis

In the final step of the utility value analysis the target values are multiplied with the weights and summed up to the so-called total benefit for each alternative. A detailed documentation of the calculation of the total benefits can be found in Appendix 3. According to the principle of utility value analysis, the alternative is considered to be the "best" with the greatest overall benefit. In Figure 1 the final results are shown for our set of alternative solutions.

Figure 1. Total benefits of the alternative solutions

4. Conclusion

In this paper, we have applied the utility value analysis (UVA) as a decision support concept to the selection process of encryption solutions for e-mail communication. In our practice-oriented project, Z1 SecureMail Gateway from Zertificon is the solution with the greatest overall benefit. We were able to show that the selection process is made much more transparent by the UVA in particular because the individual requirements of users can be taken into account directly in the selection process by weighting the target criteria.

In order to regard the individual requirements in the selecting process even more it could be useful to perform the UVA twice. By the first UVA, the product

category (client, gateway, cloud-based) is selected. By the following second UVA, the concrete product within the category is selected. Such a cascaded approach furthermore has the advantage, that more category-specific criteria could be regarded within the second UVA.

5. References

- [1] T. Campell, The first email message, <https://www.cs.umd.edu/class/spring2002/cmsc434-0101/MUIseum/applications/firstemail.html> (Accessed: 2017-09-11).
- [2] The Radicati Group, Email Statistics Report 2017-2021, Feb 2017, <https://www.radicati.com/wp/wp-content/uploads/2017/01/Email-Statistics-Report-2017-2021-Executive-Summary.pdf> (Accessed: 2017-09-11).
- [3] Thales, Global encryption trends 2017, Apr 2017, <https://gets.thalesecurity.com/pdf/ponemon-global-encryption-trends-study-infographic.pdf> (Accessed: 2016-07-05).
- [4] Phomenon, The state of email encryption, 2017, <https://www.laninfotech.com/email-security> (Accessed: 2017-07-05).
- [5] Osterman Research, Enterprise Encryption and Authentication Usage, 2016, <https://www.echoworx.com/assets/Enterprise-Encryption-and-Authentication-Usage-A-Survey-Report.pdf> (Accessed: 2017-09-05).
- [6] B. Schneier, K. Seidell, and S. Vijayakumar, A Worldwide Survey of Encryption Products, 2016, <https://www.schneier.com/academic/paperfiles/worldwide-survey-of-encryption-products.pdf> (Accessed: 2017-09-26).
- [7] B. Schneier, *Secrets & Lies*, dpunkt, Heidelberg, 2004.
- [8] B. Schneier, *E-mail Security. How to Keep Your Electronic Messages Private*, John Wiley & Sons, New York, 1995.
- [9] DsN - Deutschland sicher im Netz, Verschlüsselung von E-Mails – Leitfaden zur E-Mail-Sicherheit für Unternehmen, Berlin, 2015, <https://www.sicher-im-netz.de/sites/default/files/download/leitfaden-e-mail-verschluesselung.pdf> (Accessed: 2017-08-07).
- [10] Technavio, Global E-mail Encryption Market 2017-2021, Dec 2016, <https://www.technavio.com/report/global-it-security-global-e-mail-encryption-market-2017-2021> (Accessed: 2017-10-10).
- [11] MarketsandMarkets, Email Encryption Market by Deployment Type, Industry Vertical, and Region - Global Forecast to 2020, Nov 2015, <http://www.marketsandmarkets.com/Market-Reports/email-encryption-market-182623205.html> (Accessed: 2017-05-15).
- [12] National Institute of Standards and Technology (NIST), Guidelines on Electronic Mail Security, SP 800-45 Version 2, Feb 2007.
- [13] C. Moecke, M. Volkamer, “Usable secure E-Mail communications – criteria and evaluation of existing approaches,” in *Information Management & Computer Security*, vol. 21, no. 1, 2013, pp. 41-52.
- [14] D. Fox, “E-Mail-Sicherheit: Kriterien, Standards und Lösungen,” in *Datenschutz und Datensicherheit*, vol. 25, no. 8, 2001, pp. 452-458.
- [15] C. Zangemeister, *Nutzwertanalyse in der Systemtechnik*, Books on Demand, Norderstedt, 2014.
- [16] L. Heinrich, R. Riedl, D. Stelzer, *Informationsmanagement: Grundlagen, Aufgaben, Methoden*, Oldenbourg, München, 2014.
- [17] H. Bleich, „Abhörsicher Mail-Services im Test,“ in *Überwachung abwehren*, c't wissen Sonderheft, 09/2015, pp. 66-91.
- [18] T. Bär, “Tests: SEPPmail VM Secure E-Mail Gateway 500“, in *IT-Administrator*, 02/2015, pp. 20-26.

Appendix 1: Target Returns Matrix

Targets / Target criteria	Alternative Solutions					
	Mailvelope	Z1 SecureMail Gateway	StartMail.com	Gpg4win	SEPPMail Gateway	Mailbox.org
High confidentiality of message exchange (VN)						
VN1: Content encryption procedure	OpenPGP	OpenPGP, S/MIME	OpenPGP	OpenPGP, S/MIME	OpenPGP, S/MIME	OpenPGP
VN2: Place of encryption	Client-PC	Gateway (intern)	StartMail Server (extern)	Client-PC	Gateway (intern)	Mailbox.org Server (extern)
VN3: Encrypting e-mail attachments	No	Yes	No	Yes	Yes	Yes
VN4: Transport encryption procedure	TLS 1.2	TLS 1.2	TLS 1.2	TLS 1.2	TLS 1.2	TLS 1.2
VN5: Enhancements to transport encryption	PFS, DANE via add-ons (firefox/chrom)	PFS	PFS	PFS	PFS (in the pipeline DANE)	PFS, DANE
High integrity assurance during message exchange (IN)						
IN1: Signature creation and verification possible	Yes	Yes (automatically or manually from end user)	Yes	Yes	Yes (automatically or manually from end user)	Yes
High identity assurance of the communication partners (IK)						
IK1: Creation of certificates possible	No	Yes	No	Yes	Yes	No
IK2: Signature creation and verification possible	Yes	Yes (automatically or manually from end user)	Yes	Yes	Yes (automatically or manually from end user)	Yes
Ensure high availability (VB)						
VB1: Dependence on the manufacturer/provider	Software and add-on must be available for download	Gateway must be available (hardware or software, VM)	Service must be available	Software package must be available for download	Gateway must be available (hardware or software, VM)	Service must be available
Large scope of services (LU)						
LU1: Spam and malware filtering	No	Yes	Yes	No	Yes	Yes
LU2: Secure communication with non-PGP and -S/MIME users	No	Yes	Yes	No	Yes	Yes
LU3: Data Loss Prevention (DLP)	No	Yes	No	No	No	No
LU4: Sending large files	No	Yes	No	No	Yes	No
LU5: Subsequent encryption of incoming e-mail	No	No	No	No	No	Yes
Low installation effort (IA)						
IA1: Creation of key pairs by the end user	Yes	No	Yes	Yes	No	Yes
IA2: Certification of the public keys for each end user, if necessary	No	Only when using S/MIME	No	Only when using S/MIME	Only when using S/MIME	No
IA3: Publishing of the public keys to all communication partners by end users	Yes	Yes	Yes, but automatic signature creation is not possible	Yes	Yes	Yes
IA4: Collection of public keys from all communication partners by end users	Yes	Yes, but only attached signatures are automatically read and saved	Yes, but only automatically if the recipient is also a user of StartMail	Yes	Yes, but only attached signatures are automatically read and saved	Yes, but only automatically if the recipient is also a user of mailbox.org
IA5: Installation and configuration of software on all client PCs, if necessary	Yes	No	No	Yes	No	No
IA6: Installation and configuration of central software, if necessary	No	Yes	No	No	Yes	No
Low acquisition costs (AK)						
AK1: One-time costs	No	Yes, depending on number of employees and scope of functions	No	No	Yes, depending on number of employees and scope of functions	No
Low operating costs (BK)						
BK1: Regular (monthly) costs	No	-	Yes	No	-	Yes
Ease of operation (EB)						
EB1: Additional user actions required when sending / receiving	Yes	Depending on the settings at the gateway, user interaction can be completely avoided	Yes, optional it is possible that every outgoing e-mail is encrypted automatically	Yes, sometimes very cumbersome operation, e. g. sending, selecting certificates and encrypting attachments	Depending on the settings at the gateway, user interaction can be completely avoided	Yes, optional it is possible that every outgoing e-mail is encrypted automatically
EB2: Knowledge of encryption and signing required	Yes	Not necessarily (if the gateway is configured accordingly)	Yes	Yes	Not necessarily (if the gateway is configured accordingly)	Yes
Good support (SU)						
SU1: Help function on homepage, e. g. FAQ, documentation, interactive e-mail support	Yes (FAQ, user documentation)	Yes	Yes (FAQ, e-mail support)	Yes (multilingual, e-mail support, very detailed user documentation)	Yes	Yes (FAQ, web forum, e-mail support)
SU2: Hotline	No	Yes	No	No	Yes	No
SU3: On-site service	No	Yes, initial start-up by Zertificon possible	No	No	Yes, initial start-up by SEPPMail possible	No
High trustworthiness of the manufacturer/provider (HV)						
HV1: Data protection, legal regulations in the country of origin	Germany	Germany	Netherlands	Sweden/ Germany	Switzerland	Germany
HV2: Awards	No	Product of the year 2002 (Internet World magazine)	No	No	No	Test winner of Stiftung Warentest (Feb 2016)
HV3: Known vulnerabilities, backdoors	No	No	No	No	No	No
HV4: Source code viewable	Yes	No	No	Yes	No	Yes, partly (OX Guard)
HV5: Experience in the fields of encryption, secure digital communication, etc.	approx. 4 years	approx. 15 years	approx. 9 years	approx. 10 years	approx. 15 years	approx. 25 years
HV6: References	Use of certified DE-Mail providers	e.g. Allianz, IBM, Stiftung Warentest, Deutscher Sparkassen- und Giroverband	-	-	e.g. ING DiBa, EON, KPMG	-
High system/product maturity (SR)						
SR1: Period since the first product generation appeared	approx. 4 years	approx. 10 years	approx. 2 years	approx. 10 years	approx. 14 years	approx. 12 years
Good integrability (IB)						
IB1: Secure e-mail communication from mobile devices possible	Yes, but only via the apps of WEB.DE or GMX	No	No	No	No	No
IB2: Availability/compatibility with desktop operating systems	Microsoft Windows 7-10, Mac10.6 or higher, Linux Debian, Ubuntu, Fedora, OpenSuse	Independent of desktop OS (as embedded in the SMTP stream)	Microsoft Windows, Mac, Linux	Only Microsoft Windows OS (XP...10)	Independent of desktop OS (as embedded in the SMTP stream)	Microsoft Windows, Mac, Linux
IB3: Compatibility with e-mail clients	Only web mailer	All clients, no restrictions	All clients, no restrictions	Microsoft Outlook (Plug-in)	All clients, no restrictions	All clients, no restrictions

Appendix 2: Target Value Matrix

Targets / Target criteria	Alternative Solutions						Notes on transformation of target returns to target values
	Mailvelope	Z1 SecureMail Gateway	StartMail.com	Gpg4win	SEPPMail Gateway	Mailbox.org	
High confidentiality of message exchange (VN)							
VN1: Content encryption procedure	3	5	3	5	5	3	Best case S/MIME and PGP, then only one of the procedures; No content encryption would be the worst-case scenario.
VN2: Place of encryption	5	4	1	5	4	1	
VN3: Encrypting e-mail attachments	1	5	1	5	5	5	Better, the closer to the client PC.
VN4: Transport encryption procedure	5	5	5	5	5	5	Best case: Yes
VN5: Enhancements to transport encryption	5	4	4	4	4	5	Best case: TLS 1.2
The more extensions, the better it is.							
High integrity assurance during message exchange (IN)							
IN1: Signature creation and verification possible	5	5	5	5	5	5	Best case: Yes
High identity assurance of the communication partners (IK)							
IK1: Creation of certificates possible	1	5	1	5	5	1	Best case: Yes
IK2: Signature creation and verification possible	5	5	5	5	5	5	Best case: Yes
Ensure high availability (VB)							
VB1: Dependence on the manufacturer/provider	3	3	1	3	3	1	The worst performers are service providers.
Large scope of services (LU)							
LU1: Spam and malware filtering	1	5	5	1	5	5	Best case: Yes
LU2: Secure communication with non-PGP and -S/MIME users	1	5	5	1	5	5	Best case: Yes
LU3: Data Loss Prevention (DLP)	1	5	1	1	1	1	Best case: Yes
LU4: Sending large files	1	5	1	1	5	1	Best case: Yes
LU5: Subsequent encryption of incoming e-mail	1	1	1	1	1	5	Best case: Yes
Low installation effort (IA)							
IA1: Creation of key pairs by the end user	1	5	1	1	5	1	Best case: No
IA2: Certification of the public keys for each end user, if necessary	5	5	5	1	5	5	Best case: No
IA3: Publishing of the public keys to all communication partners by end users	1	3	1	1	3	3	Best case: No
IA4: Collection of public keys from all communication partners by end users	1	3	2	1	3	2	Best case: No
IA5: Installation and configuration of software on all client PCs, if necessary	1	5	1	1	5	1	Best case: No
IA6: Installation and configuration of central software, if necessary	5	1	5	5	1	5	Best case: No
Low acquisition costs (AK)							
AK1: One-time costs	5	1	5	5	1	5	Less is better.
Low operating costs (BK)							
BK1: Regular (monthly) costs	5	5	4	5	5	3	Less is better.
Ease of operation (EB)							
EB1: Additional user actions required when sending / receiving	2	4	3	2	4	3	Best case: No
EB2: Knowledge of encryption and signing required	3	5	3	2	5	3	Best case: No
Good support (SU)							
SU1: Help function on homepage, e.g. FAQ, documentation, interactive e-mail support	4	3	3	5	3	4	Best case: Yes
SU2: Hotline	1	5	1	1	5	1	Best case: Yes
SU3: On-site service	1	5	1	1	5	1	Best case: Yes
High trustworthiness of the manufacturer/provider (HV)							
HV1: Data protection, legal regulations in the country of origin	5	5	4	5	4	5	
HV2: Awards	1	4	1	1	1	5	Better, the more awards.
HV3: Known vulnerabilities, backdoors	5	5	5	5	5	5	Better, the less known security vulnerabilities.
HV4: Source code viewable	5	1	1	5	1	5	Best case: Yes
HV5: Experience in the fields of encryption, secure digital communication, etc.	2	5	4	4	5	4	More experience is better.
HV6: References	4	5	1	1	5	1	Many well-known customers are better.
High system/product maturity (SR)							
SR1: Period since the first product generation appeared	2	4	2	4	5	4	The longer, the better
Good integrability (IB)							
IB1: Secure e-mail communication from mobile devices possible	3	1	1	1	1	1	Best case: Yes
IB2: Availability/compatibility with desktop operating systems	4	5	4	3	5	4	Better compatibility is better.
IB3: Compatibility with e-mail clients	2	5	2	3	5	2	Better compatibility is better.

Appendix 3: Calculation of the Total Benefits (Value Synthesis)

Target criteria	Alternative Solutions					
	Mailvelope	Z1 SecureMail Gateway	StartMail.com	Gpg4win	SEPPMail Gateway	Mailbox.org
VN 1	3	5	3	5	5	3
VN 2	5	4	1	5	4	1
VN 3	1	5	1	5	5	5
VN 4	5	5	5	5	5	5
VN 5	5	4	4	4	4	5
Subtotal VN	19	23	14	24	23	19
Weight VN	3.8					
Partial Benefit VN ¹	72.2	87.4	53.2	91.2	87.4	72.2
IN 1	5	5	5	5	5	5
Subtotal IN	5	5	5	5	5	5
Weight IN	3.6					
Partial Benefit IN	18	18	18	18	18	18
IK 1	1	5	1	5	5	1
IK 2	5	5	5	5	5	5
Subtotal IK	6	10	6	10	10	6
Weight IK	3.8					
Partial Benefit IK	22.8	38	22.8	38	38	22.8
VB 1	3	3	1	3	3	1
Subtotal VB	3	3	1	3	3	1
Weight VB	3.2					
Partial Benefit VB	9.6	9.6	3.2	9.6	9.6	3.2
LU 1	1	5	5	1	5	5
LU 2	1	5	5	1	5	5
LU 3	1	5	1	1	1	1
LU 4	1	5	1	1	5	1
LU 5	1	1	1	1	1	5
Subtotal LU	5	21	13	5	17	17
Weight LU	2.4					
Partial Benefit LU	12	50.4	31.2	12	40.8	40.8
IA 1	1	5	1	1	5	1
IA 2	5	5	5	1	5	5
IA 3	1	3	1	1	3	3
IA 4	1	3	2	1	3	2
IA 5	1	5	1	1	5	1
IA 6	5	1	5	5	1	5
Subtotal IA	14	22	15	10	22	17
Weight IA	2.6					
Partial Benefit IA	36.4	57.2	39	26	57.2	44.2
AK 1	5	1	5	5	1	5
Subtotal AK	5	1	5	5	1	5
Weight AK	3.0					
Partial Benefit AK	15	3	15	15	3	15
BK 1	5	5	4	5	5	3
Subtotal BK	5	5	4	5	5	3
Weight BK	3.4					
Partial Benefit BK	17	17	13.6	17	17	10.2
EB 1	2	4	3	2	4	3
EB 2	3	5	3	2	5	3
Subtotal EB	5	9	6	4	9	6
Weight EB	2.8					
Partial Benefit EB	14	25.2	16.8	11.2	25.2	16.8
SU 1	4	3	3	5	3	4
SU 2	1	5	1	1	5	1
SU 3	1	5	1	1	5	1
Subtotal SU	6	13	5	7	13	6
Weight SU	2.8					
Partial Benefit SU	16.8	36.4	14	19.6	36.4	16.8
HVA 1	5	5	4	5	4	5
HVA 2	1	4	1	1	1	5
HVA 3	5	5	5	5	5	5
HVA 4	5	1	1	5	1	5
HVA 5	2	5	4	4	5	4
HVA 6	4	5	1	1	5	1
Subtotal HVA	22	25	16	21	21	25
Weight HVA	3.2					
Partial Benefit HVA	70.4	80	51.2	67.2	67.2	80
SR 1	2	4	2	4	5	4
Subtotal SR	2	4	2	4	5	4
Weight SR	2.6					
Partial Benefit SR	5.2	10.4	5.2	10.4	13	10.4
IB 1	3	1	1	1	1	1
IB 2	4	5	4	3	5	4
IB 3	2	5	2	3	5	2
Subtotal IB	9	11	7	7	11	7
Weight IB	3.6					
Partial Benefit IB	32.4	39.6	25.2	25.2	39.6	25.2
Total Benefit ²	341.8	472.2	308.4	360.4	452.4	375.6

¹ The part benefit of a target is calculated by multiplying the weight with the sum of the target values (“subtotal”).

² The total benefit results from the addition of the partial benefits. The alternative is considered to be the “best” with the greatest overall benefit.