Evaluating the Effectiveness of the Early Warning Information System (EWIS)

Mohamed SaadEldin(✉) and Alya Hussain Mubarak

Foresight and Decision Making Support Center, Dubai Police, Dubai, United Arab Emirates
mmsaad@hotmail.com, aahm300@yahoo.com

Abstract. Measuring the effectiveness of information systems (IS) is an issue that has generated a great deal of debate among academics and practitioners and has been the subject of much research. The aim of this research is to define an effective EWIS, to identify and rank its characteristics, and to evaluate it against these characteristics. This research also provides guidance to those setting up new early warning information systems and to those managing and reviewing current systems.

Keywords: Early warning · Decision support · Forecasting · Indicator

1 Introduction

The expression 'Early Warning' is used in many fields to mean the provision of information on an emerging dangerous circumstance where that information can enable action in advance to reduce the risks involved. A universally accepted definition of an EWS does not yet exist and most probably never will. An EWS can be defined as "a social process for generating maximally accurate information about possible future harm and for ensuring that this information reaches the people threatened by this harm, as well as others disposed to protect them from the harm" [2]. An *'Early Warning Information System (EWIS)'* can be understood as a set of institutional and technical solutions designed and implemented in a coherent way to make available, to a wide range of users and more particularly to decision makers, information useful to carry out vulnerability analyses, to evaluate and manage the risk of a hazard that can become a disaster, and to manage disasters from prevention to recovery and rehabilitation [3]. The objective of EWIS is to generate accurate information to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property or the environment. An effective information system is essential to the success of any business or organization. The effectiveness of information systems (IS) is a complex variable. The literature on organizational effectiveness suggests that it may not be possible to find a precise measure of IS effectiveness and the criteria for effectiveness may vary from one organization to another [1]. A good architecture for an information system attempts to balance the conflicting criteria of functionality, usability, reliability, performance, portability, and maintainability. Any information system (IS) derives its value from the impact it

Á. Rocha et al. (eds.), *Recent Advances in Information Systems and Technologies*,
Advances in Intelligent Systems and Computing 569, DOI 10.1007/978-3-319-56535-4_72

has on the performance of an organization [4]. The literature on organizational effectiveness suggests that it may not be possible to find a precise measure of IS effectiveness and that the criteria for effectiveness may vary from one organization to another [2]. System effectiveness is a function of system availability, capability, and dependability [5]. Evaluating the effectiveness of an Information System is a complicated process due to its multidimensionality, its quantitative and qualitative aspects, and the multiple and often conflicting evaluator viewpoints [4]. Researchers agree that IS effectiveness depends on the organizational effects produced by an information system [5]. Information systems will improve decision-making, by providing more timely and more accurate information, stimulating more interaction among decision-makers, and offering better projections of the effects of decisions [7]. The effectiveness of IS can be determined by comparing performance to objectives or by attainment of a normative state [8]. Effective early warning systems not only save lives, but also help protect livelihoods and national development gains [9].

2 Characteristics of Effective Early Warning Information Systems

A good structure is one that is useful, robust, and beautiful. This simple 2000 year-old definition attributed to the Roman architect Vitruvius, is also true of Information Systems. Users of Information Systems will judge its effectiveness by these 3 criteria, and achieving a balance between the 3 is the mark of a good Information System [10]. The good information system can also be identified by the following characteristics: Accessibility, Accuracy, Simplicity, Flexibility and Security [11]. Other researchers have characterized good information systems as being: understandable, relevant, complete, available, reliable, concise, timely and cost-effective [12]. A system's usefulness depends upon its functionality, usability, and maintainability. A system's robustness depend upon performance and reliability. A system designer must be able to select the criteria applicable to solve the posed problems more effectively [10]. The ISO 9126, an open standard for software quality, provides 6 primary architectural criteria that system designers can use to find the best fit. These criteria, and some of their primary concerns, are as follows: Functionality, Usability, Reliability, Maintainability, Performance and Portability. According to Carlson (1974), IS effectiveness is concerned with those effects on an organization that result from the development and use of an information system. Every organization should determine the main criteria for a given system, and to determine the sequence in which each priority will be addressed. From last review of previous studies, we have concluded that the effectiveness of the EWIS is determined using a number of factors that differ from one organization to another.

3 Validating the Effectiveness of EWIS

According to the effectiveness criteria previously explained in this research, we have obtained the following results:

1- Integration: The implemented EWIS sub-models are integrated into a unified model (Generic Model), The generic model is divided into set of sub-models with specific inputs and outputs. Every sub-model consists of a number of processes and functions. Each process has a number of identifying attributes: such as process name, input, output, executed by the user or the system, etc. The researchers have divided the generic model into a number of sub-models in order to facilitate and accelerate the process of development and construction of the EWIS, in addition to making it easier to evaluate each sub-model. The generic model is constructed and refined through the incremental prototyping concept (iterative series of prototype).

2- Availability: An Effective EWIS is largely dependent upon the availability of current and reliable information, which is processed to facilitate decision-making and enhance productivity. The literal meaning of ‘availability’ is “the readiness to be obtained or used”. It is a measure of the time duration when the system under consideration not only remains up without any outages, but also performs the desired function efficiently and optimally and remains accessible to its desired users. There must be some kind of metric associated with the system’s availability. Researchers generally measure availability do it in terms of Latency [13], Mean Time to Fail (MTTF) and Mean Time to Repair (MTTR) [14], also known as Mean Time to Restore & Mean Time Between Failure (MTBF). These criteria measure the amount of time an information source was unavailable, but from different perspectives. MTBF and MTTR are the most commonly used metrics [15]. MTBF measures the average amount of time between failures, on the

Table 1. Calculation of availability in year 2012, 2013

Month	[a]Downtime (hrs)		[b]Uptime (hrs)		[c]Availability %	
	2012	2013	2012	2013	2012	2013
January	11	5	709	715	98.47	99.31
February	9	4	711	716	98.75	99.44
March	6	3	714	717	99.17	99.58
April	8	2	712	718	98.89	99.72
May	4	1	716	719	99.44	99.86
June	2	2	718	718	99.72	99.72
July	1	3	719	717	99.86	99.58
August	3	4	717	716	99.58	99.44
September	5	5	715	715	99.31	99.31
October	3	6	717	714	99.58	99.17
November	7	3	713	717	99.03	99.58
December	8	1	712	719	98.89	99.86
Average availability	67	39	8573	8601	99.22	99.55

[a]Downtime refers to periods when a system is unavailable, which includes communication failures, hardware failures, software failures, power failure, overload, recovery period… etc.
[b]Uptime should be (24 h* 30 days) = 720 h
[c]Availability % = (Uptime/(Downtime + Uptime)) *100

other hand MTTR measures the average time required to repair/restore a failed system. Availability may be measured, as the ratio of the time a system remained available at the time it should have been available [16]. The ratio is calculated using both MTBF and MTTR

$$\text{Availability} = \text{MTBF}/(\text{MTBF} + \text{MTTR})$$

From the above-mentioned equation, it is evident that by keeping MTBF greater than MTTR we can achieve a healthy percentage of availability. The availability depends upon the reliability and downtime of a system [17]. The EWIS has been observed for two years (see Table 1) and it has achieved high availability ratios in the year (2013).

3- Predictability: is defined as the degree to which a correct prediction or forecast of a system's state can be made either qualitatively or quantitatively [18]. An EWIS is highly predictive and capable of forecasting the crisis before it occurs. The EWIS uses five prediction models (Linear, Quadratic, Exponential Growth, Moving average and Cubic) to forecast future data trends. In addition, the system selects the best forecasting model according to accuracy and correlation between the variables. The result of the prediction is double-checked using mathematical software (Minitab) to ensure the correctness of the prediction models. The EWIS can use the five models at the same time to predict future trends. In addition, the system chooses the best prediction model according to the some criteria such as lowest error rate and highest correlation between data.

4- Accuracy: The accuracy of the system is defined as the freedom from error (correctness), or closeness to truth or fact, resulting from the exercise of painstaking care or due diligence. Accuracy depends on how the data are collected, and is usually judged by comparing several measurements from the same or different sources [19, 20]. The EWIS is tested using different types of testing such as system testing and module (Unit) testing. In Module testing the EWIS is divided into smaller chunks known as modules, these modules are tested individually to find out if they are working individually or not. System Testing is carried out only after the module testing and integration testing are completed. In System testing the same production environment is simulated and test cases are executed in the same environment as a client environment. In system testing we perform testing based on both functional and non-functional requirements. Each unit or screen is validated and the testing includes every unit present on the screen (like controls, fields, data length, etc.) It is basically done in the development environment itself. If a number of defects found, we normalize them to a unit amount of code, 1000 lines of code, or "KLOC" which is often used as a standard base measure (see Table 2). The higher the defect density, the more defects we are uncovering. It is impossible to give an "expected" value for defect density. Mature, stable code might have defected densities as low as 5 defects/KLOC; while new code written by junior developers may have 100–200 defects/KLOC [20, 21]. Defect density is a measure of conformance to customer requirements. That is, the number of defects per lines of code is a measure of quality. In fact, defect density is by far the most popular measure of quality in the field of software engineering [20]. In order to measure the accuracy of the EWIS, we can use the following equations:

Table 2. EWIS accuracy measurements

Module name	Defects (bugs)	Line of code	Test cases	Density of test	Bug rate for 1000 line of code
Module_A	1	3327	19	0.0057	0.30
Module_B	2	3250	22	0.0068	0.62
Module_C	2	1987	36	0.0181	1.01
Module_D	2	2010	33	0.0164	1.00
Module_E	2	2568	36	0.0140	0.78
Module_F	3	1875	54	0.0288	1.60
Module_G	2	925	24	0.0259	2.16
Module_H	6	752	15	0.0199	7.98
Module_I	1	1259	32	0.0254	0.79
Module_J	1	2154	45	0.0209	0.46
Module_K	2	1020	22	0.0216	1.96
Module_L	5	2590	39	0.0151	1.93
Module_M	2	2320	35	0.0151	0.86
Module_N	1	1903	28	0.0147	0.53
Module_O	2	687	36	0.0524	2.91
Module_P	1	968	51	0.0527	1.03
Module_Q	2	658	13	0.0198	3.04
Module_R	3	5325	66	0.0124	0.56
Module_S	1	698	23	0.0330	1.43
Module_T	1	698	19	0.0272	1.43
Module_U	14	1870	74	0.0396	7.49
Module_V	3	2569	25	0.0097	1.17
Module_W	2	326	51	0.1564	6.13
Module_X	1	369	14	0.0379	2.71
Module_Y	1	369	29	0.0786	2.71
Module_Z	4	568	12	0.0211	7.04
Module_AA	1	1254	55	0.0439	0.80
Module_BB	5	654	58	0.0887	7.65
Total	73	44953	966		

- Density of Test (Number of test cases per KLOC) = Number of Test Cases/size of the project (Total Lines of Code) * 1000 = (966/44953) * 1000 = 21.5 test cases per Thousand Lines of Code
- Total Lines of code = 44953
- Defect Density (Bug Rate per KLOC (Kilo Lines of Code)) = Number of defects/ Lines of Code = (73/44953) * 1000 = 1.6 defects per KLOC
- Error Discovery Rate (It is defined as the ratio of defects per test cases) = Total number of defects found in application/Number of test cases or scripts executed = 73/966 = 0.0755 Defects/Test cases
- Quality = 1 – (defects/Lines of Code) * 100% = 1 – 73/44953 * 100% = 99.8%

5- Flexibility: In order to be effective, an information system (IS) needs to be flexible, that is, it must be able to accommodate a certain amount of variation regarding the requirements of the supported business process [22]. The flexibility of information systems has been the subject of much research for during the past decade or two. A major area of research on information system's flexibility, focused on exploring the effects of change on the alignment of organizational systems and information systems [23]. Flexibility is defined as the capability to adapt to new, different, or changing requirements [24] or in other words, flexibility is regarded to be the capability of reacting to perceived stimuli. An EWIS should be flexible and should be capable of expanding its activities to include different varieties of risks. The EWIS can be used in different organizations with different events or hazards. The EWIS is flexible to change; the system has been designed using the incremental prototyping approach. The system started to work with only two mathematical forecasting models, then the number of models used by the system increased thereafter to become five mathematical models by the end of the project, and now it is flexible to accommodate more mathematical models in the future. The system also started to work with a monolingual setting (Arabic Language) and during the data entry process, the user requested to add another language (English Language) because of the presence of non-Arabic speakers work as among the data entry personnel working on the project, so hence the system was flexible to change and now was transformed into a bilingual system.

6- Functionality: The term function is defined in the IEEE Standard 610.2 as "A defined objective or characteristic action of a system or component. For example, a system may have inventory control as its primary function" [25]. This sense of function emphasizes the dynamic aspects of software, and is complemented in the normative dimension by the definition of functional requirement as "A requirement that specifies a function that a system or system component must be able to perform". To complement these definitions, functionality is defined in the Merriam Webster's online dictionary as "the particular set of functions or capabilities associated with computer software or hardware or an electronic device" [26]. The EWIS has succeeded in achieving the following functionality:

1. An EWIS is used in capturing, detecting and analyzing the event/crisis information, determining a set of mathematical indicators for each event/crisis that should be measured frequently, providing future forecasts depending on the data calculated according to previous indicators, and finally sending warnings (alerts) to users if there is an imminent danger.
2. The EWIS provides a useful, time-saving and acceptably accurate solution to a specified task or problem.
3. The user interface is effective in explaining the data requirements and describing the sequence of calculations to the user. At the same time, the user interface is easy and is not too complicated.

To prove that the EWIS is highly functional, the researchers designed a checklist to evaluate the functionality of the system. The researchers chose 20 participants to fill in the form (see Table 3). The checklist consists of 20 questions that measure different functional aspects of the EWIS. The researchers have analyzed the answers and the result is shown in the Table 3. The average result of the EWIS functionality checklist was 93.55%, which means that around 94% of the EWIS users are satisfied with the functionality of the system and around 6% are not satisfied. Using these results and the feedback from users, the researchers made more enhancements to the system, taking into consideration most of the users' suggestions to increase the former percentage.

Table 3. EWIS functionality checklist result

Questions	Yes	No	N/A
Usage of EWIS is very simple	90%	10%	0%
EWIS is approachable to users whenever and whatever they need it	86%	14%	0%
Users and managers perceive EWIS as satisfactory	95%	5%	0%
Appearance of mistakes is minimized	90%	10%	0%
EWIS provides a great achievement of organizational goals and objectives	93%	7%	0%
High safety of data	90%	10%	0%
EWIS has a good documentations	98%	2%	0%
EWIS can be easily altered and adapted to new demands	99%	1%	0%
No large amount of effort needed for maintaining satisfactory functioning of EWIS	100%	0%	0%
EWIS is high compliance between user's demands and EWIS abilities	90%	10%	0%
EWIS provides high achievements with small investment	98%	2%	0%
Clarity of EWIS output information is high	96%	4%	0%
EWIS is compatible with other databases in the organization	85%	12%	3%
Good user training for EWIS	87%	12%	1%
Detail check can be done in order to minimize operational mistakes	95%	5%	0%
Presentation of information in an appropriate form	97%	3%	0%
EWIS in great deal provides information necessary for decision making in managing organization strategies	90%	7%	3%
Output information of EWIS is consistent	95%	5%	0%
Output information of EWIS is accurate	98%	2%	0%
Output information is very important to solve business problems and achievement of organizational goals	99%	1%	0%
Average (%)	93.5	6.1	0.35

7- Usability: refers to how well users can learn and use a product to achieve their goals and how satisfied they are with that process [27]. ISO 9241-11 defines usability as: "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". An EWIS is a highly usable system. It offers benefits to both users and businesses. The primary benefits to users are that they are able to achieve their tasks easily and efficiently. This sounds simple, but the feeling of achievement that people get when they use a computer system without frustration should not be underestimated. The EWIS is very easy to use and is simple to understand, different kinds of users were able to use the system with ease, following a brief training course whose duration ranged from 8 to 12 h. The researchers measured the usability of the EWIS by carrying out a usability test that identifies the key usability problems in the system (enabling them to be fixed); and/or collects quantitative measures of efficiency, effectiveness and satisfaction before release. The participants involved are existing users of the system. Participants attempt to carry out tasks that they would normally perform on the system. The usability test was set up in a way that is as close to the normal context as possible. The researcher chose (25) participants to fill in the form (see Table 4), which consists of (20) questions that measure the usability of the EWIS and the result was used to enhance the usability of the EWIS in later stages. The researchers then analyzed the answers in the form and the result is shown in Table 4. The EWIS average result of the usability checklist was 92.8% of all the questions in the form, which means that around 93% of the EWIS users are satisfied with the usability of the system and around 4% are not satisfied, therefore the researchers used these results as a guideline for making more enhancements to the system, also taking into consideration most of the user suggestions to increase the former percentage.

8- Reliability: is defined as the probability of performing without failure, a specific function under given conditions for a specified period of time. Moreover, according to the business dictionary on the internet, it is the ability of a computer program to perform its intended functions and operations in a system's environment, without experiencing failure (system crash) [28]. The Wikipedia also defines software reliability as the probability that software will work properly in a specified environment and for a given amount of time [29]. Software Reliability is also defined as the probability of failure-free software operation for a specified period of time in a specified environment. Software Reliability is also an important factor affecting system reliability. It differs from hardware reliability in that it reflects design perfection, rather than manufacturing perfection. The high complexity of software is the major contributing factor of Software Reliability problems [30]. According to ANSI, Software Reliability is defined as: the probability of failure-free software operation for a specified period of time in a specified environment [31]. Although Software Reliability is defined as a probability function, and comes with the notion of time, we must note that, it is different from traditional Hardware Reliability, Software Reliability is not a direct function of time. Electronic and mechanical parts may become "old" and wear out with time and usage, but the software will not rust or wear-out during its life cycle [32]. The software will not change over time unless intentionally changed or upgrade [32]. Software Reliability is an important attribute of software quality, together with functionality, usability, performance, serviceability, capability, installability, maintainability, and documentation. Software Reliability is hard to achieve, because the complexity of software tends to be high [33, 34]. While any system with a high degree of complexity, including software, will be hard to reach a certain level of reliability, system developers tend to push complexity into the software layer, with the rapid growth of system size and ease of doing so by upgrading the software [34]. While the complexity of software is inversely related to software reliability, it is directly related to other important factors in software quality, especially functionality, capability, etc. Usually, failure metrics are based upon customer

Table 4. EWIS usability checklist result

Questions	Yes	No	N/A
Are the windows forms user-friendly?	84%	12%	4%
Are the windows easy to access?	92%	4%	4%
Are the purposes and functions clear to the user?	100%	0	0
Do the buttons have meaningful label names? Do they described the appropriate actions?	80%	8%	12%
Are the labels for the buttons consistent from page to page?	88%	4%	8%
Is the button placement and grouping consistent?	100%	0	0
Are the button sizes are consistent (width and height)?	96%	4%	0
Are the menu bar labels meaningful?	84%	8%	8%
Are the labels descriptive of the associated functions being performed?	92%	8%	0
Are the menu bar labels ordered by frequency of use and/or importance?	72%	20%	8%
Do the toolbars have consistent placement from page to page?	100%	0	0
Do the icons on the toolbar intuitively represent the function that they call?	88%	0	12%
Are tool tips available to assist the user in learning the associated tools on the toolbar?	92%	0	8%
Do the check boxes contain descriptive labels?	100%	0	0
Are check boxes used only for functions allowing multiple selections?	100%	0	0
Are radio buttons used for single selection functions?	100%	0	0
Is there sufficient contrast to reduce eyestrain?	96%	4%	0
Is there appropriate use of color for attracting attention?	92%	4%	4%
Are the color appealing?	100%	0	0
Are colors used consistently when designing specific functionality?	100%	0	0
Average	92.8%	3.8%	3.4%

information regarding failures found after the release of the software. The failure data collected is therefore used to calculate failure density, Mean Time between Failures (MTBF) or other parameters to measure or predict software reliability [34]. The EWIS has proven to be consistent and has produced correct outputs and this was measured frequently through statistical mean value for error-free applications which is called Mean Time Between Failures (MTBF), The system has been observed for two years and it has a downtime of 39 h during the year 2013 which is calculated as [(39/8640) * 100 = 0.45%)], where total working hours per year = 8640 (24 h * 30 days = 720 h * 12 months), and we have calculated the 12-months average which equals to 99.55% availability this year.

4 Conclusions

A comprehensive and effective information system is essential to the success of any business. The effectiveness of Early Warning Information systems is a complex variable. The literature on organizational effectiveness suggests that it may not be possible to find a precise measure of EWIS effectiveness and the criteria for effectiveness may vary from organization to organization. The effectiveness of the EWIS can be determined according to a number of factors that differ from one organization to another. In our case study, which was applied in the law enforcement sector, the most important factors contributing to increase the effectiveness of the EWIS were determined through 8 pillars as follows: Integration, Availability, Predictability, Accuracy, Flexibility, Functionality, Usability and Reliability, So the researchers, implemented an effective EWIS that accurately supports critical functions and provide efficient and effective value added services to decision makers as well as maximizing the profitability and outcomes of the organization.

References

1. ISDR (UN International Strategy for Disaster Reduction): Terminology: Basic terms of disaster risk reduction (2003). http://www.unisdr.org/. Accessed 15 Jan 2012
2. Thong, Y.L., Yap, C.: Information systems effectiveness: a user satisfaction approach. Inf. Process. Manag. **32**(5), 601–610 (1996)
3. Scott J.: Input for Second International Conference on Early Warning (EWC II), Bonn, 23 Jan 2003
4. Cyrus, A.W.: Measuring the Effectiveness of Information Systems. Naval Postgraduate School, Monterey (1991)
5. System Effectiveness (2013). BusinessDictionary. http://www.businessdictionary.com/definition/system-effectiveness.html. Accessed 12 July 2013
6. Haga, W.J., Zviran, M.: Information systems effectiveness: research designs for causal inference. Naval Postgraduate School, Monterey (1990)
7. Carlson, E.D.: Evaluating the impact of information systems. Manag. Inform. **3**(2), 57–67 (1974)
8. Hamilton, S., Chervany, N.L.: Evaluating information system effectiveness- Part I: comparing evaluation approaches. MIS Q. **5**, 55–66 (1981)
9. United Nations: Global survey of early warning systems. In: The Third International Conference on Early Warning, Bonn, 27–29 March 2006
10. Bhattacharya, I.: Characteristics of effective information systems (2007). visualspec.org, http://www.visualspec.org/documents/07833a52.characteristics_of_effective_information_systems.pdf. Accepted 11 Sept 2014
11. Characteristics of Good Information System, January 2013. BGWDealer.com, http://www.bgwdealer.com/2013/01/characteristics-of-good-information-system/#comments. Accessed 23 Aug 2014
12. Chand, S.: 8 characteristics of good management information systems, 28 November 2014. Article Library, http://www.yourarticlelibrary.com/management/8-characteristics-of-good-management-information-systems-explained/3483/

13. Tryfonas, T., Grilzalis, D., Kokalakis, S.: A quantitative approach to information availability. In: Proceedings of the Information Security for Global Information Infrastructure. IFIP TC11. Sixteenth Annual Working Conference on Information Security, USA, pp. 37–47 (2000)
14. Candea, G.: Principles of dependable computer systems – the basics. Stanford University, USA, September 2003
15. ISSO Glossary of INFOSEC and INFOSEC Related Terms, vol. 1 (1996)
16. Alvi, B., Wasim Qureshi, M., Karim, S.: Importance of information availability: its effects on business & the proposed model. SSU Res. J. Eng. Technol. **1**(1), 17–21 (2011)
17. Cisco: Cisco cable IP solutions for high-availability networks. Cisco System Inc. (2003)
18. Predictability (2014). Wikipedia, http://en.wikipedia.org/wiki/Predictability. Accessed 08 Jan 2014
19. Accuracy (2014). BusinessDictionary, http://www.businessdictionary.com/definition/accuracy.html#ixzz3ApWPZ8Po. Accessed 05 June 2014
20. Rico, D.F.: ROI of Software Process Improvement: Metrics for Project Managers and Software Engineers. J. Ross Publishing Inc., Florida (2004)
21. Metric Analysis (2013). Smartbear, http://support.smartbear.com/viewarticle/20299/. Accessed 05 Mar 2014
22. Gebauer, J., Schober, F.: Information system flexibility and the cost efficiency of business processes. J. Assoc. Inf. Syst. **7**(3), 122–147 (2006)
23. Knoll, K., Jarvenpaa, S.: Information technology alignment or "fit" in highly turbulent environments: the concept of flexibility. In: Proceedings of the 1994 Computer Personnel Research Conference on Reinventing IS, Alexandria, pp. 1–14 (1994)
24. Flexibility (2014). Merriam-Webster, http://www.merriam-webster.com/dictionary/flexibility. Accessed 05 Apr 2014
25. Abran, A., Cuadrado-Gallego, J.J., García-Barriocanal, E., Mendes, O., Sanchez Alonso, S., Sicilia, M.A.: Engineering the ontology for the SWEBOK: issues and techniques. In: Calero, C., Ruiz, F., Piattini, M. (eds.) Ontologies for Software Engineering and Software Technology, pp. 103–122. Springer, New York (2006)
26. Functionality (2014). Merriam-Webster, http://www.merriam-webster.com/dictionary/functionality. Accessed 05 Apr 2014
27. Usability (2014). Massachusetts Institute of Technology, https://ist.mit.edu/usability. Accessed 01 Dec 2014
28. Reliability (2013). Businessdictionary, http://www.businessdictionary.com/definition/software-reliability.html#ixzz3BTZOscgf. Accessed 11 June 2013
29. Reliability_Testing (2013). Wikipedia, http://en.wikipedia.org/wiki/Software_reliability_testing. Accessed 12 Nov 2013
30. Jiantao, P.: Software reliability. Carnegie Mellon University, 18-849b Dependable Embedded Systems (1999)
31. ANSI/IEEE: Standard glossary of software engineering terminology. STD-729 (1991)
32. Kaur, G., Bahl, K.: Software reliability, metrics, reliability improvement using agile process. Int. J. Innov. Sci. Eng. Technol. **1**(3), 143 (2014)
33. Pan, J.: Software reliability, Pittsburgh. http://users.ece.cmu.edu/~koopman/des_s99/sw_reliability/ (1999)
34. Kaur, M., Singh, S., Rakshit, M.: A review of various metrics used in software reliability. Int. J. Comput. Sci. Eng. Technol. (IJCSET) **04**(07), 874 (2013)