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Abstract

Failure of systems occur in all domains of human activity. Apart from identifying who will be deemed accountable, a thorough analysis of a failure also provides understanding of the causes. This is the first step towards learning and future improvement. It has become evident that process improvement improves the resulting products and services. Prevention is always desirable, but more often than not, the predictability of future behavior of systems is difficult. Hence, most of the learning takes place in the analysis of failures. This paper focuses on a STEEPLED analysis of system failures, with particular emphasis on failed systems from the fields of Architecture, Engineering, and Healthcare systems. This transdisciplinary and multi-dimensional view of systems provides a holistic thinking instrument for structuring the analysis of failures and for enabling action in order to avoid or at least minimize future failures.

Keywords: STEEPLED Analysis, Process Improvement, System Failures, Ambiguity, Complexity

1 Introduction

No matter what the level of preparedness is, system failures can still occur. System errors refer to systems that cannot successfully achieve their intended functions and perform in unexpected or unintended ways due to software and hardware issues, malfunctions, and problems that can result in minor or major damage with the severity and consequences being dependent on the function criticality and system nature Chapman [2004]; Woolthuis et al. [2005].

Due to the digitalization of modern society, many of the system failures are related to digital infrastructure, information systems, software processes, and project management (Kaur and Sengupta [2013]; Lyytinen [1988]; Nelson [2007]). Several studies have explored and provided insights into information system failures and successes (Dwivedi et al. [2015]; Pan et al. [2008]). Taxonomies, frameworks, and performance measurement methods have also been presented (Van Camp and Braet [2016]; Woolthuis et al. [2005]; Yeo [2002]). Besides the information technology sector, system failures can occur in several other sectors, such as architecture (e.g., bridges Garg et al. [2022]; Zhang et al. [2022]), engineering (e.g., spacecraft Bedingfield and Leach [1996]; Harland and Lorenz [2007]) and healthcare (Beynon-Davies [1995]; Heeks [2006]), affecting people's daily lives and wellbeing. Although artificial intelligence (AI) is progressing and autonomous decision-making systems facilitate the development, monitoring, and maintenance processes (Lampropoulos [2023]), it still remains imperative to identify the sources of system failures, comprehend the reasons why they occurred, and avoid repeating the same mistakes after learning from past experiences (Dalcher and Drevin [2004]; Lyytinen and Robey [1999]; McManus and Wood-Harper [2007]). No other study has been conducted, as yet, using the STEEPLED multidisciplinary and multidimensional analysis of system failures.

Section 2 of the paper briefly introduces three catastrophic failures from the fields of Architecture, Engineering, and Healthcare. Section 3 presents in tabular form the STEEPLED Analysis of one example from the three domains in tabular form showing the similarities across the disciplines. Section 4 juxtaposes the STEEPLED dimensions to the Values and Principles of the SPI Manifesto.

2 Bridges over the ages

Harrington and McIntyre [2020] observed that: *"the world is full of highways and roads that cross over rivers or valleys. For centuries, they have been made passable by bridges, and the oldest bridge in the world is Arkadiko Bridge in Argolis, Greece. It was built by Mycenaean Greeks c.1300-1190 and it is still in use".* Figure 1 shows a selection of bridges built across the world over a period of almost 3,500 years. As shown in 1a the stone bridge is 'primitive', yet it still remains functional and is still in use. Many other stone bridges (built over the preceding 3 millennia are still in use).

1a) Arkadiko Bridge. Built: c.1300 – 1190 BCE.

1b) Living root tree in India (unknown date)

1c) Zhao Zhou Bridge built in 661 BCE

Id) Pons Aemilius in Rome built in 192 BCE

1e) Millennium Bridge London built in 2000

1f) Hong Kong-Zhuhai-Macao Bridge built in 2018

Figure 1: Bridges through the ages

Blockley, D. [2010] emphasized that *"Bridges connect people and communities, enable the flow of people, traffic, trains, water, ….and many goods and materials".* The significance of bridges is reflected in the expression "bridging the gap" used whenever there a chasm, a dispute, or a disagreement of any type among individuals, communities, or countries signifying connection/reconnection and reconciliation.

3. From folklore to scientific reasoning

3.1 Bridge Failures

In Balkan folklore, a sacrifice of an animal was deemed necessary or especially in the case of a large and complex undertakings such as the building of a bridge a human sacrifice was deemed necessary in order to appease the river gods. To give an example, the Bridge of Arta in Greece (Figure 2) was built on earlier Roman foundations during the Ottoman period (r. 1230–1268) by 45 builders/stonemasons and 60 apprentices (denoting the enormity of the task at the time). It fell many times and was reconstructed. The legend (still surviving in a Greek folk song) tells us that all work carried out during the day collapsed every night until a bird with a human voice instructed the desperate master builder that his wife should be sacrificed in order for the bridge to be constructed. His wife was sacrificed and the bridge is still in use!

Figure 2: The Bridge of Arta [Source: youimg1.tripcdn.com]

Legends stopped providing explanations of bridge failures whether minor, correctable or catastrophic. Bridge failures continue to occur even in the 21st Century, as is the case of the Millennium Bridge in London. When the London Millennium Bridge was opened in June 2000, it swayed alarmingly. This problem generated huge public interest and the bridge became known as London's "wobbly bridge." The large number of pedestrians that flogged to see it at the same time excited the bridge's lateral vibration modes [David, 2003]. The bridge closed, the problem was rectified and the bridge reopened a year later.

"*Bridge building is a magnificent example of a practical and everyday use of science. Unfortunately, there are always gaps between what we know, what we do, and why things go wrong. Bridge engineers must manage risks carefully* [Blockley 2010].

Olson et al. [2015] in their Quick Study described the collapse of the Tacoma Narrows Bridge as follows:

"*On 7 November 1940 the Tacoma Narrows Bridge in Washington State collapsed during a gale. The remarkable oscillations of its long and slender centre span in the months leading up to the catastrophe earned the bridge the moniker "Galloping Gertie…"".*

The actual collapse can be seen in Fig. 3 and on film [Tacoma Bridge Collapse: The Wobbliest Bridge in the World? (1940) [British Pathé News]. Fortuitously no human loss occurred. Only the dog in the car of a reporter perished in the river. Holloway [2004] described the oscillation and twisting of the Tacoma Bridge*: "the clamps holding one of the added checking-cables slipped in a wind of about 40 miles per hour. When this happened, Galloping Gertie began to move in a new way. Instead of just oscillating up and down as it had before, it started twisting about its centreline."*

Figure 3: The collapsed Tacoma Bridg

3.2 The Space Shuttle Challenger Disaster

Despite the misgivings and objections by Boisjoly and others the Space Shuttle Challenger was launched on January 28, 1986. It broke apart 73 seconds [Fig.4] into its flight, killing all seven crew members aboard. The spacecraft disintegrated 46,000 feet (14 km) above the Atlantic Ocean, off the coast of Cape Canaveral, Florida, at 11:39 a.m. EST as the first fatal accident involving an American spacecraft in flight. [Boisjoly et al., 1989].

Figure 4: The Challenger Disintegration

All 7 astronauts died. This disaster impacted on the Space Travel programme, dented the belief in the American dream and infallibility, and shocked the whole world. Six months after the disaster later the Rogers Commission report [Fenman, R, P. (1986)] "*faulted NASA as a whole, and its Marshall Space Flight Center in Huntsville, Alabama, and contractor Morton Thiokol, Inc., in Ogden, Utah, for poor engineering and management. Marshall was responsible for the shuttle boosters, engines, and tank, while Morton Thiokol manufactured the booster motors and assembled them at the Kennedy Space Center at Cape Canaveral, Florida. The Rogers Commission heard disturbing testimony from a number of engineers who had been expressing concern about the* ***reliability of the seals for at least two years and who had warned superiors*** *about a possible failure the night before 51-L was launched. One of the Rogers Commission's strongest recommendations was to tighten the communication gap between shuttle managers and working engineers. In response to this implied criticism that its quality-control measures had become slack, NASA added several more checkpoints in the shuttle bureaucracy, including a new NASA safety office and a shuttle safety advisory panel, in order to prevent such a "flawed" decision to launch from being made again. Aside from these internal fixes at NASA, however, the Rogers Commission addressed a more fundamental problem. In NASA's efforts to streamline shuttle operations in pursuit of its declared goal of flying 24 missions a year, the commission said, the agency had simply*

been pushing too hard. The shuttle program had neither the personnel nor the spare parts to maintain such an ambitious flight rate without straining its physical resources or overworking its technicians".

3.3 The London Ambulance Service Computer Aided Dispatch Failure

The London Ambulance Service (LAS) Computer Aided Despatch (CAD) system failed dramatically on October 26th 1992 shortly after it was introduced. The system could not cope with the load placed on it by normal use. The response to emergency calls took several hours. Ambulance communications failed and ambulances were lost from the system. A series of errors were made in the procurement, design, implementation, and introduction of the system [Sommerville, 2004].

Dalcher [1999] summarised "*the failure of the 1992 London Ambulance Service's computer-aided dispatch system arguably caused several deaths soon after its deployment, from failing to deliver emergency care in time, including an 11-year old girl dying from a kidney condition after waiting for an ambulance for 53 minutes and a man dying from a heart attack after waiting for two hours."*

Information Systems Failure have been occurring regularly, especially as systems became large and complex. Since 1994, the Standish Group publish the CHAOS report where they identify the most important reasons for IS failures. In the first Chaos Report by the Standish Group (1994 failures in bridge building and in software were juxtaposed. Bridges are mostly delivered on-time, and on budget and do not usually fail. The design is frozen and the constructor has hardly any flexibility in changing the specifications. When a bridge fails a report is written on the cause(s) of the failure. This is not so in the computer industry (which 3,000 years younger than bridge building) is plagued by computer systems which are often covered up, ignored, and/or rationalised. The same mistakes are repeated over and over. As the years progressed the Standish Group observed an increased in the number of computer systems failures.

Cases of system failures suggest that the development of appropriate software is a complex task. Projects frequently result in unfinished projects, project overruns and system failures. Software Process Improvement (SPI) approaches are viewed as potential solutions to address such instances. The SPI methodology plans and implements improvement activities to achieve specific goals, such as increase development speed, achieve higher product quality, and reduce costs [Winkler et al, 2011].

4. Research Methodology and Product Life Cycle

In this paper the authors carry out a STEEPLED (Sociocultural, Technical, Economic, Environmental, Political, Legal, Ethical and Demographic) analysis of three systems from Architecture, Engineering, and Medical Systems failures with the purpose of identifying multivariate causes and effects of each failure. The aim of a STEEPLED Analysis is to help organizations to understand the rich contextual situation in which they are operating [Georgiadou et al, 2020]. STEEPLED is a multidimensional and multi-faceted analysis tool which assists in identifying causes, effects, strengths, gaps and impact of failures [Georgiadou et al., 2019].

The quality of the process is inextricably linked to the quality of the resulting products and services. [Siakas and Georgiadou,, 2005]. For example, the SPI manifesto which is based on values and principles guides practitioners and researchers in their process software improvement efforts so that the resulting products and/or services are also of a high quality. Figure 2 shows the life cycle of a product. There are different variations existing of lifecycles. This life-cycle is derived from the combined experience of the authors. Different processes are showed in a sequence with feedback loops in all stages in two directions. The feedback from all phases must always go back to the concept development which is kept as a historical document for learning of the failures and improving future product developments.

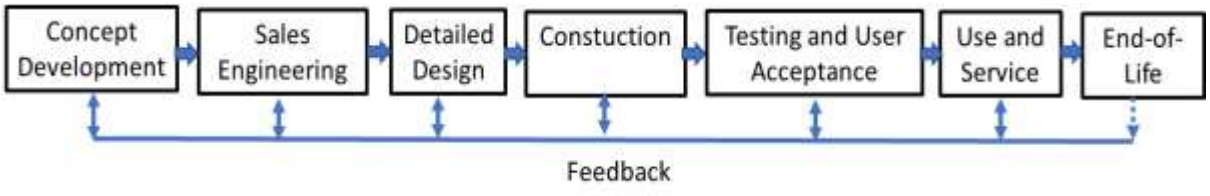

Figure 2: Product Life Cycle

The product concept is the first stage followed by a preliminary design, often called sales engineering because the concept is developed depending on potential sales. The sales engineering uses the product concept and modifies it to fulfil the tender requirements. If the sales contract gets signed the detailed design starts, followed by construction, testing and user acceptance. After the product is handed over to the customer usually a guaranty and service agreement is agreed upon. Through the service agreement feedback is received about the product's performance and failures discovered in the different phases.

In most of the cases the end-of-life is not taken into consideration. Because of this the feedback arrow in figure 2 below the End-of-Life process is dotted. However, in today's world of sustainable requirements this stage is of utmost importance for calculating the value of the cost of environmental impacts, demolition and environmental restoration.

The European Commission is preparing a '*green claims'* regulation to make the environmental labels and credentials listed by companies – like their recyclability or biodegradability – reliable, comparable and verifiable across the EU[1]. It aims to be an instrument to tackle '*greenwashing*', or companies making false claims about the environmental footprint of their products. This is likely to help consumers to make better-informed choices about the products they buy.

The customer takes part to various degrees in all stages of the life-cycle. Customer involvement improves final products [Berki et al., 1997; Chen et al, 2021]. When developing new product concepts, it is also important to look at end-of-life feedback from similar earlier products and projects to minimize environmental exposure. The feedback in addition to failures also includes e.g. delays, costs, product optimization, other competitive products in the market etc. Also, positive feedback needs to be taken into consideration.

Table 1 summarizes findings from published reports and research papers. Each entry in the table is either a cause or an affect, and is categorized by the authors as Sociological, Technical, Economic, Environmental, Political, Legal, Ethical, or Demographic i.e. one of the 8 STEEPLED dimensions.

[1] https://www.euractiv.com/section/circular-economy/news/eu-to-tackle-green-claims-with-unified-product-lifecycle-methodology/

Table 1a – STEEPLED Analysis (Sociocultural, Technical) of failures from three different domains

	Examples of Systems Failures		
Disciplines → **↓ Dimensions**	**Architecture** (Tacoma Bridge Collapse, 1940)	**Engineering** (Space Shuttle Challenger Disaster 1986)	
Sociocultural	**Causes** • Overconfidence of Engineers (not following regulations) • Unforeseen human behavior • Multidisciplinary team misunderstandings • Lack of social responsibility • Career advantage or disadvantage **Effects** • No loss of life in this case but high danger • Loss of product services (e.g. you cannot use the bridge)	**Causes** • Cultural conditioning • Organizational hubris • Pressure to launch • Psychodynamics • Transdisciplinarity • Accountability • Bureaucratic decisions • Whistleblowing • Poor management control • Different teams, different locations • Confusion with measurements and specification **Effects** • Loss of life • Loss of credibility • Worldwide chock	**Causes** • Bad communication • Poor relations between stakeholders • Low user participation • Incomplete requirements • Inexperienced software engineers • Underestimation of the impact of systems failure on the local population **Effects** • Chaos • Loss of lives • Mistrust in system • Anxiety • Stress • Depression • Anger
Technical	**Causes** • Overemphasis on aesthetics instead of robustness • Design mistakes • Limited or no checking off system • Theory but no prior data - Untested innovation • Ambiguities in design specs • Implementation deficiencies • Underestimation of danger • Unknown risks in materials • Designers without personal experience of bridges **Effects** • Destruction of bridge • Non-availability of bridge • Man-made reef	**Causes** • Poor Engineering • Design mistakes • Limited or no checking system • Theory but no prior data - Untested innovation • Ambiguities in design specifications • Implementation deficiencies • Underestimation of danger • Unknown risks in materials **Effects** • Loss of credibility	**Causes** • Incomplete system released • Testing was only carried out on individual modules and subsystems • Miscalculation of variations in traffic congestion and obstacles like bridges **Effects** • Mistrust in automation • Loss of credibility • Failed to adopt stepwise approach to deployment of system. • Configuration issues • No paper backup system • Poor interface between users and system • Inaccurate data feeds • Delays in training • Lack of clarity in development of original requirements
Economic	**Causes** • **Effect** • Cost for rebuilding	**Causes** • Loss of productivity **Effect** • Cost for rebuilding	**Causes** • Procurement, the cheapest contractor was employed • Unrealistic budget **Effect** • Cost for improvement / re-development

Table 1b – STEEPLED Analysis (Economic, Environmental, Political, Legal, Ethical, Demographic) of failures from three different domains

Examples of Systems Failures			
Disciplines → / **Dimensions** ↓	**Architecture** (Tacoma Bridge Collapse, 1940)	**Engineering** (Space Shuttle Challenger Disaster 1986)	**Health Service Systems** (London Ambulance Service Disaster 1992)
Environmental	**Causes** • Terrain • Weather **Effects** • Unforeseen impact (e.g. reef rubble)	**Causes** • Melting sills **Effect** • Energy Waste	**Causes** • Miscalculation of congestion • Inadequate management organization • Poor communication channels between various stakeholders **Effects** • Distrust in Management
Political	**Causes** • Unrealistic deadlines • Ambition **Effects** • Reputation • Fear of blame	**Causes** • Pressure from politicians • Press concerning time and cost **Effect** • Reputation	**Causes** • Procurement • Pressure from politicians • Press concerning time and cost • Poor relations between management and staff **Effects** • Loss of trust in health system / political system • Fear of lawsuits
Legal	**Causes** • Mismanagement **Effects** • Fear of lawsuits • Financial loss • Loss of reputation • Fear of blame	**Causes** • Fear of contractual violation **Effects** • Fear of lawsuits	**Causes** • Testing deficiencies • Ambiguities **Effects** • Fear of lawsuits • Testing deficiencies • Lack of systems development knowledge and experience in key stakeholders including consortium
Ethical	**Causes** • Pressure of time • Ambition • Disregard of danger **Effects** • Potential loss of life	**Causes** • Ambition instead of safety **Effects** • Loss of life	**Causes** • Pressure of time • Ambition instead of safety **Effects** • Testing deficiencies • Loss of life • Loss of trust • Lack of Autonomy and Informed Consent felt by end users • Increase sense of ownership for all stakeholders
Demographic	**Causes** • Miscalculation **Effects** • No loss of life (in this case)	**Causes** • **Effect** • Loss of young scientists	**Causes** • Stakeholder mainly male in latter stages of career • *'Us and them'* culture between stakeholders **Effects** • Pressure due to potential personal claims (delays, causing harm to the patient or death) • Loss of life • Emergency care affected young and old • Loss of trust

4. Thematic Analysis

Braun and Clarke [2006] state that Thematic Analysis is a method of analysing qualitative data. The method is typically applied to texts, e.g., interviews or transcripts. In the analysis, the researcher is tasked with examining the data to identify common "*themes, topics, ideas and patterns of meaning that come up repeatedly*".

Maguire and Delahunt [2017] suggest that there are various approaches to conducting thematic analysis, but the most common form follows a six-step process, as advocated by [Braun and Clarke, 2006]:

- Familiarisation
- Coding
- Generating themes
- Reviewing themes
- Defining and naming themes
- Writing up

However, thematic analysis is a flexible method that can be adapted to many kinds of research. Based on the qualitative data presented in Table 1, above, a Thematic analysis is conducted to identify commonalities between the three cases. The aim of this paper is to Generate Themes

STEP 1: Familiarisation: A thorough overview of the data collected from the STEEPLED analysis of the three cases in presented in Table 1. The data has got from second hand sources (references) and presented accordingly.

STEP 2: Coding: To complete coding sections of our text presented in Table 1 are highlighted, typically specific phrases or texts, so that shorthand labels, or codes to describe their content. Table 2 below, shows examples of extracted data and the corresponding codes.

Table 2. Examples of extracted data and the corresponding codes

Extracted Data	**Codes**
"Organizational hubris" "Poor relations between stakeholders" "Bureaucratic decisions" "Us and them"	Poor industrial relations
"Fear of lawsuits" "Fear of blame" "Fear of Failure" "Whistle blowing"	*Fear of Failure* Culture
"Ambiguities in design specs" "Inaccurate data feeds"	Poor Design
"Multidisciplinary team misunderstandings" "Lack of clarity in development of original requirements"	Ambiguity
"Need to meet Unrealistic Deadlines" "Unrealistic Budget"	Unrealistic Project Deliverable Indicators
"Distrust in Management"	Trust
"Underestimation of the impact of systems failure on the local population" "Underestimation of danger"	Poor risk analysis
Etc....	

STEP 3: Generating Themes: The codes that have been created and presented in Table 2, are further analysed to help identify patterns among them, and therefore declare themes. Themes are generally broader than codes. Most of the time, several codes are combined into a single theme.

Table 3. Examples of extracted codes and the corresponding themes

Codes	Theme
• Poor Risk Analysis • Unrealistic Project Deliverable Indicators	Lack of Project Management (Time, Budget and Risk)
• Poor Industrial Relations • Trust • Fear of Failure Culture	Management Oversight
• Poor Design • Ambiguity	Poor adoption and deployment of systems development methodology
Etc...	

These themes are got from the STEEPLED analysis of the three cases of failure described in Section 3, above. The themes are present in the cases that were analyzed. We cannot suggest that these are universal themes in all projects that involve human endeavor. Further research would have to be completed, based on a substantially greater number of cases.

5. Future Work

5.1. Case-based Reasoning

Kolodner [1992] defines Case-based Reasoning CBR as "*a means of using old experiences to understand and solve new problems*". A reasoner calls to mind a previous situation, like the current one, and uses that to solve the new problem. CBR can mean "*adapting old solutions to meet new demands; using old cases to explain new situations; using old cases to critique new solutions; or reasoning from precedents to interpret a new situation or create an equitable solution to a new problem*". Case-based reasoning is rooted in artificial intelligence theory and cognitive psychology. It describes the pervasive behavior in everyday human problem solving; that most people assemble solutions based on earlier experiences with similar situations.

Rahanu et al. [1999] report that the key conclusion to be drawn from the study of failed computer systems development and implementation cases is that the idea of failure can rarely be understood satisfactorily solely from a technical perspective. This is because a definition of the success or failure of a given case of computer systems development and implementation is as much reliant on the social, economic, political, and ethical setting within which it is developed as it is on the technical quality of its construction. The authors advocate that case histories are a particularly valuable means of helping to understand the success or failure of computer systems development and implementation in terms of professional ethics. The analysis of case histories was the backbone for the development of a case-based reasoner (CBR) computer system, which can offer ethical advice with reference to cases of failed IS projects. This was accomplished by ethically analyzing cases of failed IS projects to determine whether and to what extent a neglect of professional ethics contributed towards their failure. This case library formed the basis for development of the base-cased reasoner.

The novelty of this paper is the proposal that not only can failed information systems projects be understood in terms of technical failure, and professional ethics, but also in a much wider context, i.e., a social, economic, political, and ethical setting within which it is developed. Therefore, this paper advocates the use of a STEEPLED multidisciplinary and multidimensional analysis of cases of system failures. The hope is that by showing the STEEPLED analysis of 3 cases, reported in Section 3, that these could become case histories, which are the backbone for the development of a case-based reasoner (CBR) computer system, which can offer STEEPLED advice with reference to cases of failed IS projects.

Conclusion

Failures continue to happen often causing disruption, economic losses, political upheaval and worse of all loss of life. If the causes of failures can be identified are identified and understood the first step towards ensuring prevention of failures is ensured. Pressure to change protected completion date, reduce costs, modified design for additional usage, and respond to upgrades of software, hardware and design methods, compared with earlier times, with less immediate communication with stakeholders and press. Decisions to oversee warnings as is the case of

the Space Shuttle launch, may be legal but not ethical. Similarly, the economic factor, although important, should not be judged as more important than the safety of people. Employing the cheapest contractor should never be the overarching criterion. The trust placed on automatic generated measurements, such as with the ambulance system, does not take account of the traffic problems with some of the bridges, where the shortest Geographic distance is not the shortest in time. Political ambition or expediency should never come before safety. As Parfitt [2012] concludes "*Fear of blame, lawsuits, damaged business opportunities and ruined reputations are all often cited as reasons for keeping failure cases and actual examples under legal non-disclosure agreements and in insurance company files. But we need to find a way to at least generically share the lessons through more comprehensive failure dissemination methods and educational repositories*".

One of the problems is that the full details of many failure examples are not published so the appropriate lessons cannot be learned.

References

Bedingfield, K. L., & Leach, R. D. *Spacecraft system failures and anomalies attributed to the natural space environment* (Vol. 1390). National Aeronautics and Space Administration, Marshall Space Flight Center, 1996. https://doi.org/10.2514/6.1995-3564

Berki E., Georgiadou E., Sadler C., Siakas K. A Methodology is as Strong as the User Participation, *International Symposium on Software Engineering in Universities* - ISSEU 97, Rovaniemi, 7-9 March 1997, pp.36-51-

Beynon-Davies, P. Information systems 'failure': the case of the London Ambulance Service's Computer Aided Dispatch project. *European Journal of Information Systems*, *4*(3), 171-184, 1995. https://doi.org/10.1057/ejis.1995.20

Blockley, D. *Bridges: The Science and Art of the world's most inspiring Structures,* Oxford University Press, ISBN 978-0-19-964572-5, 2003.

Braun, V. and Clarke, V. Using thematic analysis in psychology. *Qualitative Research in Psychology*. Vol. 3, pp. 77-101, 2006.

Chapman, J. *System failure: Why governments must learn to think differently*. Demos, 2004.

Chen, Y.-C., Arnold, T. and Tsai, H.-T. Customer involvement, business capabilities and new product performance, *European Journal of Marketing*, Vol. 55 No. 10, pp. 2769-2793.2021, https://doi.org/10.1108/EJM-01-2020-0034

David E. Vibration of the London Millennium Bridge: Cause and Cure Newland *International Journal of Acoustics and Vibration*, Vol. 8, No. 1, 2003

Dalcher, D. Disaster in London. The LAS case study, *Engineering of Computer-Based Systems, Proceedings. ECBS '99*. IEEE Conference and Workshop 1999, https://doi.org/10.1109/ECBS.1999.755860

Dalcher, D., & Drevin, L. Learning from information systems failures by using narrative and ante-narrative methods. *South African Computer Journal,* 88–97, 2004

Dwivedi, Y., Wastell, D., Laumer, S., Henriksen, H., Myers, M., Bunker, D., Elbanna, A., Ravishankar, M., & Srivastava, S. Research on information systems failures and successes: Status update and future directions. *Information Systems Frontiers, 17*(1), 143–157, 2015. https://doi.org/10.1007/s10796-014-9500-y

Garg, R., Chandra, S., & Kumar, A. Analysis of bridge failures in India from 1977 to 2017. *Structure and Infrastructure Engineering, 18*(3), 295–312, 2022. https://doi.org/10.1080/15732479.2020.1832539

Georgiadou, E., Siakas, K., Berki, E., Estdale, J., Rahanu, H., Ross, M. (2020). A STEEPLED pilot validation of the Sociocultural Dimension of the SPI Manifesto. *Journal of Software Evolution and Process*, Wiley & Sons Limited on-line, pp. 1-15, https://doi.org/10.1002/smr.2304

Georgiadou E, Siakas K, Berki E, Estdale J, Rahanu H, Ross M. (2019). A STEEPLED Analysis of the SPI Manifesto, In: Walker A, O'Connor RV, Messnarz R, (eds), *Systems, Software and Services Process Improvement*, Communications in Computer and Information Science; 2019. https://doi.org/10.1007/978-3-030-28005-5

Harland, D., & Lorenz, R. *Space systems failures: disasters and rescues of satellites, rocket and space probes*. Springer Science & Business Media, 2007.

Heeks, R. Health information systems: Failure, success and improvisation. *International Journal of Medical Informatics, 75*(2), 125–137, 2006. https://doi.org/10.1016/j.ijmedinf.2005.07.024

Holloway, C.M. *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA. Chicago*: University of Chicago Press, 1996-

Kaur, R., & Sengupta, J. Software process models and analysis on failure of software development projects. *arXiv preprint arXiv:1306.1068*, 2013. https://doi.org/10.22541/au.149693987.70506124

Kolodner, J. An Introduction to Case-based Reasoning. *Artificial Intelligence Review*. Vol. 6, pp. 3-34. 1992.

Lampropoulos, G. Artificial Intelligence, Big Data, and Machine Learning in Industry 4.0. In J. Wang (Ed.), Encyclopedia of Data Science and Machine Learning (pp. 2101-2109). IGI Global, 2023. https://doi.org/10.4018/978-1-7998-9220-5.ch125

Lyytinen, K. Expectation failure concept and systems analysts' view of information system failures: Results of an exploratory study. *Information & Management*, *14*(1), 45-56, 1998. https://doi.org/10.1016/0378-7206(88)90066-3

Lyytinen, K., & Robey, D. Learning failure in information systems development. *Information Systems Journal, 9*(2), 85–101, 1999. https://doi.org/10.1046/j.1365-2575.1999.00051

Maguire, M. and Delahunt, B. Doing a Thematic Analysis: A Practical, Step-by-Step Guide for Learning and Teaching Scholars. *All Ireland Journal of Higher Education.* Vol. 9, No. 3. 2017.

McManus, J., & Wood-Harper, T. Understanding the sources of information systems project failure. *Management Services, 51*(3), 38–43, 2007.

Nelson, R. R. IT project management: Infamous failures, classic mistakes, and best practices. *MIS Quarterly executive*, *6*(2), 2007. https://doi.org/10.1002/9781118835531.ch2

Olson, D. W., Wolf, S. F., & Hook, J. M. The tacoma narrows bridge collapse. *Phys. Today*, *68*(11), 64-65, 2015. Parfitt, M.K. *Why Buildings Fail: Are We Learning from Our Mistakes*? *Buildings,* 2012, 2(4):326-331, https://doi.org/10.3390/buildings2030326

Pan, G., Hackney, R., & Pan, S. Information Systems implementation failure: Insights from prism. *International Journal of Information Management, 28*(4), 259–269, 2008. https://doi.org/10.1016/j.ijinfomgt.2007.07.001

Rahanu, H., Davies, J. and Rogerson, S. Failed IS Projects: Definition in Terms of a Neglect of Professional Ethics. Failure and Lessons Learned in Information Technology Management, Volume 3(1), pp. 1-22, 1999.

Siakas, K., Georgiadou, E. PERFUMES: A Scent of Product Quality Characteristics, The 13th International *Software Quality Management Conference*, SQM, 2005.

Van Camp, J., & Braet, J. Taxonomizing performance measurement systems' failures. *International Journal of Productivity and Performance Management, 65*(5), 672–693, 2016. https://doi.org/10.1108/IJPPM-03-2015-0054

Woolthuis, R. K., Lankhuizen, M., & Gilsing, V. A system failure framework for innovation policy design. *Technovation*, *25*(6), 609-619, 2005. https://doi.org/10.1016/j.technovation.2003.11.002

Winkler, D., O'Connor, R., and Messnarz, R. Systems, software and services process improvement. Berlin: Springer, pp. 97-108, 2011.

Yeo, K. Critical failure factors in information system projects. *International Journal of Project Management, 20*(3), 241–246, 2002. https://doi.org/10.1016/S0263-7863(01)00075-8

Zhang, G., Liu, Y., Liu, J., Lan, S., & Yang, J. Causes and statistical characteristics of bridge failures: A review. *Journal of Traffic and Transportation Engineering (English Edition), 9*(3), 388–406, 2022. https://doi.org/10.1016/j.jtte.2021.12.003