PART I

SYSTEMS SCIENCE AND ENGINEERING METHODOLOGIES

CHAPTER 1

A SYSTEMS FRAMEWORK FOR SUSTAINABILITY

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1.1 INTRODUCTION

The ability to maintain a balance in a process or state in a system, whether ecological, technological, or social is currently known as sustainability. This balance is often viewed from multiple perspectives namely, desirability, longevity/survivability, affordability, and social/environmental impact. The UN World Commission on Environment and Development [1] has provided a human focused definition that is now widely accepted as the norm stating that sustainability amounts to "*[meeting] the needs of the present without compromising the ability of future generations to meet their own needs.*" This is a strategic vision and a macro perspective that qualifies the subject matter as a potent candidate for the exploration, development, and progression as a scientific systems framework.

The pervasive significance and prominence of sustainability is typified by the UK Engineering Council in their guidance notes for the entire engineering profession under the Principles for Sustainability [2]. These comprise contributing to building a sustainable society, present and future; applying professional and responsible judgment and taking a leadership role; doing more than just complying with legislation and codes; using resources efficiently and effectively; seeking multiple views to solve sustainability challenges and managing risk to minimize adverse impact to people and environment in all matters related to engineering. Alas, the principles do not elaborate the makeup and constituents of the concept of sustainability itself and mainly amount to a code of behavior and practice for the profession. However, these highlight the emergent sensitivity to the tenets of sustainability in a domain that

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has traditionally propounded safety, reliability, integrated risk management [3], and social responsibility alone.

The performance of a generic product, process, system, or undertaking can be viewed as a symbiotic balance of many systemic emergent behavioral and structural properties namely:

(1) technical functionality;

(2) cost/schedule, programmatic balance;

(3) environmental impact;

(4) reliability, availability, maintainability;

(5) safety and security;

(6) quality; and

(7) perceived and/or absolute value.

We posit that from a holistic systems perspective [22], all of these are essentially sustainability qualifiers in that compromising any of the above set of requisite performance attributes renders a product, process, system, or undertaking unsustainable.

In this chapter, we approach sustainability as an emergent holistic property of hard, soft, or hybrid systems including large and often complex system of systems. We use the following nomenclature:

Assurance: Increasing confidence and certainty

Gain: Lives saved, improvements made, damages prevented or avoided in the natural habitat, or benefits accrued to a business/society or a combination thereof

Hazard: Object, state or condition which in the absence of adequate detection or containment could lead to an accident

Health: Soundness of body and mind, freedom from illness

Loss: Physical harm to people, detriment to a business/society, or damage/destruction of the natural habitat or a combination thereof

Reward: A forecast for a desirable event or gain. The expected value of a future gain

Risk: A forecast for an accident or loss. The expected value of a future loss

System: A (purposeful) composite of inter-related parts/elements with discernible collective output(s) or emergent property(ies) not manifested by any of the elements

Safety: Freedom of people from (physical) harm

Security: Freedom from vulnerability or loss caused by deliberate and malicious acts

Sustainability: A blend of social, economic, environmental, resources, and technological considerations which render a product, system, or undertaking viable and continually optimal

Systems assurance: The art, science, and technology of ensuring and demonstrating that a system is likely to achieve its objectives without engendering unacceptable levels of loss

Systems safety: The art, science, and technology of ensuring and demonstrating that a system is not likely to lead to unacceptable levels of (physical) harm to people

Systems security: The art, science, and technology of ensuring and demonstrating that a system is not likely to be vulnerable to malicious deliberate acts aimed at engendering unacceptable levels of loss

Vulnerability: Susceptibility to injury, fatality, or loss

Welfare: Wellbeing and quality of life for individuals and the society

1.2 A UNIFIED SYSTEMS SUSTAINABILITY CONCEPT

In the research or debate on many critical issues concerning global climate change, energy and financial system crises in recent years, while there is growing recognition of the importance of system sustainability (SS), there is little or no consensus on the definition of systems sustainability that is widely accepted by the world scientific or policy-making communities. In order to delineate a comprehensive, inclusive yet generically unified concept for system sustainability, we begin by exploring the concept of sustainable systems. It is generally accepted that sustainability applies to integrated systems (or system of systems; SoS) comprising societal and technological infrastructures, humans, and the nature. Beyond the conventional systems concept, a key characteristic of the sustainable systems is that the structures and operation of the human component, in terms of society, economy, governance, law and regulatory apparatus, etc. must be such that these system attributes reinforce or enable the existence, persistence, resilience, and long-term wellbeing of the structures and operation of the natural component.

In the concept of sustainable systems within the realm of Gaia [4], such attributes should also include energy, natural resources and ecosystem dependencies, environmental stability, technology safety and security and dependability, biodiversity, resource cycling, human–nature interactive complexity and biogeochemical cycles, etc. In fact, the term "sustainability" most widely used in recent years, is more of a macro concept. Its strategic perspective usually applies more broadly to entire systems and infrastructures such as the global economy, energy systems, transportation, information, and agriculture systems. However, the true gravity of the term is often loosely defined, and even appears somewhat elusive. Confusion or ambiguity often arises due to many researchers and stakeholders often having their own unique definitions within a wide range of disciplines, in part because the term "sustainability" seems to imply absolute system behaviors, as it is indeed difficult to define or describe a "partially sustainable system" as opposed to a "fully sustainable system," especially given the lack of a precise, clear, and unified definition. So, in an attempt to explore a comprehensive and unified concept for system sustainability which may be referenced or applied to a broad category of systems, based on the principles of the emerging

SoS concept [5], the authors intend to present a sustainability concept by probing into both realms of macro-based (at top layer) and micro-based (at lower layers) lexicons pertaining to sustainability. Relationships of how these concepts converge at different hierarchy of layers (or levels) of clarity are also discussed. In practice, a large and complex system of systems can possess a wide range of sustainability qualities at a macro level. To refer to a system as "more sustainable" is to essentially imply that a system has more resilience to survive or possesses a blend of many other qualities. Meanwhile, in a measurable or metrics-based value judgment system, we could also try to define a sustainable system at a lower level, or in a micro or metrics-based (quantitative) perspective.

Apart from formalizing a comprehensive and inclusive view of the sustainability, we also raise the necessity for evaluation, benchmarking, and aggregating a whole suite of qualities that positively or adversely influence the sustainability of products, processes, systems, and undertakings. However, the treatment of the latter requirement is beyond the scope of the current chapter, and it will be addressed in our future work.

1.3   SUSTAINABILITY ASSURANCE: THE FRAMEWORK

Given the multi-disciplinary and multi-dimensionality of the sustainability as a holistic and macro property, we develop and propose an integrated perspective on the subject through a systems framework. This is intended to clarify the context, components, topology, and the scope of sustainability at any level of perspective from consumable products to a large system of systems such as the ecosystem. The systems framework is developed and represented in weighted factors analysis methodology (WeFA) [6].

1.3.1   Weighted Factors Analysis

The underpinning philosophy for WeFA, the elicitation process, and the representation schema are detailed in the published literature [6, 7–10]. However, a brief account is given here as a quick reference to the methodology in view of the extensive use of WeFA's notation for the elicitation, capture, and encoding of a systems sustainability framework.

WeFA is a group-based knowledge capture, representation, encoding, and evaluation methodology. The expert panel are chosen to represent related but diverse and non-overlapping aspects of the problem being studied. The focal point of a group study in WeFA is an "AIM" (A0) represented graphically by an oval annotated with a brief relevant text. With the active participation of the expert panel, the AIM is debated, formalized, agreed, captured, noted, and decomposed into a number of influencing factors called "GOALs." The GOALs that are deemed to support the attainment of the AIM are classified as Drivers and those opposing the attainment of the AIM are considered Inhibitors. The Driver GOALs are represented by ellipses with bright background linked toward the AIM or other GOALs with green forward

arrows implying positive influence. The Inhibitor GOALs are represented by ellipses with a dark background color, linked to the AIM or other GOALs that they influence with red arrows pointing backward (toward themselves) implying negative influence.

All GOALs are annotated with a brief text to indicate their nature and a unique numbering system to simplify referencing. In WeFA, each factor (GOAL) can be in turn decomposed into its localized Drivers and Inhibitors and the process is repeated until the AIM is studied and analyzed at a desirable level of detail. The influences of factors in a WeFA schema, represented by green or red arrows, can be hierarchical as well as lateral. This creates a powerful and inter-related network capable of representing the factors, their influences, dependencies, and relationships with respect to the AIM under scrutiny.

WeFA diagrams are hierarchical and the GOAL numbering system is designed to reflect the hierarchy as well as type, that is, Driver or Inhibitor. The closest layer of GOALs to the AIM of a WeFA diagram is referred to as level 1 and its GOALs are annotated by G followed by a number. The numbering scheme for Driver GOALs is clockwise from 12:00 (top) starting from 1, for example, G1, G2, G3 and anticlockwise for the Inhibitors, for example, G1 and G2, etc. Deeper layers of the hierarchy are annotated as G1.1, G1.1.2, etc. These are referred to as level 2, 3, etc.

The graphical representation of all the factors and their positive and detrimental influences upon an AIM is referred to as a WeFA schema. This form of knowledge representation is principally aimed at ease of comprehension and review due to the graphical representation of the key factors, their influences, and their position within the hierarchy of other factors. This underpins the approach to the development of an objective evaluation and assessment regime for the sustainability assurance framework. In this spirit, WeFA is a knowledge capture, representation, verification, validation, evaluation, and reuse methodology principally suited to strategic complex scenarios such as sustainability.

1.3.2 The Framework

Traditional wisdom about sustainability refers to an amalgam of social, economic, and environmental dimensions in this complex concept [11]. The current bias however is mainly toward ecosystems whilst also assuming a blend of the right ingredients from the social, economic, and environmental dimensions is adequate to give a semblance of sustainability in a given context. By adopting the WeFA methodology, we challenge this unipolar conception of sustainability, thus treating it as a dynamic balance between a host of factors that support and detract from its attainment in a given context. This, we posit, is a more holistic and potent route to understanding [1], representation, evaluation, and benchmarking of this key attribute than the classical hierarchy of summative approaches. To this end, the system sustainability assurance framework, as an extension of the current conventional wisdom is presented in the WeFA schema of Figure 1.1. The framework embodies five key driver and three inhibitor class of goals. This suite of goals in the WeFA methodology essentially constitute the highest level of abstraction for the major influencing factors on the aim of the schema. Furthermore, given the hierarchical and relational nature of the
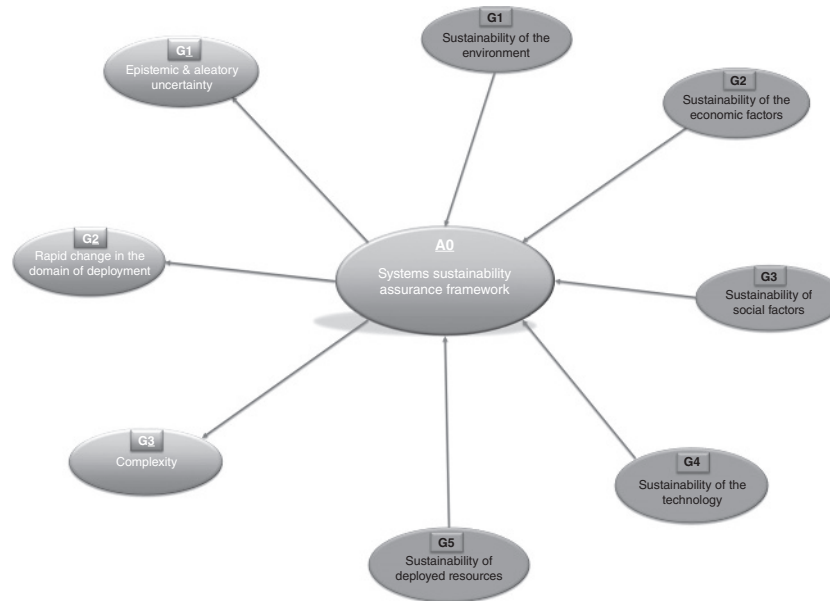
FIGURE 1.1   Systems sustainability framework, level 1 WeFA schema.

WeFA methodology, the so-called Level 1 schema is decomposed into a number of subsequent layers, Level 2 (as shown in Figure 1.2), Level 3 etc. An illustrative level 3 decomposition focuses on the technological facet as shown in Figure 1.3. An outline elaboration of the level 1 schema of Figure 1.1 is given as follows:

G1-Sustainability of the environment. All factors that qualify and underpin sustainability as far as the environmental impact is concerned.

G2-Sustainability of the economic factors. All factors that qualify and underpin sustainability from an economic cost, value, and market response perspective.

G3-Sustainability of the social factors. All factors that qualify and underpin the social acceptance, desirability, and values.

G4-Sustainability of the technology. All factors that influence the long-term viability of the materials and technology employed.

G5-Sustainability of the resource. The factors influencing the availability, desirability, and renewability of the resources employed.

G1-Uncertainty. The factors influencing the degree of uncertainty in any facet or performance.

G2-Rapid change in the domain of deployment. The factors underpinning the potential for rapid change internal or external.

G3-Complexity. The factors indicative of the degree of complexity in time behavior, structure, or composition.

FIGURE 1.2   Systems sustainability framework, level 2 WeFA schema.

Whilst WeFA is a creative and hierarchical knowledge capture, representation, and evaluation methodology, the level 1 schema of Figure 1.1 in principle depicts a taxonomic perspective on sustainability. The suite of dependent and independent influencing factors emerge in level 2 and higher decompositions in a given schema.

Taking the level 3 schema of Figure 1.3, we focus on the technological sustainability (G4) as an illustration of the key concepts of a sustainable system at macro and micro perspectives. This is in turn driven by:

G4.1 Sustainability of the architecture.
G4.2 Sustainability of the structure and build.

The driver goals for G4 are in turn decomposed as an illustration of the underlying concepts.
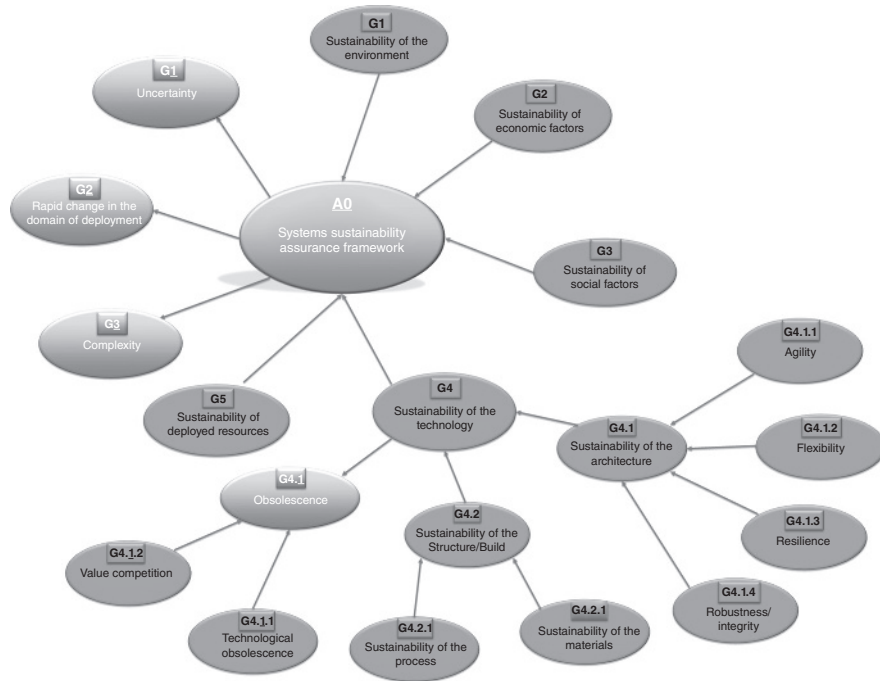
FIGURE 1.3   Systems sustainability framework, technological focus.

1.3.3 The Macro Concept of a Sustainable Architecture (G4.1)

We believe that a system or system of systems is considered architecturally sustainable in a macro perspective, if the following high-level key characteristics are assumed or attained:

(1) Resilience
(2) Robustness
(3) Flexibility
(4) Agility and efficiency

The macro (top-level) concept of a sustainable system can be qualitatively assessed for the sustainability of macro systems, such as the global economic system, environmental system, transportation system, information system, agriculture system, energy and global climate systems. Such a development of the sustainability concept is based on a top-down, goal driven, and attributes-decomposition process [12, 13]. Each of the four major attributes of the sustainable architecture of a system is defined below and also delineated in a graphic form as shown in Figure 1.4:
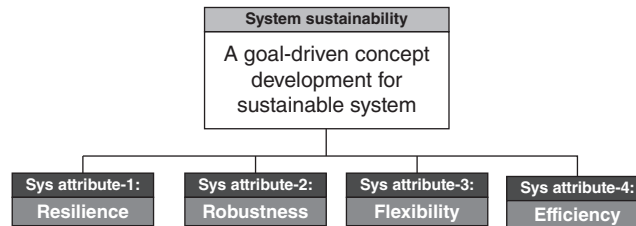
FIGURE 1.4   A macro (top-level) concept delineation of sustainable architectures.

System resilience – system attribute used to imply or indicate the evidence of system operability and survivability within an existing and changing environment or condition.

System robustness – system attribute used to imply or indicate the evidence of system capacity or performance capability given variations in an existing environment.

System flexibility – system attribute used to imply or indicate the evidence of system adaptability, and the ability to reconfigure itself for continued operability under a dynamic or disruptive changing environment (or internal/external conditions).

System agility and efficiency – system attribute used to imply or indicate the evidence of system capability to maximize performance while minimizing waste of resources.

1.3.4   The Micro Concept of a Sustainable System

A system or system of systems is considered sustainable in the micro or low-level sense, if the following low-level attributes or metrics-based characteristics are ensured and assumed:

(1) long-term operability and survivability within an existing and changing environment;

(2) flexibility and capability to adapt to the dynamics of the evolving external–internal conditions;

(3) system structure and interdependencies that support and promote accountability and efficiency;

(4) ability to expand and accept the use of new technologies for increased health and performance;

(5) robustness and capability to handle uncertainty and avoid severe risks of system catastrophe;

(6) system security and safety to resist or tolerate deteriorating or disruptive internal or external threat conditions;

(7) system efficiency and simplicity for satisfying performance expectations while preventing wasteful consumptions of resources; and

(8) long-term system availability or capacity for self-rectification to ensure continued existence and operation for achieving required system performances.

1.3.5 A Top-Down Hierarchy of a Multi-Level Sustainability Concept

As described in the previous two sections, a top-down hierarchical approach is employed to delineate the conceptual framework of a goal/objective-driven and attribute-decomposition process to derive a more comprehensive and unified generic definition of system sustainability. Based on a generic hierarchy (as shown in Figure 1.5), the macro- and micro-levels of system sustainability concepts introduced in this paper is thus logically related to one another.

The term "goal/objective-driven" used here is to explain the thought process of the necessity to define a precise "goal" or purpose and objectives of any sustainable system at the very high level of considerations. Meanwhile, the term "attribute decomposition" is used to describe the top-down process because a low-level sustainability concept (micro concept) is based on the metrics or system performance measures, which are generated from decomposing the high-level system attributes.

For instance, a top-level goal for sustainability of any generic systems could be simply defined as "assurance of system health," or to put it more specifically as "maximizing long-term system operability and successful performance while minimizing resources and system collapse." A top-level goal for sustainability of a globe system for humanity could be defined as "maximize global system survival and long-term security and prosperity." Therefore, under this top goal of achieving the globe system sustainability, a set of key system attributes (secondary or lower-level goals) can be readily developed and defined, and such a macro concept of a global system sustainability is shown in Figure 1.6.
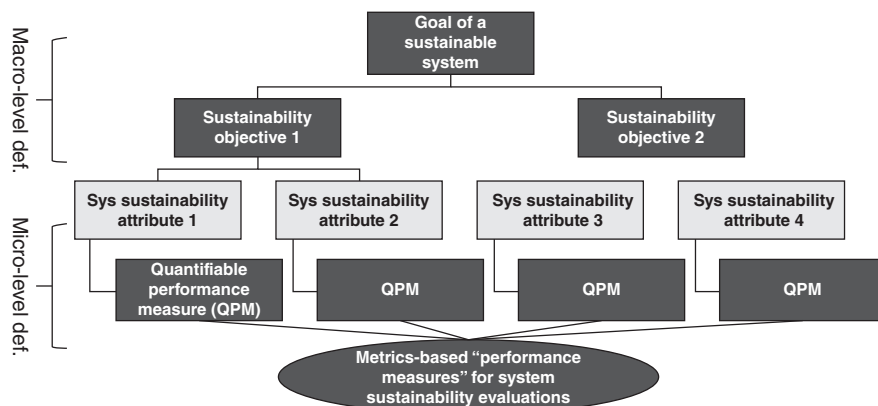

FIGURE 1.5   A goal-driven top-down hierarchy for defining system sustainability.
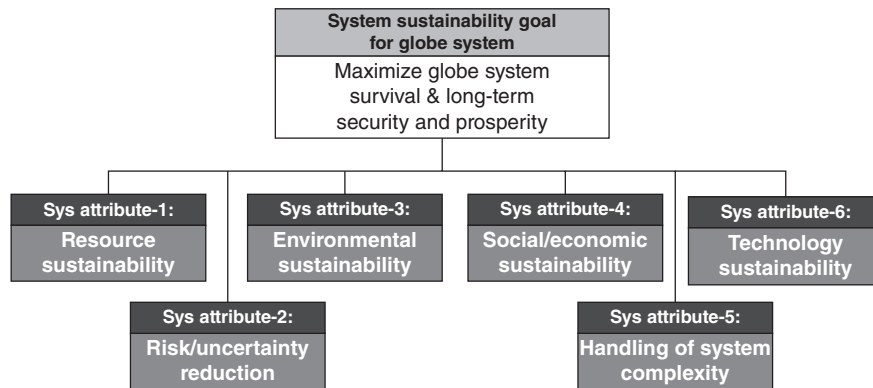
FIGURE 1.6 Illustration of a macro concept for global system sustainability.

In order to advance and properly define the concepts of systems sustainability, we must realize the important nature of sustainability concept with its interdisciplinary and multidisciplinary characteristics. In other words, interdisciplinary research and collaborative efforts with diverse stakeholders need to be carried out to develop and apply life-cycle based system models [14] for the evaluation of system sustainability. Furthermore, a set of complete sustainability metrics or performance measures need to be carefully defined for systems that meet societal needs. The sustainability concept as introduced in this section, can be summarized in the following respective definitions provided for a generic system and for a global system as well:

System sustainability for the generic system – an integrated set of inter-related parts, assemblies, rules, and processes or group of self-contained independent systems working together to deliver functions or services that satisfy a desirable blend of emergent properties pertaining to social, economic, environmental, technological, and resource utilization dimensions.

System sustainability for the global system – an integrated set of industrial, technological, social, and natural processes or systems purposefully working together to deliver products and services that satisfy a desirable blend of emergent properties pertaining to social, economic, environmental, technological, and resource utilization dimensions to ensure the well-being and continued progression of global societies while maintaining the integrity of human and ecosystems over a long-term time horizon.

1.4 TECHNOLOGICAL SUSTAINABILITY CASE STUDY—INFORMATION SYSTEMS SECURITY

We introduce a brief case study in one of the facets of sustainability in the information infrastructure. Even though the case presented does not directly align with

the sustainability framework depicted in the schema of Figure 1.1, it highlights an important aspect of sustainability in the cyber-domain context.

Policies and procedures are an important tool in the information security toolbox. The processes upon which sound security engineering management policies, procedures, and practices should be built need to be repeatable, reportable, and auditable (RRA) [15]. A process that is repeatable by two or more people will produce the same desired outcome and thereby provides confidence in the outcome. A process that is reportable ensures that any threat can be identified and assessed before it becomes destructive and allow managers to deal with it. Finally, a process that is auditable allows verification of the process. Processes that meet the criteria expressed as RRA are sustainable and allow cross-skilling and improve the recovery time when information security is threatened.

Organizational design is one of the biggest challenges facing business in the twenty-first century [16]. Even in the information society, most organizational structures were developed at a time when physical assets were managed and processed by physical labor. In today's world many assets are intangible and operate in a mutation of electronic communication networks which has increased complexity and introduced new threats and hence risks to the well-being of nations.

In today's business environment it is difficult to obtain senior management approval for the expenditure of valuable resources to "guarantee" that a potentially disastrous event will not occur that could affect the ultimate survivability of the organization.

Advanced level of network security provides maximum network flexibility as well as an additional layer of protection against unauthorized computer access. Moreover, this advanced security level also makes possible an audit trail of network usage. Another benefit is that a user authorization can be quickly and efficiently rescinded from the network. In general, this advanced security level can help reduce, if not eliminate, the need for costly additional security hardware such as data encryption devices.

Most companies tend to be reactive and respond with quick infrastructure solutions. A strategic approach to computer network security leads to a more efficient plan and a less expensive risk-management strategy. Aligning computer network security to corporate goals provides management with a framework for steering resources, whether it is toward infrastructure, improved controls, training, or insurance, based on a carefully thought-out process that analyses the level of risk the company is willing to absorb.

1.4.1 Network Security as a Business Issue

Many organizations run on information, and a well-planned network circulates this information lifeblood to all parts of an organization as efficiently as possible. Inappropriate network security provisions, however, can reduce network flexibility and still not close the door against unauthorized access and information loss. The ability of a network to blend an advanced level of security with maximum operating flexibility, therefore, must be considered carefully in any network plans.

An effective information security program incorporates a combination of technological and human controls in order to avoid the loss of information, deter accidental or intentional unauthorized activities, prevent unauthorized data access, detect a loss or impending loss, recover after a loss has occurred, and correct system vulnerabilities to prevent the same loss from happening again [17]. Correspondence among businesses, internal or external, is conducted through data transmissions. Data transmissions pass in networks of interconnected portals where parties could get in touch with one another. Networks need to be protected from both outsiders such as hackers and crackers, and insiders such as employees and other individuals with access to the network.

Unprotected information and computer networks can seriously damage a business's future. This happens because of the loss of classified or customer critical information, exposure of trade secrets, unacceptable business interruption, or lawsuits stemming from security breaches. As information and computer network security involves more than technology, companies are now spending more money and man-hours than necessary on cutting-edge technology. Inaccurate analysis of the company's needs can result in greater risk of information loss and higher frequency of security breaches.

Making computer and communication systems more secure is both a technological challenge and a managerial problem. The technology exists to incorporate adequate security safeguards within these systems, but the managerial demand for secure systems is virtually non-existent outside of the defense and financial industries. That so many of our commercial systems provide marginal security at best is a reflection of the lack of managerial awareness and understanding of the need to protect the information stored in, and transmitted between, computers.

Unprotected information and computer networks mean loss of data that are deemed crucial and confidential for the company's own development; loss of confidential third-party data; and business interruption or slowdowns that significantly impact the business as well as other parties.

Senior managers are becoming more and more aware of the need to address security and information technology investments within the context of the corporation's business goals. As Schwartau [18] has observed, security is no longer just about security. This also involves the proper identification of roles. Today, security is about resource and information management and it turns out that good security is a by-product of a well-run organization.

Information systems (IS) executives are most concerned with ensuring that their technology goals are consistent with those of the overall business, believing that an effective organization and usage of the company's data is a critical IS activity.

1.4.2 The Focus of Investment on Network Security

In all organizations the directors are faced with the problem of achieving organizational goals using limited resources available to them. Investing in network security should always seek to move the organization nearer to securing the entire network.

The directors should also keep in mind that investing in network security is an on-going process as the threats are always being upgraded time and again. This is so due to the fact that the hacking tools are readily available on the market and minimal training is required. Investment decisions are essentially search projects which are worth more than they cost to exploit and which thus create value.

Information security, right now, is a confused and paradoxical business. For example:

(1) You have increased spending significantly, and you are told that this is a good thing, and yet it has had zero effect in mitigating security breaches.

(2) You are constantly warned about "digital Pearl Harbours" and yet the vast majority of incidents you report are relatively small, do not last long and do not cost much.

(3) You are told that aligning security and business strategies is a top priority, and yet those who have fared best in avoiding breaches, downtime, and security-related damages are the least likely to be aligned with the business. But in another sense, you seem to be contributing to the confusion.

(4) Respondents who suffered the most damages from security incidents were two times more likely than the average respondent to plan on decreasing security spending next year.

(5) Those with the most damages were nearly half as likely to list staff training as one of their top three priorities.

(6) A quarter of you neither measured nor reviewed the effectiveness of your information security policies and procedures in the past year.

In short, as much as the emerging information security discipline has grown since its baptism—on September 18, 2001 (one week after the terrorist attacks and the day the Nimda worm hit)—it has not much improved with age.

Network resources allow worldwide access to information, no matter where it resides, or where the users are located. Unfortunately, the physical and logical controls used by an organization to secure its information offer no protection when that information is being electronically transmitted.

As Frankwood [19] observed, a successful financial decision is one that creates value, that is, it is worth more than it costs to implement. The investment decision is perhaps the most important of all decision an organization makes. In any organization there are strategic, technical, and political issues as well as financial aspects to tackle with. It involves more than simply number-crunching or relative financial costs and benefits. Many costs and benefits in network security investment are difficult if not impossible to quantify. Moreover, the numbers are often secondary, what determines whether an investment is accepted or not depends on the strategic direction the organization wants to pursue. Moreover, the approval of investment may hinge on the nature of the decision process within the organization, that is, investment approval in reality is often a question of internal politics. To obtain an approval of investment in network security management, managers must demonstrate that an investment is

necessary to maintain security by replacing old or obsolete technology. Many organizations classify investments into various categories in which different amounts of information are required as inputs to the evaluation process. The foregoing discussion highlights the need for a high-level systems framework to address the essential facets of information security. This in essence, can be a facet of the sustainability framework depicted in Figures 1.1.

1.5 CONCLUSIONS

Sustainability is highly desirable yet more complex than is often perceived, hence the need for an integrated systems framework to characterize, verify, validate, and communicate the underpinning factors globally. The secondary gain from a systemic framework is the extension, customization, evaluation, benchmarking, and assessing sustainability properties in products, processes, systems, and undertakings. In the latter context, it is vital that a systems framework for sustainability provides a scalable and adaptive architecture thus rendering it applicable at any level of perspective, from individual components, sub-systems and products to the macro-level consideration of the Gaia. The systems sustainability framework depicted in Figure 1.1 delivers a scalable systemic architecture capable of customization and application at any level of perspective.

However, apart from inclusivity and adaptability, sustainability and its systemic framework should lend themselves to application throughout the life-cycle from concept and feasibility to deployment, maintenance, and disposal. The systems framework depicted in Figures 1.1 and 1.5 is capable of adaptation and transverse application throughout the life of a product, process, system, or undertaking irrespective of the scale and scope of the case.

Given its inclusive and generic nature, the systems sustainability framework developed and proposed here provides a potent candidate for a unification of many emergent properties from safety and quality to security and technical performance. This enables stakeholders, business enterprises, and influential government and private institutions to achieve legal compliance and many other goals alongside other business imperatives.

Whilst the framework provides an image that transcends beyond ecological concerns, it is inevitable that sustainability will gain a more ecological bias should the dire predictions of the climate change begin to surface as real threats to the whole planet. To this end and to ensure risk/reward-based informed decision-making by all stakeholders, an objective set of metrics and benchmarks for sustainability will gain more urgency in an attempt to make this pervasive and increasingly vital facet, an integral aspect of decision-making.

We have developed the case for an inclusive, generic and systematic approach to sustainability which integrates many business and regulated facets of performance namely safety and environmental dimensions. Once verified, validated and adopted across many fields, sustainability may require regulation to ensure that it continues to

remain a potent weapon in our quest to preserve the integrity and continued survival of Gaia.

The extension of systems thinking to sustainable systems can span from ethical sustainable decisions in the face of dwindling natural resources [20] to developing sustainable business practices [21]. The scope of the application from soft to hard systems is vast and necessitates adoption of an underlying framework for consistency, transparency, and relative comparability of the potential assessment outcomes. The systemic framework depicted in Figure 1.1 is recommended for such underpinning. As a universal model for systemic sustainability, the framework can be applied to any soft or hard domain through decomposition of the so called level 1 goals in the schema to domain specific factors as we have illustrated in the decompositions depicted in Figures 1.2 and 1.3, respectively.

We should endeavor to progress and prosper whilst assuring the rights of the future generations to enjoy the same privileges. This should be our ultimate goal, beyond short-term gains and losses. Our creativity and ingenuity is the sole weapon in this battle. Systems thinking is the strategic guide and a framework of systemic factors the route-map.

"Whatever you can do or dream you can, begin it. Boldness has genius, power and magic in it. Begin it now!"

—Johan Wolfgang von Goethe

REFERENCES

[1] United Nations General Assembly. Report of the World Commission on Environment and Development: Our Common Future. Transmitted to the General Assembly as an Annex to Document A/42/427—Development and International Co-operation: Environment, 1987.

[2] Engineering Council UK. Guidance on sustainability for the engineering profession, May 2009. Available at www.engc.org.uk/sustainability, accessed May 2009.

[3] F. Hsu. The triple-triplet conceptual framework for integrated risk management (PSAM-0278). In: Proceedings of the Eighth International Conference on Probabilistic Safety Assessment and Management, New Orleans, LA, May 2006.

[4] J. Lovelock. *Homage to Gaia: The Life of an Independent Scientist*, Oxford University Press, 2001.

[5] S. Popper, S. Bankes, R. Callaway, and D. DeLaurentis. System-of-Systems Symposium: Report on a Summer Conversation, July 21–22, 2004, Potomac Institute for Policy Studies, Arlington, VA, 2004.

[6] A. Hunter and A. G. Hessami. *Formalization of Weighted Factors Analysis, Knowledge-Based Systems*, Elsevier, 2002.

[7] A. G. Hessami. Safety assurance, a systems paradigm. *Hazard Prevention—Journal of System Safety Society*, 35(3), 8–13, 1999.

[8] A. G. Hessami. Risk, a missed opportunity. *Risk and Continuity Journal*, 2: 17–26, 1999.

[9] A. G. Hessami. A systems framework for safety & security, the holistic paradigm. *Systems Engineering—The Journal of the International Council on Systems Engineering*, 7(2): 99–112, 2004.

[10] A. G. Hessami. Risk management a systems paradigm. *Systems Engineering—The Journal of the International Council on Systems Engineering*, 2(3): 156–167, 1999.

[11] Conceptual Framework Working Group of the Millennium Ecosystem Assessment. *Ecosystems and Human Well-being*. London: Island Press, 2003. Chapter 5. ISBN 155634030.

[12] F. Hsu. Managing programmatic risk in strategic decisions—a methodology for programmatic & strategic risk assessment and management. In: Proc. PSAM9, HK, 2008.

[13] F. Hsu. A goal-driven hierarchy process of metrics-based decision assessment for the lunar surface science scenarios, NASA OSEWG Report, 2009.

[14] ISO/IEC 15288, System Life Cycle Processes, October 2002.

[15] P. Maloney. Security zone: opinions and insights from experienced professionals. *Computer Weekly*, December 16, 2008.

[16] J. Holt. A Pragmatic Guide to Business Process Modelling, Second Edition, British Computer Society, 2009, ISBN 1906124124, 9781906124120.

[17] H. Jahankhani, S. Fernando, and M. Z. Nkhoma. Information systems security: cases of network administrator threats. *The International Journal of Information Security and Privacy*, 1(3): 13–25, 2007.

[18] W. Schwartau. Securing the enterprise. Technology alone won't make you safe. Tackle it as a management problem. *Network World*, 42, January 27, 2005.

[19] Frankwood. *Introduction to Accounting*. Prentice Hall, 2000.

[20] P. L. Kunsch, M. Theys, and J. P. Brans. The importance of systems thinking in ethical and sustainable decision-making. *Central European Journal of Operations Research*, 15(3): 253–269, 2007.

[21] H. Bradbury. Sustaining inner and outer worlds: a whole-systems approach to developing sustainable business practices in management. *Journal of Management Education*, 27(2): 172–187, 2003.

[22] A. Waring. *Practical Systems Thinking*. International Thomson Business Press, 1996. ISBN 0-412-71750-6.