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Chapter 9: Governance, Security, and Responsible System Design

9.1. Introduction

The timely and efficient delivery of public services often relies on complex integration of diverse digital systems. These systems, developed and operated by a myriad of organizational stakeholders, must work together reliably and as intended to ensure positive social outcomes. Consequently, resilient governance, security, and responsible design are essential for the successful delivery of such systems. Yet, although governance, security, and responsible considerations are often included in the planning and development of information and communications technology projects, the approaches and supporting frameworks are rarely integrated. This research develops an expanded foundation that covers governance, security, and responsible design for information and communications technology systems. Complementing addressing scholarly gaps, evidence-based analysis is useful for practitioners, as real-world case studies, comparative analysis, and architecture design patterns are also included.

Governance by design ensures that appropriate stakeholder engagement and accountability processes are integrated into the architecture of systems for public services. Such design can help avoid difficulties associated with determining whose actions, omissions, or decisions should be held accountable when public sector systems fail, misbehave, or are attacked. Security by design incorporates threat modeling and risk assessment; effective asset management and appropriate design, development, and operational processes; defense-in-depth; secure by default; and secure by design into information and communications technology. Responsible system design covers policy, ethical, and societal considerations; the decision to use artificial intelligence; and transparency, explainability, and user trust. Designing systems for public service that are secure, governed, and responsible by design increases the likelihood that resilient, trustworthy systems will be delivered.

9.1.1. Overview of the Study and Its Significance

System design should satisfy the desires and intent of all stakeholders, including society. Governance mechanisms should therefore be integrated into the system architecture and supporting development life cycle. An evidence-based analysis of vocation and intent, inclusion and accountability, policy and law, threat and risk, defense and assurance, ethics and impact, transparency and explainability, and user trust identify foundations for governance criteria that can be applied at each level of Abbot's Governance Hierarchy. Governance integration by design reduces the pressure to govern post deployment. Security integration by design reduces the cost and pain of assurance. System responsibility integration reduces the risk of unexpected consequences. The combined synergy produces a lower-risk, lower-cost, and higher-trust system that fulfills its vocation.

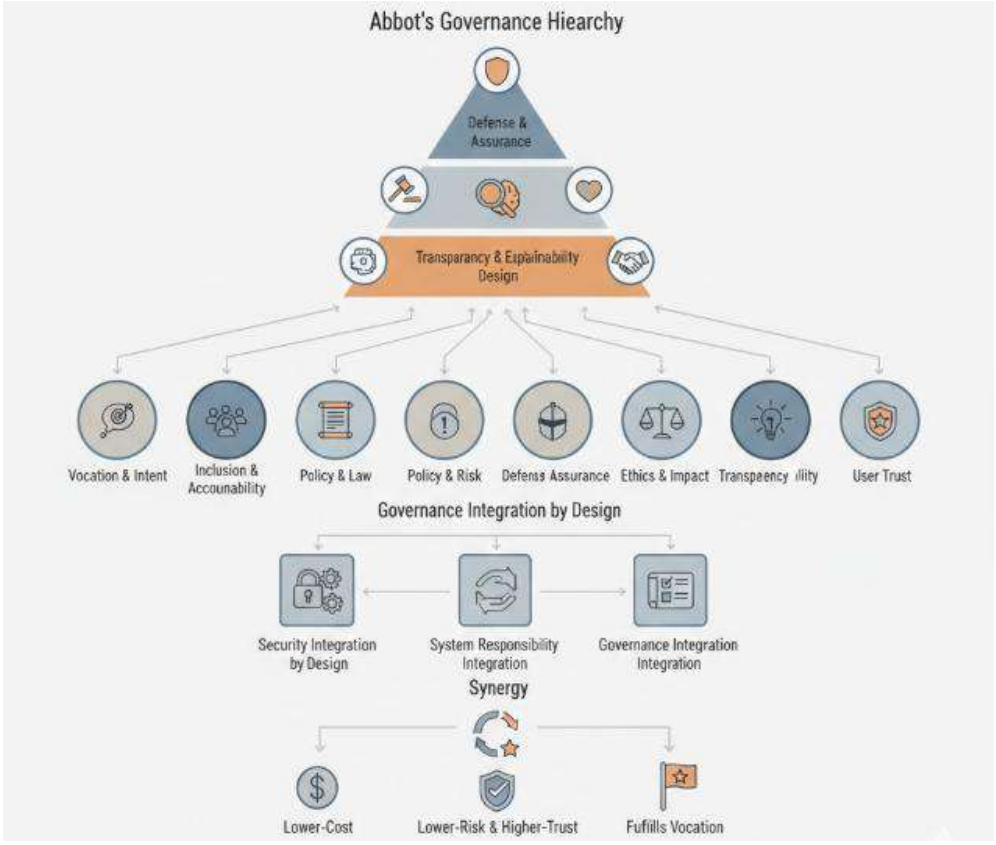

Fig 9.1: Architecting Societal Trust: A Framework for Integrated Governance, Security, and Responsibility by Design in Intelligent Systems

Case studies investigate public sector implementations and current industrial adoption of Industry 4.0 concepts. Comparative analyses across national Security Policy Statements reveal a common set of themes. Society has a vested interest in ensuring that

technology fulfills its intended vocation and does not produce unintended consequences or become a weapon for rogue or criminal actions. The responsibility primarily rests with the designers of technology-based systems, and these responsibilities should be fulfilled by design rather than express approval of the final design and operation.

9.2. Foundations of Governance in System Design

Analysis of governance in system design begins with an assessment of stakeholder engagement and accountability, consideration of relevant policy frameworks, and mechanisms for support and compliance. Stakeholder activities should include ongoing engagement with, and consideration of, the perspectives of all parties who may be affected by the system or its operation. The establishment of policies and processes to explicitly support compliance with all applicable data protection and privacy regulations, standards, and policies is essential. Adoption of tools and processes supporting continuous compliance is desirable and, where possible, the implementation of architecture patterns for governance by design.

Consideration of the above issues contributes to the identification and assessment of governance by design patterns that not only facilitate compliance with laws, regulations, and standards, but also support accountability and reinforce community trust. Consideration should also be given to the architecture pattern “Governance as a Service” to provide the ongoing support and capability required when deploying and operating public sector systems designed for high levels of citizen engagement, stakeholder accountability, and the ability to integrate and federate disparate data across jurisdictions. Processes supporting engagement with key stakeholder communities should also be established. For systems in sensitive jurisdictions and when handling sensitive data, consideration should also be given to independent ethical review as an effective means of facilitating community trust.

9.2.1. Stakeholder Engagement and Accountability

Governance is a multidisciplinary field of study that leverages insights from economics, political science, and business management. Within system design, governance pertains to stakeholder engagement for the purpose of stakeholder accountability. Stakeholders can be broadly segmented into direct and indirect stakeholders based on the degree to which they are affected by the system's operation. Stakeholders representative of the operating environment's flash point together constitute the direct stakeholders. These stakeholders specify the intended operational behavior of the system for fulfilling societal needs, as reflected in the system's requirements and objectives.

Consequently, the specification of the intended operational behavior requires active engagement with stakeholders and those acting on the stakeholders' behalf. In democratic societies, this role typically resides within government and formal structures. Implicitly or explicitly, political representation derives from the need for accountability to these stakeholders. Their objectives typically extend beyond the level of particular systems, notwithstanding coalition-building, and their perspectives often integrate a blend of societal concerns and influencer motivations that can be mutually supportive or conflicting. In contrast, societal requirements represent the collective operational needs of all stakeholders and must be satisfied for the system to remain socially accepted and useful. This requires engagement with society—a much larger stakeholder group with global-scale requirements.

9.2.2. Policy Frameworks and Compliance

Technical and operational policies provide necessary conditions for accountability, and assume a diplomatic, internal–external focus. They address various aspects of the operation and development of systems that affect the achievement of desired governance outcomes, such as policies and their accompanying directives that provide detailed guidance for setting up, operating, and securing systems; and data management policies that guide the creation, processing, retention, and disposal of data acquired by systems. Technical and operational policies are essential to the implementation of the governance-by-design approach.

Although external compliance frameworks are generally devised with a broader goal in mind, they often lead to improved governance by design. Privacy compliance frameworks cover requirements for what data can or cannot be collected, data minimization, purpose limitation, and other provisions that mitigate the consequences of a lack of transparency. Audit frameworks also contribute to governance by design.

9.3. Security Principles in System Design

Sufficient controls for governing information systems can be ensured if main stakeholders are involved during the development phase by complete and formal engagement in the design process of the system. Subsequently, a listing of possible threats to the asset, an evaluation of these threats and their impact as well as a listing of the assets and threats relations may reveal if any of the participating stakeholders may harm another, purposefully or not. A formal representation of all possible security violations may also be elaborated to evaluate whether a defence strategy ought to be deployed.

Principles of security by design consist of techniques and precautions that ought to be taken during the early phases of the development of the information system, whilst following best practices. Defence in depth consists of layers of defence with specific purposes, designed with knowledge on attackers. Secure by design is the principle of designing an asset with regard to the set of threats containing risk of exploitation and consequences of impact once exploited. Security cannot be added on top, it must be taken in account the whole life-cycle of the information system and development but as also foreseen with the governance process during the phase of security testing and exploitation as well.

9.3.1. Threat Modeling and Risk Assessment

To facilitate a better understanding of potential threats and to guide the allocation of resources for security measures, threat modeling and risk assessment are crucial steps in system development and use. In threat modeling, the system's potential security

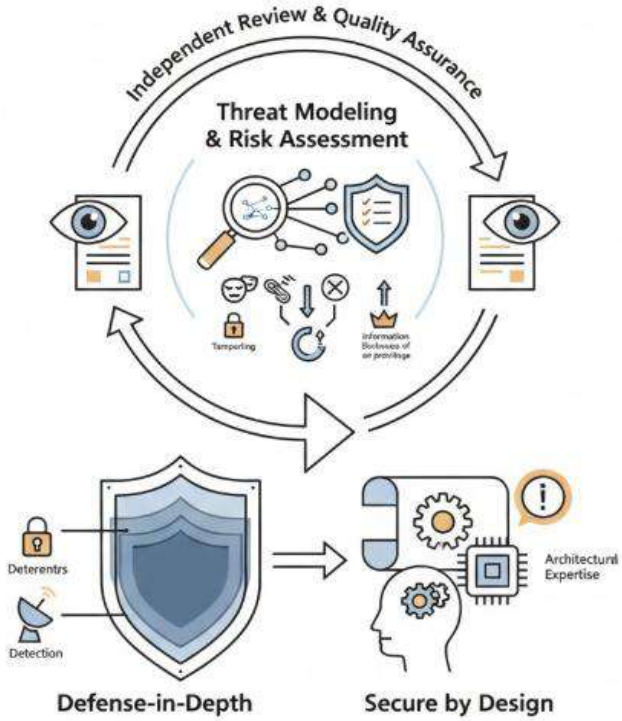

Fig 9.2: Integrated Resilient Systems: An Iterative Framework for Threat Modeling, Risk Assessment, and Secure-by-Design Architectures

weaknesses, particularly within the context of its current environment, are identified and categorized, typically using a framework such as STRIDE (spoofing, tampering,

repudiation, information disclosure, denial of service, and elevation of privilege). Risk assessment examines the usefulness to an adversary of exploiting individual weaknesses and the potential damage associated with such exploitation. Threat modeling and risk assessment should be performed iteratively and, for quality assurance, the potential weaknesses identified should be reviewed by an independent source to ensure no key resources are overlooked.

Two further important security principles are defense-in-depth and being secure by design. Defense-in-depth entails the provision of multiple layers of security controls (defensive mechanisms) so that, should one control fail, other controls will still offer protection. These controls can include deterrents, preventive measures, and active and passive detection mechanisms. Systems that are "secure by design" are built such that their implementation will not introduce newly exploitable weaknesses. To achieve this, the system architect must have expertise in identifying weaknesses associated with coding errors, system configurations, and inherent protocols.

9.3.2. Defense-in-Depth and Secure by Design

Defense-in-depth describes a strategy of layering multiple complementary security controls with the goal of protecting the system even when individual components fail, similar to a fortress with multiple concentric walls backed by troops and supplies at each stage. The approach to actual implementation of the controls is referred to as secure by design. Security controls act as both deterrents and practical responses to threats. Deterrents differ from actual responses in that their effect is achieved without an event occurring, while practical responses take effect only after an event has happened and can help bring a system or entity back to a functional state.

Deterrents generally operate to keep a notorious threat actor from attempting an attack, while practical responses aim to keep an attack from succeeding. They can best be understood through the incident management procedures of the telecommunication operator categories established to ensure the reliability of the necessary, no-fail elements in a telecommunications infrastructure. An operator categorised appropriately must demonstrate sufficient capability to be able to respond quickly to any incident and must be well registered and integrated into the overall communications strategy. Categorisation according to incident management capability enables a faster and more proportionate response to critical incidents or emergencies. Even when rapid recovery measures are invoked, the design must seek to avoid a repeat of prior incidents over time.

The telecommunication incident management processes form one part of a comprehensive defence roadmap developed by the United States as part of their National Strategy for Trusted Identities in Cyberspace. In that roadmap, identification is

recognised as the essential first step in cybersecurity and incident management strategy. Secure identification permits the use of the full range of deterrent controls, and the monitoring it provides permits the recording and grouping of attacks to identify and deter crude patterns of attack.

9.4. Responsible System Design

Responsible system design encompasses social responsibility, ethical considerations, transparency, explainability, and user-centered design. Research shows that responsible design leads to more secure systems by increasing focus on human factors. Stakeholders need systems that are secure, that they can trust, and that have a positive societal impact.

Systems have a stronger impact on users and society if they are developed based on ethical considerations, following ethical principles, releasing ethically aligned systems, and addressing ethics during the entire lifecycle of a system. Transparent and explainable systems are significantly easier to trust, which is why trustworthy systems should be developed. Finally, when a tool fulfills the needs of the user and follows user-centered design principles, it is much easier to be trusted by the user. Users cannot be expected to note and react to every security warning.

9.4.1. Ethical Considerations and Societal Impact

The design of ICT systems can benefit from integrating ethical considerations and an awareness of social and societal impact into the principles that underpin the design approach. Ethical frameworks and approaches to ethical risk management can guide ICT system design by imposing obligations on designers and manufacturers to consider the possible negative effects of ICT products and systems on users, either alone or in combination with other factors. The ethical design approaches base a normative framework on human rights supported by The International Bill of Human Rights. This human rights framework issues an ethical obligation on designers and manufacturers to consider the potential negative social and societal impact of new technological products or systems. The impact of both the deployment of a technology and its continuing operation is expected to affect a larger layer of society than the more narrowly focused deployment risk.

The likely impact of a new technology or product is more easily overlooked in the short-term and, given the increasing complexity and interactions of many of today's systems, it may be equally difficult to predict whether the continuing use of the technology will remain beneficial in the long-term. The ethical considerations should thus apply to the wider aspect of social and societal consequences as much as to the narrowest view based

on a user risk. Such a widening of the risk landscape moves it significantly beyond traditional risk assessment techniques, which are often limited by practical or political realities and have difficulty capturing either the significance or reality of a change.

9.4.2. Transparency, Explainability, and User Trust

Transparency, explainability, and user trust are ethical design principles that relate to how users perceive an information system and the purpose for which it was created. The system's purpose and the manner in which it operates should be clearly communicated to likely users as part of the system's design. Those most closely associated with the system's creation and ongoing operation have the greatest obligation to ensure this communication is as informative and clear as possible. Good such communications will explain how and why the system operates as it does, what kinds of situations or interactions will lead to different kinds of responses, which kinds of interactions can be expected to yield insights or observations that the system is being used 'correctly', and which kinds of interactions can be expected to lead to pareidolia or soot. Doing so is essential in enabling users to have appropriate expectations of the system, understanding when its observations or insights may be valid or useful, and avoiding situations where reliance on its capabilities leads to adverse consequences.

Users must be given clear and realistic indications of the system's capabilities. The common tendency to invest emerging technologies with almost magical abilities, such as claiming a generative art model can never create anything but an artistic masterpiece, should be actively countered. Users should be encouraged to appreciate limitations of the system and guard against exaggerations of its capabilities. For example, although a particular compound may be predicted by the model as a likely candidate for experimental synthesis, it is a mere receptacle for other people's intellectual insights and creativity, and no more a 'virtual chemist' than a powerful but little-used synthesis-planning program such as A* or MARS. Information probing areas of stark pareidolia should also be presented clearly.

9.5. Integration of Governance, Security, and Responsibility

Governance, security, and responsible system design are closely intertwined. Discussions of governance cannot ignore security concerns, since operational inability resulting from security breaches clearly impacts the ability of organizations to fulfill their obligations. Security approaches cannot disregard governance issues since there are many aspects of security that cannot be adequately addressed solely through engineering. Finally, while neither governance nor security can ensure that a system behaves in a manner that is ethical or socially acceptable, designing and implementing governance

mechanisms that facilitate user trust or utilizing secure-by-design principles are important steps in this direction. A holistic approach should therefore consider architecture patterns that implement governance structures, operational models incorporating secure DevOps with continuous compliance, and the discussion of trust in artificial intelligence systems.

An important aspect of governance by design is establishing architecture patterns that align the power relations among the various stakeholders with the stakeholders' requirements and with expected system use. Such patterns represent ways in which governance mechanisms can be integrated with system architecture and are best defined in a top-down manner, starting from the engaged stakeholders, the obligations imposed on the operating bodies, and the related design principles. Security is also key for responsible system design and, more generally, for responsible technology development. Stakeholders generally value responsible design because it contributes towards possible negative consequences of a product or system, especially for the end users themselves.

Fig 9.3: The Triad of Responsible Design: Integrating Governance by Design, Secure DevOps, and Stakeholder Trust in AI Architectures

9.5.1. Architecture Patterns for Governance by Design

Establishing effective governance mechanisms in a system requires consideration of the interactions of all involved stakeholders during the design phase and implementation of suitable architecture patterns. Governance mechanisms come in many forms, including

engagement of stakeholders, facilitating adherence to laws and policies, and defining systems of hierarchy in which actors within the system are accountable to others. Modelling the relevant stakeholders and understanding their roles is crucial for effective governance. Engaging with the appropriate stakeholder community throughout the design process and beyond enables systems to be built that work for the entire community rather than just a subset. A candy vending machine, for instance, may not meet the needs of a community concerned about childhood obesity. Governance by design needs to consider iterative interactions with the surrounding environment and showcase how regulation is simply another layer of the interacting ecosystem.

Distributed ledger technology (DLT) constitutes a governance capability in itself, providing chronological and immutable logs of transactions involving all actors. A blockchain can act as the source of truth, shared among all the parties involved, obviating the need for centralised trust in a standard court system. Policy compliance can be integrated into a DLT-based system, capable of dynamically assessing the state and compliance of all parties and offering transparency to an external auditor. A cryptocurrency system can naturally incorporate the principles of KYC (know-your-customer) and AML (anti-money laundering), with the governance-tech stack serving as a border-control agency for all participants. When nodes reside within a single jurisdiction, this capability can facilitate real-time compliance for transaction amounts below the reporting threshold.

9.5.2. Secure DevOps and Continuous Compliance

Within an organization, alignment with governance and compliance frameworks requires ongoing validation even during platform development and maintenance. Specific security policies must be observed by development and deployment teams for each new service or application, as well as during the operation of services and applications. A logic-based approach examines, computes, and enforces security policy compliance continuously on resources used by applications and services. In addition, support activities of specialized teams can be automated through integration in pipelines used by deployment teams.

A central security team defines the security and compliance framework in terms of security policies required by various government and industry standards and policies, the security implications of every line of code in the application, and compliance with every requirement in supportive security services. The security policies define the holistic view of the security and compliance framework and are then translated into YAML templates that can be consumed by external services for validation. Detecting breaches before they happen is a significant improvement over having additional

resources responding to alerts, which should be optimized to react only to genuine incidents.

9.6. Case Studies and Comparative Analyses

Research developments across governance, security, and responsible system design culminate in case studies and comparative studies that demonstrate their application and reinforce their relevance to society. They chart important directions for further development of responsible systems. Concrete examples illustrate how the diverse topics integrate into a coherent whole.

Information and communications technology research has pioneered practical governance by design approaches. Practical applications include the integration of technology with policy frameworks to support emerging digital societies. The design of digital service delivery in government has drawn on frameworks for stakeholder engagement and accountability, and for compliance with privacy legislation—both spanning governance, security, and responsibility. A second application focuses on technology to enable safer online environments through compliance with child protection legislation. Analysis of deployment in the online gaming sector illustrates frameworks for continuous compliance. Further examples demonstrate the approach in game asset exchanges and in cryptocurrency developers and exchanges.

The principles are equally relevant to defence, critical infrastructure protection, and Defence-in-Depth for 5G and Industry 4.0. Frameworks for Technology and Communication enable end-to-end risk assessment, management, and mitigations; a special focus addresses the hardware-software-lifecycle aspect of secure by design, as reiterated by the ENISA guidelines on risk management and German 5G Security Guidelines.

9.6.1. Public Sector Implementations

An emerging body of work integrates governance and security in DevOps-related architectures through governance-as-code. The aim is the automation of technical policies across a system's cloud, network, systems, security, and application layers, with principles and measures expressed in code executed by services such as Kubernetes Admission Controllers, OpenPolicyAgent, and AWS Config Rules. The work's implementation in the public sector is anchored in Australian Cyber Security Centre policies and guidelines; these determine the code-driving principles. Like the collection of policies and safeguards in the broader information assurance landscape, the principles apply differently at different classification levels, from non-sensitive systems all the way

to classified systems. Critical to this integration are the sound governance measures that determine compliance, establish the assurance framework, and derive the risk controls. The adequacy and effectiveness of implementation are across-the-board operations during system acquisition, operation, or decommissioning.

Despite the increasing cyber exposure of the public sector, the responsibility and effort of integration remain insufficient. The Accenture Security and Privacy in the Public Sector report identifies six industry challenges and reveals that maturity in adopting leadership controls is weaker than in business investment, strategy, and focus. It finds that information-security budgets have not kept pace with the rising threat environment and therefore remain static or in decline. The impatient researcher might conclude that development continues with little thought of architecting for governance and security. Nevertheless, for no class of system can such implementation be acceptable. Indeed, one might argue, based on a military analogy, that when an enemy has the advantage, playing on immutable habits is the wise course of action for an attacker.

9.6.2. Critical Infrastructure and Industry 4.0

In the public sector, the “smart city” concept promises citizens safer environments, improved quality of life, optimized resources, and lower expenditures. However, these systems can become sources of severe risks, as evidenced by ongoing protests against intransparent, unethical, and poorly secured applications, such as facial recognition or behavioral, emotional, and predictive surveillance systems. The conclusions and recommendations of the International Institute for the Unification of Private Law could provide clear benefits if properly deployed in the governance of the design and development lifecycles of smart city systems and infrastructures. Private-sector adoption of Industry 4.0 technologies offers a wealth of benefits, such as greater efficiency, agility, product quality, availability, and reduced costs. Yet, the security implications must not be neglected; negligent companies may expose not only their business operations but also the physical safety of users and citizens. Meanwhile, malicious operators are interested not just in stealing money but also in sabotage and terrorism. Governance, Security, and Responsible Design must be current priorities in the development of Industry 4.0 systems. In both sectors, specific architectures enabling Security DevOps practices can ensure continuous compliance across the system’s entire lifecycle.

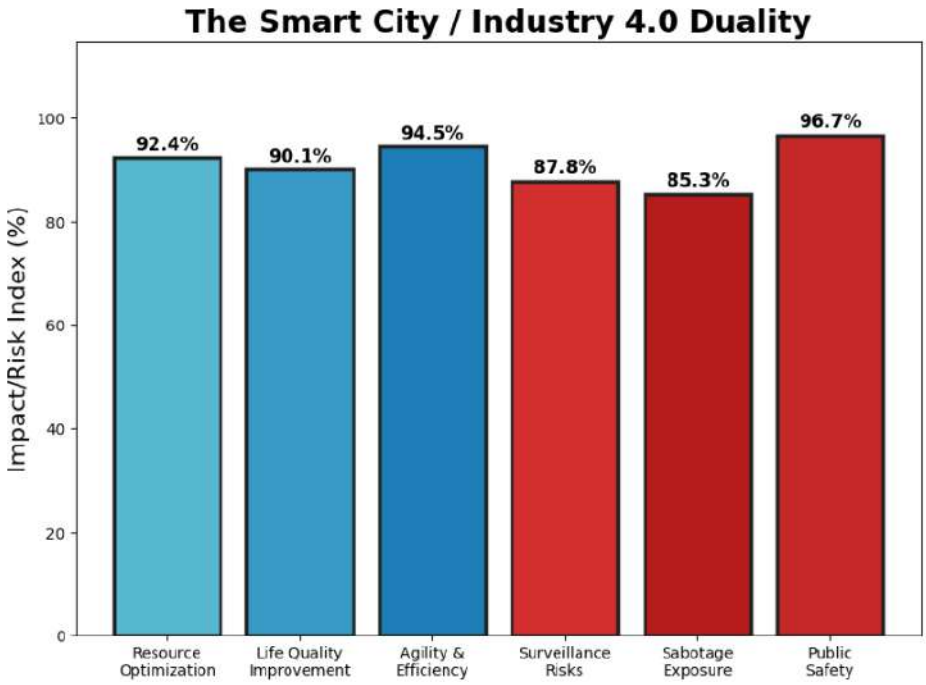

Fig 9.4: The Smart City / Industry 4.0 Duality

9.7. Conclusion

Advancing an evidence-based analysis of governance, security, and responsible system design highlights the interconnections among these themes and identifies key concepts for integration into systems. Evidence that the inclusion of governance, security, and ethical considerations in system design and deployment improves user trust and utility has been achieved; however, there is currently little guidance regarding how to integrate these elements. Key concepts enabling the integration of governance, security, and responsibility within systems include stakeholder engagement and accountability; policy frameworks and compliance; threat modeling and risk assessment; defense-in-depth and secure by design principles; ethical considerations and societal impact; transparency, explainability, and user trust; architecture patterns supporting governance by design; and Secure DevOps, enabling continuous compliance with legislation.

Objective, evidence-based recommendations for future research and practice are presented, drawn from multiple investigations of complex systems, with a focus on public sector implementation and critical infrastructure. In public sector settings, systems must balance the expectations of diverse stakeholders, with the potential for reputational harm in the event of failure. Security is paramount during operation as any exploitation may have far-reaching ramifications. Integrating governance and security

throughout the system lifecycle is thus essential. In specific domains, such as industry 4.0, threats may pose both immediate risk to operations and longer-term cost to end users. Given the emerging necessity to mitigate these threats, the appropriate integration of governance, security, and Socio-Technical System concepts will have substantial positive impact.

9.7.1. Summary of Key Insights and Future Directions

A rigorous examination of governance, security, and responsible system design generates three key insights. First, a comprehensive approach to Governance by Design requires not just attending to the formal procedures for strategy definition and stakeholder engagement but also modelling accountability through derivations of an accountability graph starting at the level of stakeholder engagement. Second, the fulfilment of external policies and regulations, which constitute Security by Design, cannot be attuned to the formal processes of Security by Design without a Policy Framework-as-a-Code that registers all policies and regulations in a database format from which risk treatment plans, security controls, and compliance records can be generated and maintained. Third, Developers of modern information and communication systems—including not only software developers, but also business analysts, solution architects, systems engineers and project managers—nowadays require an understanding of ethical system design and not just Regulation-by-Design in order to address important ethical considerations such as societal impact, transparency and explainability for trust.

Future research is required to deepen the examination of Security by Design through the lens of Governance by Design and to explore additional opportunities for the integration of Security by Design with Responsibility by Design. Also meriting further exploration are practical, real-world illustrations of the multiple architectural patterns—based on the utilitarian principles of the governance archetype—for the incorporation of Governance by Design. Finally, a comparative analysis of systems deployed in the public sector and in critical infrastructure—such as the technologies for Industry 4.0—would shed light on possible architectural patterns incorporating Security by Design and Regulation-by-Design.

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