

INFORMATION & COMMUNICATIONS TECHNOLOGY EVOLUTION AND CONSEQUENTIAL DAMAGE

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Abstract

Information and Communications Technology (ICT) has continued to evolve to a point where its use and application is both impressive and ubiquitous. ICT is able to solve a wide range of social human challenges and issues. The technology is able to link people from all over the world, facilitate scientific discovery and break-through, and is able to bridge many social divides. Indeed information and communication technology has evolved; however there is recent evidence that this same technology may have unintended consequences. This paper suggests that a trend has emerged where the benign and correct use of ICT may unexpectedly result in social disruption and harm to others, resulting in consequential damages. Whilst technology may be used in a malevolent way by a person intending to cause harm, the subject of this paper is on the negative consequences caused by benign, perhaps by unsuspecting individuals, rather than the malicious user. Evidence indicates this trend is now occurring, suggesting that a key point has been reached in the power and strength of ICT that no longer permits the luxury of candid use without due consideration to the potential un-intended consequences. To counter these problems we suggest that policy development and technology assessment methods are required by institutions to manage the use of ICT in order to reduce the possibility of un-intended social harm and consequential damage.

Key Words: Unintended Consequences, Innovation, Information & Communications Technology, ICT, Consequential Damages, Technology Assessment.

1. Introduction

An informal review of the hottest new industry trends in 2007 has identified 16 Information & Communications Technology (ICT) related innovations out of a total of 50 innovations [1]. In other words, ICT represented 32% of the emerging ideas discussed, which included progress in space exploration, advances in molecular science, and environmentally efficient energy solutions. The significance and importance of ICT is clearly visible in its positive impact to our society. ICT improves our lifestyle with entertainment devices and gadgets, social benefits through collaboration and communication, and numerous business efficiencies and productivity improvements are bestowed through its use. While ICT has become a necessary asset to many aspects of our every day life, there is growing evidence that this same powerful technology can sometimes have undesirable side effects which impact the community and our society.

This paper suggests that a key point has been reached in the power and strength of ICT that no longer permits the *luxury of candid use* without considering the consequences. The term

candid use is used here in this context to denote *unreservedly straightforward* (or casual) use of technology. Moreover, a trend is emerging where the benign and correct use of ICT may unexpectedly result in unintended social disruption, causing harm to others and with consequential damages to institutions. For the individual the results may be personally devastating, for corporate institutions this may result in financial impact, legal activity, and loss of community standing.

Recently, there are a number of instances where the presumed benign use of technology has resulted in unintended consequences. This includes breaches of trust in security measures [2], concerns regarding radio emissions [3], and rapid increases in electronic waste [4]. The technologies associated in these instances were not manufactured to be intentionally malicious; however the technology was applied by users in a way that resulted in both direct and indirect harm. Such scenarios provide motivation to industry and government for developing policies to guide technology implementers on how to moderate the use of ICT so as to not cause such unintended consequences. Developing such policies will also help mitigate the social and financial repercussions when such consequences do occur and foster corporate responsibility to the community.

We build upon the theories of Merton on what factors cause unintended consequences [5], by proposing additional contributing factors that are relevant to ICT. These principles are then used to highlight several examples that involve ICT of how such consequences have occurred. This serves to draw attention to the theme presented that ICT has evolved to a point where its casual use is no longer available without due consideration of consequences. We also suggest parameters to guide industry and government on how to prepare policies that may mitigate the impacts to institutions and the community. Hence, we view the main contributions of this paper as follows.

- Suggests that technology has recently evolved to a point that no longer permits the *luxury of candid use* without due consideration to the potential unintended consequences.
- Establishes the factors relevant to ICT that contribute to such consequences, presenting several scenarios and the likely repercussions if ICT is applied without appropriate safety checks applied on its use.
- Outlines several parameters for developing policies, guidelines, and technology assessment methods for industry and government.

The next section discusses the literature related to the evolution of technology and its societal impact. Section three identifies contributing factors based upon Merton's theories and section four outlines several examples of how ICT has resulted in un-intended consequences. In section five, an initial set of parameters for establishing policies and guidelines is presented. The final section summarises the key observations made and suggests areas of further work.

2. Background and Related Literature

Bargh and McKenna observe that the Internet as a communications technology follows a similar trend established by telegraph, telephone, radio and television, by building upon the capabilities of previous innovations [6]. They examine the effects of Internet on the psychological well-being of users and the community, noting several risks with communications technology.

Naisbitt studies the relationship between technology and the human element. He suggests that an eco-system exists where as technology is introduced in our lives, there is a counterbalancing need that offsets this introduction. He also observes that humans introduce technology without thinking about how relationships will change, what will be enhanced,

what will be displaced and what is diminished. He suggests that the introduction of a new species is similar to the introduction of new technology into the home, the workplace or society and will have significant consequences [7].

In [8], Williams suggests that studies on the effects of technology introduction may be superficial unless deeper analysis of the cause and effect between technology and its impact to society, culture, and psychology is carried out. For instance, he points out that in many ways television was a technological accident with several unforeseen consequences. This included its impact to other forms of entertainment and news media, but also on aspects of the family, cultural and social life.

Hargittai reviews the impact of the radio as a large scale communications technology and draws several comparisons to the recent introduction of the Internet [9]. She observes that the origins and evolution of both forms of technology follow a similar path that led to regulations being imposed on institutions offering these technologies. Several consequences of the technology's introduction were inevitably dealt with. This included personal privacy, national security, information reliability, and children's use of technology. She observes that this was addressed at the start of the 20th century with radio and once again at the start of the 21st century with the Internet.

Healy conducts a panel discussion on the unanticipated consequences of technology [10]. The panel more broadly discusses the implications of unanticipated consequences as both positive and negative. He also points out that the inventor, or designer, of a new system is not usually the best judge in assessing the good or harm that may be incurred. In [11] Tenner critically analyses several forms of technology and why 'ironic' unintended consequences emerge, suggesting that a general rule seems to pervade technology which explain 'why things bite back'. Additionally, there are a number of other more general studies on the consequential impact of ICT in various industry segments [12, 13, 14].

The previous works have observed that new technology has the potential to introduce risk, and that existing analysis techniques may not fully divulge the potential consequences. It appears to be accepted in the literature that technology has the potential to inflict un-expected outcomes. We extend this notion here suggesting that a point has now been reached in the evolution of ICT that simply no longer permits candid, i.e. casual, use without due consideration to unintended consequences. This is a fundamental shift in the way we perceive ICT, from the possibility of causing unintended harm, to an acceptance that ICT will cause harm if precautionary measures are omitted. More specifically, the power and strength of ICT warrants a more systematic analysis of the potential impact to the community if negative consequences are to be avoided.

3. Unintended Consequences

Unintended consequences may be generally classed as unexpected positive outcomes, or unexpected negative outcomes. The literature does focus on the later and in the context of this paper the negative unintended consequences are of interest. We study this aspect further here by providing a formal analysis of the factors that contribute to such negative outcomes.

3.1 The Merton Principles

It is suggested that the first complete analysis of unintended consequences was conducted by Robert K. Merton in 1936 [15, 16]. At the time the notion was referred to as unanticipated consequences, however it is widely regarded that Merton coined the term *unintended consequences*. Arguably one of the most influential sociologists of his time [17], Merton

suggests that there are five factors that contribute to unintended consequences: ignorance, errors, immediate interests, basic values, and self defeating prophecies [16, 18]. We briefly outline these factors.

Ignorance is the incomplete knowledge of the domain and the fundamental tenet that it is impossible to anticipate everything. This often involves acting upon opinion and estimate, with perhaps misplaced confidence on incomplete information.

Errors in the appraisal of the current situation and of future possible situations contribute to unintended consequences. This includes the error of applying historical precedence to predict outcomes to the current situation. Further, a failure to observe that recognised procedures, that have been previously successful in certain circumstances, may not be so under all conditions.

The immediate interest will influence and override longer term interests. Intense interest precludes objective analysis of the broader issues, resulting in emotional bias. This may also include decisions made that intentionally ignore longer term impacts due to the short term goals.

The basic values we possess as humans will influence certain actions. The actions taken in accordance with our values will focus on a particular value area. Often, no additional consequences are considered based upon our value judgement. What we judge as right for one another is considered right based upon our values, regardless of whether this is in fact true or not. This obviously has severe limitations. Individuals who have differing sets of basic values will yield different results (unintended consequences). Merton also points out here that the complex interaction of society will mean that impacts in one area will, in the longer term, ultimately impact adjacent areas and the value-system held by the change agents. Such a result will potentially alter the original set of basic values of those who instigated the change.

The final factor identified by Merton is that predictions of social development do not eventuate because the prediction itself is a new element, changing the course of what may have originally occurred. This is more generally referred to as the 'self-defeating prophecy'. In other words, the fear of certain consequences drives people to find solutions before the problem occurs; hence the prediction does not eventuate. How this relates to unintended consequences is a little obscure at first. However, if one predicts a consequence of dire proportions, this may alter people behaviour significantly. Unfortunately, the new balance that eventuates, in order to avoid the original prediction, may actually contribute to a far greater range of new unexpected consequences, often more serious than the original predicted consequence.

3.2 Time and Dimensional Factors

In addition to Merton's primary factors that contribute to unintended consequences, he also makes the observation for the need of "time" and "resources", remarking upon how diminished time contributes to ignorance. Merton also notes that such resources must be distributed amongst several aspects of innovation, which includes the anticipation of consequences.

This notion of time and resource constraint is particularly relevant to ICT in the present innovative culture. A number of elements contribute to time-to-market pressure including product obsolescence, global competition, and gaining early market share from rapid introduction [19]. The conventional wisdom of R&D institutions is that *radically innovative products* provide the best competitive advantage [20, 21]. It is suggested that incumbent organisations often fail to innovate due to their culture of risk aversion [22]. Hence, there is a need and willingness to take risks [21].

Research and industry appears to be focused on time-to-market reduction [23], perhaps due to the “winner takes all hypothesis” [24]. New product development is often a trade-off between time-to-market and product performance, and can be affected by development resources [24]. Further studies, in related engineering disciplines, show that high-tech products that reach the market six months late, even if on budget, earn 33% less profit over five years; conversely, if delivered on time with a 50% budget overrun will reduce the profit by only 4% [25, 26]. Taken together, these innovation constraints inevitably place further pressure on the ability of individuals to fully explore the potential for unintended consequences. We suggest that the issue of time and resource constraint warrants individual analysis as an additional factor that contributes to unintended consequences.

The ideas discussed thus far are based upon the impact of a particular technology as a single instance of innovation. A further perspective on consequences is the potential impact of technology due to the absolute dimensions associated with the innovation. This may be the mass production of unit items, volume or capacity of information storage, or significant increases in functional capability of advanced technology.

Table 3
Factors in Unintended Consequences

Factor	Description
Ignorance	Incomplete knowledge of the domain. The impossibility of anticipating everything.
Errors	Errors in the appraisal of the current situation and of future possible situations.
Immediate Interest	The immediate interest will influence and override longer term interests.
Basic Values	The basic values we possess humans will influence certain actions.
Self Defeating Prophecy	The prediction itself introduces a new element, giving rise to a self defeating prophecy.
Constraints	Time-to-market versus product quality trade-offs, versus resource constraints.
Dimensions	Mass production scale and deployment, complexity, and volume of information.

It may be viewed that by merely duplicating instances of a simple problem, an overall increase in problem domain complexity results. For example, it is suggested that technologies introduced into mass culture, such as the Internet, create disorder from excessive use of applications [27]. Due to the magnitude of functionality introduced in present day devices, product design and engineering complexity increases; and, increased complexity contributes to unforeseen events [12]. Mass production of mobile devices introduces problems in distribution, revision management, and control. Further studies point out that the increased

prevalence of consumer electronics is the single most significant contributor to electricity consumption in the home [28]. The capability to mass produce technology may be considered a modern phenomenon, generating new consequences in e-waste [29]. With recent advances in manufacturing capacity together with increasing capabilities of ICT, we suggest that this is an additional factor contributing to consequences.

Dorner suggests that complexity, dynamics, intransparency, ignorance, and mistaken hypothesis also contribute to the difficulty of understanding the problem domain of systems engineering [30]. The additional factors of constraints (time and resource) and dimension contribute further to the underlying causes, and perhaps augment the degree of impact that each of Merton's primary principles have on society. While the primary principles defined by Merton are fundamental human qualities, the additional properties of constraint and dimension are more correctly classified as characteristics associated with the human innovation process. We now summarise the factors contributing to unintended consequences that are relevant to ICT and the broader domain of technology, see Table 1.

3.3 Definition of Consequential Damages

Before focusing on the more specific impact of the recent evolution of ICT we first provide a formal definition of the term consequential damages. This helps to understand the potential liabilities when consequences do occur. West's encyclopaedia of American Law provides a concise definition [31], see Table 2 below.

Table 4

Consequential Damages

Injury or harm that does not ensue directly and immediately from the act of a party, but only from some of the results of such act, and that is compensable by a monetary award after a judgment has been rendered in a lawsuit. Detriment that arises from the interposition of special, unpredictable circumstances. Harm to a person or property directly resulting from any breach of warranty or from a false factual statement, concerning the quality or nature of goods sold, made by the seller to induce the sale and relied on by the buyer.

This definition refers to the injury or harm caused to person or property that is indirectly associated with the act of a party. This is the result of special, unpredictable circumstances, concerning the quality and nature of goods. Further definitions refer to a foreseeable consequence [31 p.332], or 'ramifications of a particular course of conduct that are reasonably foreseeable by a person of average intelligence' [32]. Merton also remarks upon the foreseeable aspect of such events [16]. The term foreseeability is defined as 'the facility to perceive, know in advance, or reasonably anticipate that damage or injury will probably ensue from acts or omissions' [33].

This point regarding foreseeability may be particularly relevant today, with comprehensive supporting tools and processes that render the consequences of our actions as quite foreseeable. However, due to the factors outlined in Table 1, particularly time and resource constraints, institutions may elect to forgo, or compromise, the necessary due diligence tasks that thoroughly assess the potential for unintended consequences. This would naturally suggest that any remedial actions are not in place, with no clear visibility of the potential financial liability that may be incurred. Such inaction of foreseeable consequences may be interpreted as negligence [33, 32 p.221].

4. Socially Disruptive Behavior of ICT

In the previous section we discussed the factors that contribute to unintended consequences. This was generalised to the broader domain of innovation. Using the established criteria as a vehicle for analysis we now focus and apply this discussion to information and communications technology. Several scenarios are immediately obvious when one considers the potential unintended consequences and these are discussed. However, the longer term repercussions of the consequences occurring may be more illusive to determine. Given the recent advances in the strength and power of ICT, it is argued that where ICT is applied without the appropriate due diligence reviews carried out, the impacts and liabilities may increase in severity. Before considering these notions further, we first clarify the behavior of disruptive technology.

The term *disruptive technology* generally refers to an innovation or breakthrough that eventually displaces established technologies [34]. While the authors also suggest that such breakthroughs initially under perform, these technologies usually imply radical innovation and change, having severe financial repercussions for the incumbents and greater financial reward for the innovators. Although the specifics of the definition are argued [35], this interpretation of the term perhaps represents the general consensus amongst industry and research.

In addition to the accepted disruptive characteristics, the potential exists for a concomitant socially disruptive aspect of technology. Moreover, the unintended consequences of ICT may disrupt our social fabric and the well being of others, causing injury or harm to person and property.

It is important to re-iterate that the type of consequence discussed here are not intentional, or at the hand of a malicious user. Rather this is the result of the benign or candid use of technologies. Moreover, ICT has matured to a level that no longer permits straightforward use without an investment in time and energy to understand the potential negative impact to others. We now analyse each of the factors in Table 1 in relation to ICT, identifying examples that illustrate how consequences can occur.

4.1 Ignorance

Perhaps the key protagonists of ignorance are familiarity and complacency, which deceive us into ignoring the potential impacts of our actions. A new technology is often considered well founded and perhaps well understood when its presence has been adopted for several years. However, there is a failure to make fundamental observations of the impact of these innovations once deployed. Any initial observations may serve as early warnings to future hazards.

Web based technologies is one example of a recent ICT innovation that is fundamentally accepted. This is often viewed as necessary in organisational change to improve many aspects of how we conduct business. For instance, while the Internet has been applied to increase electronic commerce in business, it has also increased Internet fraud making identity theft easy [36].

A further example is a study that conducted research on the impact of web based technologies on a contact service business for sharing information within a firm [14]. This was carried out in order to understand the impact on time, control, and organisational change. Both the anticipated and unanticipated consequences were assessed, the key unanticipated findings included:

- increased pressure and stress of work for managers and employees,
- managers gained control in monitoring employee performance and increased access to information, and
- employees felt they were being watched by “big brother”; this also contributed to increased stress and served as a disincentive to perform.

Examining the last consequence noted above further, we observe that incentive to perform is a key theme of innovative institutions. Further work also points out that performance measurement approaches actually inhibit innovation [37]. There is both a human impact due to additional stress and a financial impact in market competitiveness through innovation. Considering the importance of innovation to competitive advantage [20, 21], any action that negates this would seem to warrant careful consideration.

4.2 Errors

Krueger and Funder conduct in-depth study on the sources of human error [38]. They observe over 40 published sources of errors, remarking upon the more salient, which include: conformity with false majority judgements, the allure of counter-intuitive findings, incoherent interpretations of errors, adherence to norms not requiring explanation, self-enhancement, and emotional biases.

Often we base judgement upon the advice of custodians, and this information may not be accurate. For example, a recent study on Internet safety highlighted significant discrepancies between what parents claim to know about their children’s Internet activities and their actual activities [39]. These misunderstandings contribute further as a source of errors, with decisions made upon flawed data. Studies conducted by Dorman and Howell conclude that analysis with few subjects also greatly increases the likelihood of errors [40].

Data quality and completeness appears to be an industry wide problem. Much time and effort is expended by organisations to ensure data accuracy. However, mistakes and errors continue to persist. The degree to which data errors contribute to harm is perhaps related to the way in which such data is applied. A recent example has shown that immigration system data errors have led to illegal detainment in the majority of cases [41]. Some of which have resulted in court proceedings [42]. In addition, the data-matching possibilities of these types of innovations are at risk of error and abuse [36].

Perrin equates the concept of innovation to Campbell’s theory of evolution of science and the importance of trial and error [37]; as long as these are subject to evaluation [43]. ICT innovations come about due to the trial and error approach [44]. However, such ICT innovations may not be subject to evaluation, particularly in regard to consequences.

4.3 Immediate Interest

The issue of immediate interest is exemplified by commercial factors that influence the behaviour of business. Business institutions are driven financially and key objectives are oriented towards short term gains, with quarterly fiscal targets. An additional, and perhaps more subtle, observation is that ICT solutions are often deployed to address an immediate business problem. As the prevailing environment changes, the original solution is applied to address a far greater range of issues; some of which are perhaps not aligned with the original objectives of the system. This mismatch in short term needs and longer term outcomes is demonstrated through seizure of information systems for alternative purposes. ICT deployment within libraries serves as an example in this instance.

Libraries are under increasing pressure to maximise technologies in order to keep up with publisher offerings and academic demands [45]. These are immediate interests, and the longer term impact on the use of these technologies is seldom considered. While checks are placed upon the information maintained within these systems, the degree of auditing and validation placed on library records would naturally seem to be less rigid than those applied to mission critical systems; such as immigration systems. Moreover, it is suggested that ‘library technology networks often evolve in a semi-wild environment rather than emerge as carefully planned systems developed with full realisation of the consequences for patron privacy’ [45]. In spite of this, increasingly information maintained in these systems is being seized for other purposes, even prosecution [45]. Hence, longer term ICT objectives may be forced to change, contributing further to a range of consequences.

Herrman, Fox, and Boyd also note that both the short and long term consequences of learning technologies be analysed as far as possible [46]. Citing a study on the installation of telephone systems in remote areas, they observed that an immediate interest was in addressing communication; however, a longer term impact was a “loss of community” [46], which is perhaps crucial to the survival of many remote communities.

Rogers introduced formal theories on the diffusion of innovation [47]; the rate at which new technologies spread. He points out that when a certain take-off point is reached, innovations can spread rapidly. When the innovation involves communication technologies, the diffusion process is accelerated [48]. The escalation of take-up is also likely to contribute further to longer term unforeseen consequences, particularly when one considers that societal trends encourage the rapid take-up of new technologies. More recently, Rogers also observes that little research has been conducted into unintended consequences [49].

4.4 Basic Values

Schwartz postulates that there are ten basic values (e.g. benevolence, security, achievement, etc.) derived from three human conditions: the needs of individuals as biological organisms, requisites of coordinated social interaction, and the survival and welfare needs of groups [50, 51]. He points out that values are the standards or criteria people use to evaluate actions, policies, people, and events. They are beliefs tied to emotion, are not objective, and that we all hold values in varying degrees of importance [51].

In a society of increasing technological dependence, it is plausible to consider that our basic human values are commuted to the innovations that we create. These innovations will invariably foster aspects of social well being and may also yield unexpected negative results. The degree to which we scrutinise these technologies is also guided by our values. Accordingly, it is reasonable to theorise on two aspects of human values here: the commutation of values into technology and the degree of scrutiny exercised.

The broader domain of human identification and monitoring technologies involve moral and ethical issues [52]. One emerging innovation is the use of radio frequency identification (RFID) devices for tracking and monitoring. This technology is particularly useful in a number of tracking scenarios: assets for the enterprise, toxic hazards, medical supplies, and wildlife preservation. Recent advances have also enabled these devices to be applied to human authentication and monitoring, as a subdermal implant [53], or worn as an external adornment. The use of technology for tracking people is a hotly contested debate in human values and ethics, “tracking animals is ok, but not people”. With arguments presented for and against the contribution to humanity of this technology applied in this way [52, 53, 54, 55]. This example embodies the commutation aspect of values. The human values have been commuted to a technology; the ability to track people is believed to be acceptable and the

technology embodies this value. How this technology is subsequently applied also extends the commuted values, in scenarios that rely upon individual scrutiny (how it is applied).

In extending the values discussion of tracking devices applied to people, the prospect of liability, in the case of a mishap, is evident. For instance, the potential consequential harm, due to subdermal tracking devices, has been clearly pointed out by the US Food and Drug Administration [56] and security experts [57]. When considering the original definition of consequential damage and the notion of foreseeability, it would seem difficult to entertain the position that a convincing argument could be mounted to deny liability in the case of unintended consequences. This is a degree of scrutiny in the application of technology, the values that guide human concern to scrutinise.

Realising or ignoring the possibility of danger to others comes down to a human values perspective. Schwartz observes that what is considered important by one is considered unimportant by another and that we prioritise values differently [50, 51]. This suggests that the possibility exists that some individuals will consider their needs above the welfare and needs of the group when casting judgement on ICT innovations. In other cases, this is merely an interpretation on personal and organisational values. Notwithstanding, the judgement will rest with one or several individuals, and institutions will be held accountable and liable when negative consequences do occur. This further motivates the need for well founded policies and guidelines.

4.5 Self Defeating Prophecies

Self defeating prophecies are predictions that result in new actions which create a feedback loop that cause the original prediction to fail [58, 59]. The new actions and elements may have unintended side effects [15, 16]. The notion of a self defeating prophecy and unintended consequences, particularly in ICT, may seem abstract at first. However, we explore an example that engages networks, smartcards, and Internet commerce to elucidate the relevance of this theme.

In 1982, Chaum introduced the idea of anonymous electronic cash [60]. Over time, several predictions were made regarding a cashless society and the replacement of conventional physical money [61, 62]. A number of early issues were proposed regarding consumer privacy, anonymity, and fraud [63]. This list of e-cash properties continued to expand [64, 65]. Ultimately, the electronic cash protocols proposed employed sophisticated cryptography to address the concerns raised [64, 66, 67]. However, the protocols were complex, varied considerably, and held features that were undesirable to banks and government [68]. This made e-cash difficult for many financial institutions to agree upon and adopt. The solutions suffered from technological overkill [69, p.106]. The advent of the Internet created real demand for electronic commerce and e-cash was not adopted. Numerous e-cash start-up companies subsequently failed [69, p.74]. This contributed to the use of simple (less secure) electronic commerce forms such as traditional payment cards. This became the *de-facto* standard and has led to increased payment card fraud, identity theft, and spam.

The original predictions of e-cash and the cashless society initiated actions which contributed to its defeat, and the alternatives have had negative consequences. While the initial predictions did not eventuate, it may be that some electronic currency form will be adopted as an inevitable progression of money. Although perhaps not in the style of true secure anonymous electronic cash that was originally invented.

4.6 Constraints: Time and Resource

How the compression of time and resources contributes to the troubled delivery of technology projects is well understood. Innovation involves activities from concept to commercialization and when key project steps are eliminated or compromised, product quality may be impacted. While such compression during innovation impacts the traditional project delivery phases, this may also eliminate key tasks such as product readiness reviews and risk analysis of unanticipated outcomes.

Risk management involves the management of both foreseen and unforeseen risks which may have negative effects [70]. Traditional risk management is focused upon reducing risk during project delivery, and similar risk methods may be used to evaluate the risk of consequential impact of ICT [71]. In section 3.2 it was observed that innovation involves the need and willingness to take risks [21]. When the project management tasks associated with risk are further compromised by time and resource constraints, the possibility of unexpected outcomes would naturally seem to increase.

The paradigm of risk taking and expected failure in innovation, suggests it is likely that the precautionary step of conducting risk analysis may be overlooked. Due to time and resource constraints, this may be an intentional decision not to take such precautions, or a compromise in the quality of the measures taken. Provisions in law, such as proximate cause and dependent compliance error, may conclude liability when duty of care and related precautions are not exercised suitably [72].

4.7 Dimensions: Scale & Complexity

The complexity of ICT has and continues to increase significantly, in some instances exponentially. In 1965, Moore predicted a doubling of chip transistor density approximately every two years (Moore's Law) [73]. Metcalfe's Law states that the community value of a telecommunications network is proportional to the square of the number of nodes (users) on the network [74]; often used to explain the exponential growth of the Internet. Gilder's Law states that bandwidth will triple every twelve months [75]. It is perhaps ambitious to assume that such rapid increases in the strength, reach, and scale of ICT would have minimal unexpected consequences.

The problem of increasing complexity in all areas constantly increases the probability of the occurrence of unforeseen events [12]. A more recent example of further complexity is the use of mash-up technology for developing web applications. Mash-up solutions draw content from many peer and subordinate sources and hence render content from many, often hidden, service providers. The number of dependencies and inter-relationships increase significantly, and it is strongly suggested that emerging mash-ups technology has many legal consequences [76].

The volume of ICT that pervades society has created new issues in excessive energy consumption [28], electronic waste [4], and environmental sustainability [77]. Given the prevalence of so many radio emitting devices, there is recent work suggesting this to be a factor in colony collapse amongst bees [78]. In addition, ubiquitous deployment of devices that can be tracked has raised a range of issues in security, privacy, and the ethics of human monitoring.

A final point to consider is the trend in amassing volumes of information. In many situations such broad knowledge has important benefits. However, the capture of personal and private data has introduced important societal consequences [79]. Centralised data compounds can aggravate identity theft problems, particularly when data operations are outsourced. Perhaps

a more compelling concern is the increasing practice of reapplying information that has been originally gathered for some more benign purpose. Moreover, the information is applied to serve other functions, without the express permission of the owner. This highlights the *de facto* approach of retaining all data until some other compelling need emerges.

Sobel cites legal cases to make the point that privacy embodies the moral fact that a person belongs to himself and not others, nor to society as a whole [52]. Given that information originally captured to meet one objective is subsequently being seized for other purposes [45], the practice of reapplying data without obtaining express permission from the true owners introduces potential liabilities in the advent of a negative consequence. It follows, that a practice of deprecating sensitive information gathered on people, when the original purpose has been served, is necessary.

4.8 Revisiting the Consequences of ICT

It is important to re-iterate that the points considered in this section are in the context of technology that is introduced in good faith to improve society. The technology introduction however, may invite unintended consequences. Due to the strength and power of ICT, the *luxury of candid* use of new technology is no longer available without due consideration given to the potential consequences.

While a number of important contributing factors have been discussed, it is important to observe that these factors are not limited to ICT. Rather, they are persistent issues that affect all forms of technology and innovation. In addition, it may be the case that one or more of these contributing factors are present with a particular invention. Logically, this would seem to lay the foundation for more severe consequences.

Perhaps a final observation that can be made is that exceptional time, energy, and resources are often spent to ensure fast and on-time market delivery. However, when consequences have emerged, the magnitude of the response to correct a negative outcome is minor in comparison to the efforts to deploy. Given that current reactive measures may be considered tepid at best, this further motivates the need to ensure that sound policy and guidance is in place as a preventative measure, particularly as the financial consequences may be severe.

Development of such policies is the responsibility of the institution developing an ICT innovation, the implementer (deploying organization) of the technology, and is also the responsibility of the institution accepting the innovation for deployment. Thus in practice, several sets of policies and guidelines will be developed independently and applied by the respective parties.

5. Policy Approaches in Managing ICT

In referring to the Internet and modern technology in general, High Court Justice Kirby stated the need for reviewing applicable laws and policies to adapt them to new technology in order to protect people [80]. It is important to consider however, that the establishment of policies guiding the use and introduction of technology may equally be harmful to the community.

In referencing policies to manage addictive gambling, Bernhard and Preston point out that the development of noble intentioned policies itself may have unintended consequences [81]. Bernhard further notes that noble intentions alone are insufficient for policy development, rather scientific research is required to evaluate the real effects of policies, and that such research is essential to develop best practice to effect the changes we seek [82]. Others observe that once a tragedy occurs, the public and government are both more likely to endorse and implement serious limitations with little deliberation as to their consequences [9].

Notwithstanding, we seek to identify candidate tools and processes that will assist in defining policies that will mitigate the potential for negative consequences while advancing the field of ICT.

5.1 Technology Assessment Methods

In 1972, the Office of Technology Assessment (OTA) was introduced in the U.S. The mandate was to assess adverse and beneficial consequences of applying technology [83]. Technology assessment reports that aided policy makers were prepared by considering input from interest groups, stakeholders, and experts. The office served for 23 years and there is much debate on how the legacy is to be replaced or reintroduced, with several initiatives proposed to advance such assessments.

The precautionary principle has been proposed as a method for anticipating risk of novel technologies [84]. The principles have been incorporated into a number of international treaties and agreements, in order to avoid serious damage and anticipate harm, or risk of harm. This has been largely adopted to address environmental issues, providing a framework for decisions when uncertainty prevails. The authors argue that that the approach may be used to evaluate ICT, in particular pervasive computing. By illustrating several unintended effects of ICT, it is shown how the basic tenet is applied to mitigate risk of harm. A key theme of the approach is the definition of a system of values.

A further analytical tool exists such as Life Cycle Assessment, with its application to the telecommunications industry [85]. The objectives are broadly aligned to addressing environmental issues, with four key steps that involve goal and scope definition, inventory, impact assessment, and interpretation. Other authors suggest that a qualitative approach for establishing criteria be used for evaluating potential risks in new ICT innovations such as pervasive Computing [71]. A technology assessment method is proposed that involves the steps of scenario development, screening for potential risks, and the application of a risk filter.

There is a great deal of history and work on technology assessment, with further proposals for assessing the actual technology assessment methods as well [86]. However, we suggest that given the variety of technology and risk assessment methods, it seems prudent that the establishment of well founded social values is necessary. More precisely, sound values for guiding analysis, decisions, and policy making is an essential first step towards any proposed method.

The broader theme of values in decisions on risk is actively researched [87]. Science, technology, and human values continue to increase in importance with literature spanning some 40 years [88]. Porter *et al.* point out that basic core assumptions are the major determinants of forecast accuracy [89, p.112]. Fundamental assumptions regarding social values, and the embodied errors, are key determinants of unanticipated consequences [16]. Others remark upon the importance of social values and how these become embedded within innovations [90]. It follows, that such values would lay a solid foundation for any assessment method, and hence any policy that is subsequently conceived. Due to potential bias, conflict of interest, and variation in human values, it follows that the formulation of such guiding values involves the public as widely as possible.

5.2 Evidenced Based Policies

There are several aspects to consider with regard to policy development. Policy development itself is a task in innovation, as it introduces new notions and ideas. As such, it would naturally seem that policy development is also likely to succumb to the influences that Merton

raises for innovation [16]. We briefly touch on two aspects here, evidence based policies and the strength of peer review for determining efficacy of candidate policies.

In reference to cable technologies, it is suggested that policy makers will find it more difficult to create regulations that focus on one service without considering the fallout of a policy on other services [91]. Furthermore, Campbell suggests that there is a need for testing candidate policies to see if they remedy the problems that give rise to their introduction [92, p.141]. In the UK, the use of pilot projects, provide a basis for evidence-based policies [37]. Such measures are likely to contribute to a broader impact analysis. However, to obtain scientific credibility on outcomes, peer review of the methods, analysis, and results appears necessary.

Studies have been conducted to assess the impact of future ICT for input to policy decision making [93]; and have been subject to peer review. Other Technology Assessment centers have contracted relevant experts to conduct impact analysis, which have been peer reviewed and published [71]. A key proposal for subsequent Technology Assessments initiatives within the U.S. is that assessment reports be subject to rigorous external peer review before delivery [83]. A convincing argument seems logical that any such technology assessment be subject to peer review to validate the scientific basis, credibility, and remove any potential bias.

It is important to observe that even the best intentioned policies that pay little regard to evidence-based peer review, have the potential to cause more harm than good. As Roots points out, policies intended to protect may have unintended consequences and backfire [94]. Where policy development is not supported with appropriate time, is not subject to peer review, nor accompanied by evidenced based methods to support introduction, then such policies will not be of the necessary quality to warrant introduction.

6. Conclusions and Discussion

A generally accepted view is that in order to be truly innovative one must expect an element of risk, make mistakes, and accept the possibility of severe failure [37]. This general view is epitomised by mainstream venture capital, where it is suggested that 'our single biggest advantage may be the fact that we've screwed up in more ways than anybody else on the planet when it comes to bringing new technologies to market' [37, 44]. Considering the potential for consequential impacts of ICT, such continued practice has the potential to further aggravate any negative outcomes. In order to preserve the integrity of ICT and its propensity to do more harm than good, both socially and economically, these views must be challenged.

Authors have made the general observation that the increasing power of innovation makes it difficult to anticipate implications of novel technologies and that this is outrunning the capacity to anticipate consequences [84]. Grunwald suggests that ambivalence towards science and technology is largely acknowledged today; leading to risk research, technology assessment, and ethical reflection to anticipate, counter and minimize negative effects [95]. We suggest in this paper that the evolution of technology has taken a step further, and is now at a point where the strength and power of ICT no longer permits the *luxury of candid use* without considering the potential consequences. This is not due to malicious intent, but rather an un-intended consequence of using ICT in good faith. In many ways this may be considered a familiar notion, as it represents a general trend in society where there is no longer a luxury of casual use of water, energy, and the environment.

In addition to the Merton principles, we suggest that the additional factors of time and resource constraints, and dimensions in scale and functionally of new technologies are contributors to unintended consequences. We discuss several examples against the identified factors to illustrate the potential impact and harm to others. Finally, we propose several

parameters to guide policy development. This includes an activity to define a set of values, drawn widely from society, for underpinning technology assessment methods, and the use of evidence-based techniques such as pilot studies together with peer-review in formulating suitable policies.

As Guston and Sarewitz note, the over arching goal of research based innovation is to improve the human condition [90]. Taken together, these issues present society with a new challenge that must be dealt with if one is to avoid harm to others, social disruption to the community, and the financial losses that ensue.

6.1 Further Work

While there is considerable research in risk management and risk assessment for project delivery, there is less work in the area of consequential risk analysis. That is, the methods and processes that help identify risk of unintended consequences.

There is further work to define more comprehensive criteria and guidelines for government and business institutions in policy preparation. For instance, how does one handle disagreements during values based evaluations? In addition, the analysis of legal liabilities and ethical responsibilities of institutions are also suggested as further work.

6.2 Acknowledgements

We thank the anonymous reviewers for their insightful feedback and suggestions. In particular, the observation that almost every major communications technology in the 20th century (including radio, personal computers, and the Internet), have been applied in ways never envisaged by the original inventors; and the suggestion of further work in policy formation when values based disagreement arises.

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