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Informatics and the Challenge of Determinism

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Abstract: *Motivation*: There is a paradox at the heart of informatics where practical implementation generally fails to understand the socio-technical impact of novel technologies and disruptive innovation when adopted in 'real-world' systems. This phenomenon, termed technological determinism, is manifested in a time-lag between the adoption of novel technologies and an understanding of the underlying theory which develops following research into their adoption. *Methods*: We consider informatics theory as it relates to: social informatics and how humans' function in society, the relationship between society and technology, information systems, information systems design, and human–computer interactions. The challenges posed by novel technologies and disruptive innovation are considered as they relate to information systems and information systems design. Open research questions with directions for future research are discussed with an introduction to and our proposed approach to socio-technical information system design. *Significance*: We conclude that the adoption of disruptive innovation presents both opportunities and threats for all stakeholders in computerised systems. However, determinism is a topic requiring research to generate a suitable level of understanding and technological determinism remains a significant challenge.

Keywords: informatics; social informatics; information systems; information system design; disruptive innovation; technological determinism; software life cycle

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1. Background

Information science [1] is a research field which addresses: (a) the collection, analysis, classification, manipulation, storage, retrieval, movement, dissemination, and security of data and information; (b) the study, application, use of knowledge in organisations along with the interactions between people, and organisations; and (c) any existing information systems (IS) to create, replace, improve, or understand how an IS functions. Traditionally, information science has associations with computer science and addresses diverse topics which include cognitive science, linguistics, and social science with the relationship between society and technology.

Informatics is a research field that considers the principles of information science to address problems in the use of data [2,3] with information processing [4] and the engineering of information systems (IS) [5]. Additionally, the research field addresses interactions between humans and information with the design and development of interfaces, technologies and systems. Informatics has considered many academic disciplines, including computer science, information systems, and information technology. Research in this field studies the development, replacement, improvement, and general understanding of information systems (IS) and how they function. The pervasive nature of computerised systems has resulted in digital information processing by both individuals and organisations, which has led to Informatics research addressing multiple academic disciplines including: computer science, IS, information technology (IT), and information communication technology (ICT) (the terms IT and ICT are frequently used interchangeably), cognitive science, and social science.

The informatics research field may be considered in terms of facets and layers applied to the processing of data and, given that IS are highly domain specific, a systems analysis and information system design (ISD) must consider the domain of interest (e.g., the primary function of an organisation), the organisational structure and culture, and the specific requirements specification (RS) for the proposed IS (we defer consideration of the RS to Section 4.1). Informatics incorporates Information technology engineering (ITE) [6] which is a software method that applies an architectural approach to provide an effective basis for: (i) systems analysis and requirements planning, (ii) ISD and development, and (iii) an implementation and testing strategy suitable for use over the software life cycle (SLC). We introduce our proposed ISD approach in Section 8 with our proposed socio-technical requirements determinist context introduced in Section 4.1

The application of the general theory of informatics must consider the social context which is an area of research that has gained traction over time in social informatics (SI) [7–10] and social anthropology (SA) [11]. SI and SA address: (a) the role of information technology in social and organisational change, (b) the uses of IT in the social context, (c) how the social use of IT is influenced by social forces and practices, and (d) patterns of human behaviour with the relationships that exist between society and technology. Accordingly, informatics theory research addresses: (i) how humans interact with technology, (ii) applications and their use of data, (iii) human–computer-interaction (HCI) [12–15], (iv) computer-to-computer (CTC), (v) the relationship between data, information, and knowledge (including tacit and explicit knowledge) [4,16], and (vi) the societal context (interactions between people and groups of people) based on SI and SA.

This brief overview shows that informatics is fundamental in the systems analysis, ISD, and the implementation and testing of an IS in an organisational context. However, there is a paradox at the heart of informatics where practical implementation generally fails to understand the socio-technical impact of 'novel technologies and disruptive innovation' (hereafter referred to as DI) when implemented in 'real-world' systems. This phenomenon is termed *technological determinism* (TD) [17,18]. The term is generally used in the social context as a negative term [19]; however, we question the generally expressed negative connotation of TD and consider it from both the negative and positive impact perspective as discussed in Section 5.

Consider the concept of TD and the relationship between the (*practice* and *theory* that informs ISD and development. There is a time lag (delay) between the practical adoption of DI and an understanding of the socio-technical impact generated by the adoption of DI. Figure 1 models the relationship between *theory* and *practice* and the impact identified in published research and in empirical reports in the media. The delay in understanding the theory can range from the technological aspects (which include socio-technological factors such as HCI and security considerations [20]) to socio-technical factors [9], socio-economic aspects [21] and geopolitical issues as experienced in the 2016 presidential election in the USA (https://edition.cnn.com/2016/12/26/us/2016-presidential-campaign-hacking-fast-facts/index.html) where social media was used to disrupt and influence the election.

The impact of DI has been documented in empirical reports in the media and academic research studies conducted over the SLC. We have identified the challenge presented by TD which lies in two general areas: (i) understanding the nature and drivers of TD, and (ii) developing an approach to ISD to promote the positive aspects of new technologies while addressing (or at least mitigating) the negative affects. In this paper we consider informatics with a focus on IS and ISD along with the nature of TD and the challenge it presents over the SLC. We consider ISD from a socio-technical design perspective [5,22–28] and introduce open research questions, our current research, and proposed direction(s) for future research. We conclude that, while technological determinism remains a significant challenge, the implementation of new technologies presents both opportunities and threats for all stakeholders in computerised systems.

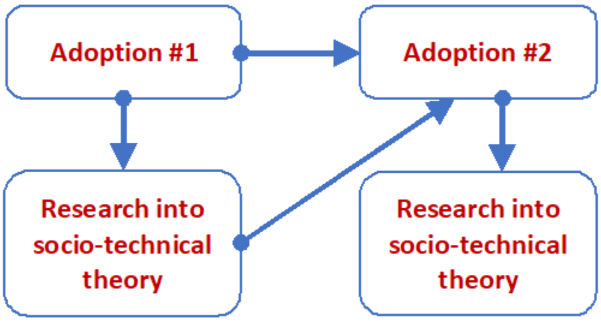

Figure 1. A model showing a process model of the relationship between the adoption of DI and research into socio-technical theory and the impact of determinism.

Our contribution lies in: (a) an review of the nature and scope of determinism with an analysis and summary, (b) our proposed approach to IS analysis and design with the potential to understand the potential social and technical impact (positive and negative) of determinism while addressing (or at least mitigating) the negative impact of TD, and (c) a proposed ITE approach to ISD designed to generalise to multiple domains of interest in an organisational setting.

The remainder of this paper is structured as follows: Information systems is introduced in Section 2 with an overview of the principles of information systems design set out in Section 3. We consider the question 'what is technology?' in Section 4 and introduce the requirements specification (our determinist context) in Section 4.1. Determinist theory is introduced in Section 5 with related research considered in Section 5.4 and counter arguments discussed in Section 5.5. In Section 7 we consider the relationship of determinism to informatics, IS, and ISD with an analysis. Section 8 sets out our ongoing research into ISD along with open research questions and potential future directions for research. The paper closes with Section 9 where we set out concluding observations.

2. Information Systems

There is an often-repeated mantra that 'information is power'. As such, data processing with data processed into information useful to users [4] performs a vital function for organisations which include: commercial and Governmental organisations, healthcare [29–32], education [33], and social networks [30,34,35]. The ubiquity and pervasive nature of computers and computerised systems have created an environment in which individuals and organisations have increasingly created, stored, and processed data and information digitally. This has led to the study of informatics with computational, mathematical, biological, and societal considerations [7–11].

Furthermore, data processed into useful information plays a pivotal role in developing technologies and the impact of informatics research has been observed in diverse research fields which include: (a) affective computing [36], (b) intelligent context-aware systems [37], (c) smart environments [38,39] implemented in cloud based systems [40] which include the developing fog and edge computing systems [34], and (d) robotics where the development of autonomous robots capable of path planning and 'assistive' robotic systems [41,42] pose significant societal challenges as discussed in Section 5.4.7.

IS are (generally) created in an organisational context [43] and are principally designed to provide decision-support within an organisation. A discussion on management theory is beyond the scope of this paper; however, there exists a large body of published research addressing the topic under the a general heading of management information systems (MIS) [44]. For a detailed exposition on MIS see [43,45–49] . In summary, a MIS is designed to enable effective and timely management decisions within an organisations which include: coordination, control, analysis, and presentation (often termed *visualisation*) of information in a human friendly format. A MIS provides information in an appropriate format from a 'time-task-function' perspective. Viewed from an IS perspective, there are essentially three types of information: (i) *operational decisions* (short-term day-to-day tasks such as account management and sales), (ii) *tactical decisions* (medium-term tasks such as marketing and sales strategies), and (iii) *strategic decisions* (long-term decisions such as new product development with research and development, geopolitical change, and socio-economic developments). Figure 2 models the three decision levels and shows the range and nature of the supporting information.

Figure 2. A conceptual model showing a typical organisational decision-making structure. Shown isthe relationship of information to the decision levels and the related *structured* to *unstructured* information.

Management information is (generally) highly structured for the operational decisions, less structured for the tactical decisions, and least structured for the strategic decisions. However the decision-levels and the range of information (*structured* to *unstructured*) are not discrete and can be viewed in terms of a continuum with information shared between the decision-levels dependent of the topic under discussion. However, viewed from the IS and ISD perspective, the *time-decision relationship* is important for both the nature of the information and how it is used. An additional consideration is the manner in which the information is presented along with the level of detail and granularity. Digital dashboards integrate multiple IS and enable summaries of key 'real-time' metrics to facilitate informed decision making [50].

3. Information Systems Design

IS are formal, socio-technical systems designed to collect, process, store, disseminate, and distribute information [5,51,52]. While IS have traditionally focused on technology with limited consideration of the social context, socio-technical theory extends the traditional concept to include the societal and human elements. Checkland and Holwell [52] have argued:

> *The technological system cannot be separated from the social system of those involved in it; hence, in the context of ISD, good design and implementation of an IS should focus equally on both the technical and human concerns.*

Research supports the observation that 'human-to-system' and 'system-to-human' (HCI) interactions [12] must be considered along with technical and systems factors. An IS requires a clearly defined boundary and function (form-follows-function), a set of defined users, the required technologies (including the method of procurement), data storage (in memory and persistent [37,53], inputs, outputs, and communication networks. A computerised IS (our focus in this paper) is created with reference to *organisations*, *actors* and *technology*, we defer a discussion on the nature of technology and the requirements specification to Section 4.

To address IS in organisations ITE must identify the technical factors with the social and interpersonal considerations. Checkland and Holwell have introduced the *Process of Organization Meanings* (POM) model which identifies "Organisation Meanings" where the "organisational" form of the model identifies the social process in which 'meanings' are established which leads to support for people (or groups of people) undertaking tasks (purposeful actions) [52]. The POM model is a 'rich picture' which captures the complexity of the interactions between the 'actors' in an organisational setting including the societal and technological factors. The POM model "is not a system model" [52] but is intended to identify the iterative nature and scope of the interactions between the elements shown in Figure 3 in IS and ISD.

As we have discussed in this paper, viewed from a socio-technical perspective IS and ISD must address many socio-technical factors. IS are composed of four principal elements:

- *Organisation*: the sponsoring and proposing authority commissioning the analysis and design of the IS. Factors will include the organisational and management structure, management style, the culture, the staff roles, and the system requirements as discussed in Section 4.1;
- *Technology*: the current technologies, the proposed new technologies, the IT staff capabilities and expertise, the procurement method (generally driven by the available staff skill set) including the use of *enterprise systems* [54,55];
- *Agents* (also termed *actors*): individuals (people or groups of people) with an interest in in the design, development, and adoption of the IS;
- *Stakeholders* [56]: this element is very difficult to define as the term is very 'slippery'. A dictionary definition is: *"a person such as an employee, customer, or citizen who is involved with an organisation, society, etc. and therefore has responsibilities towards it and an interest in its success"* (Cambridge English Dictionary: https://dictionary.cambridge.org/dictionary/).

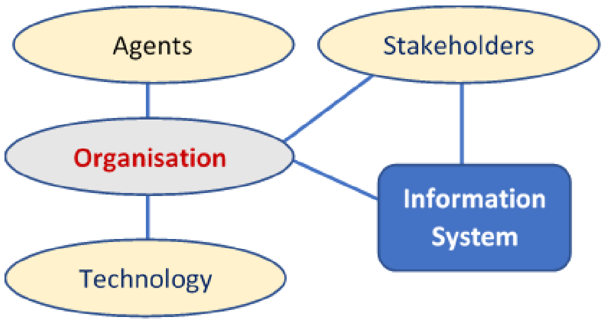

Figure 3. A conceptual model showing the elements to be considered in socio-technical ISD. The elements cover the requirements of the technological, social, and organisational factors that combine to create an effective IS. Further consideration is given in Section 8 and as modelled from an ISD perspective in Figure 7.

Viewed from an ISD perspective, Figure 3 models the interacting components and relationships that exist between the IS and the organisation, actors, technology, and stakeholders. There are two general ISD approaches are: (a) the *hard systems methodology* (HSM), and (b) the *soft systems methodology* (SSM). We include in the SSM *socio-technical design* [5] as there is a close symbiotic relationship between the two approaches. The components shown in Figure 3 for the basis for a systems analysis to identify the requirements specification (see Section 4.1) for ISD.

3.1. The Hard System Methodology

Traditionally, ISD has employed the HSM approach because it is simple to understand and implement in a structured approach with the design process documented using computer aided software engineering (CASE) tools [57]. Moreover, for managers in organisations, the HSM approach provides greater scope to manage and monitor the design, development, and implementation process which frequently uses the 'waterfall' model as this approach enables simple monitoring of the stages in the development of a system where each stage is completed incrementally with a sign-off for each stage. While managers generally understand the importance of people in their organisation (the societal perspective), the HSM focuses on the organisation, the management structure, and the technology elements. As such, the generally fails to suitably address the societal and human considerations.

An IS functions in a highly dynamic socio-technological environment and ISD must accommodate the demands of such environments along with the updating and maintenance of a system over the SLC. The HSM approach generally fails to address these requirements and, while there have been attempts to address such limitations by introducing some degree of iteration into the 'waterfall' model, the well documented failures in software engineering (Tricentris: https://www.tricentis.com/blog/real-life-examples-of-software-development-failures/) attest to the failure of the HSM approach.

3.2. The Soft System Methodology and Socio-Technical Design

Modern ISD employs the SSM with socio-technical design to address the issues and limitations identified in the HSM. The SSM and socio-technical design approach extends the HSM approach by recognising the technological and organisational components within an organisation structure based on the elements shown in Figure 3. SSM and socio-technical design results in an understanding of:

- Human and social structures and interactions in an organisational setting;
- How people (and groups of people) interact with each other and with computerised systems;
- Socio-technical considerations as they relate to human–computer-interaction along with computer-to-computer interactions (both are relevant in the current IS environment);
- How technologies and systems are designed and used by individuals and stakeholders.

As noted in Sections 2 and 3.1, while proposers of information systems understand the relevance and importance of people in their organisation socio-technical design and agile methods are often not used in ISD and development. In this paper we introduce our research (see Sections 7 and 8) which aims to facilitate socio-technical ISD.

4. What Is Technology?

What is technology? In considering this question we must first address the meaning of technology where in practice the "meaning" is domain specific [58]. As such, there is no commonly agreed definition of the term as different disciplines propose a range of definitions [58] with different *elements*, *tasks*, and societal (human) factors that combine to create a specific definition. While the proposed definitions [58] pre-date current technologies, they still address many of the elements that apply to current digital systems. In discussing "technology and the paradox of TD" [58] Fleck and Howells consider the "meaning of technology" and observe that:

> *... if definitions of the term 'technology' are collected from different disciplines, it is immediately apparent that they differ significantly in the elements ....*

Fleck and Howells [58] have proposed a "technology complex" which is an hierarchical list of elements to be considered in terms of the requirements specification (RS) (see Section 4.1). While relatively dated, the list of elements proposed remains relevant to current digital systems and applications. The list of distinctive elements are ordered from the 'physical' (technological) to the 'cultural' (social). Fleck and Howells note:

> *The principal point of this ordering is that in every definition of technology, there is an artefactual component which is embodied into a specified pattern of human activity and organisational or social context. While this changes between particular definitions, there are none that isolate the artefact from such a context.*

In Section 3 we have introduced the fundamental ISD methodologies where the SSM and socio-technical design emphasises the social element in ISD [5]. The technology complex [58] provides a basis to resolve the imprecise terms 'social' and 'technical' with increased precision; in Section 4.1 we propose our determinist context with elements scaled from the technical to the social.

4.1. The Determinist Context

In an analysis of an organisation the fundamental purpose is to identify the RS for a proposed IS. However, the RS in socio-technical design must consider not only the technical components used in an IS but also the social component as discussed in this paper. A RS is domain specific and, while there are common components (between different RS) each domain will require a different mix of technologies and requirements. The following list sets out a proposed hierarchical RS, while the elements are general, they are relevant to socio-technical ISD and the challenge of managing TD. The list is enumerated where: (1) has the most technological and the least societal focus and (8) has the least technological focus and the most societal focus.

1. ***Primary focus***: the domain of interest can be classified (for example) as: commercial organisations, Governments and not-for profit organisations (charities), social-network platforms. The primary focus and purposeful action(s) (tasks) will differ between domains. The domain will inform the RS and therefore the elements required.
2. ***Implementation and network infrastructure***: an organisation may opt (for example) for a cloud-based solution using Software-as-a-Service (SaaS), Infrastructure-as-a-Service (IaaS), Context-as-a-a-Service (CaaS) [59], and network connectivity. The implementation strategy will cover the approach adopted for data backup, risk management, and disaster recovery.
3. ***Geographical location***: globally, there is a wide variability in the available infrastructure and network capability; this will inform the selection and procurement of technologies both for national and multi-national organisations.
4. ***System and application software***: this is a critical element in ISD and encompasses: (a) the approach to systems design and development, (b) the procurement process which may be developed 'in-house' with the development of a 'bespoke system' or the procurement of an enterprise system [54]. Similar consideration must be given to systems for big data analytics, and artificial intelligence. An essential aspect of the procurement process will be the available skill-set of the IT staff in the organisation.
5. ***Management structure***: the management structure of the organisation may be a traditional hierarchical pyramid model or alternatively a flat model [60]. The model an organisation adopts will often vary according to the type of organisation. For example, consider a software company, a traditional commercial organisation, and a Governmental organisation. Furthermore, the type of management structure will often be reflected in the social and cultural elements.
6. ***Social structures and relationships***: each organisation will have unique social networks and grouping. This element is related to item (6). Correctly identifying such groups and relationships is vital in socio-technical design to capture the social and technological requirements.
7. ***Culture***: each organisation will have a unique culture. This element is related to item (6). Compare the culture of an vehicle manufacturer to a software development organisation, games developer, or social network platform. Each type of organisation will have a different culture which forms an important aspect of socio-technical design.
8. ***Supply chain***: while this may not immediately appear to be relevant to ISD; organisations must cooperate using human–computer interactions and computer-computer interactions. The IS in place must be capable of managing the downstream and upstream supply chain. For example, current order and accounting procedures (at least in large organisations—those most likely to require an IS) are automated with 'just-in-time' ordering and delivery [61] with computerised accounting systems.

The elements in the proposed list are not discrete but are inter-related and inter-connected. However, the elements encapsulate the needs of socio-technical design and succinctly express the essential features of an IS. We will further consider this list in Sections 4.1, 7, and 8.

5. Determinism

Determinism [62] explains societal and historical phenomena with reference to principles or determining factors. In this section, we introduce three types of determinism: (a) technological determinist (TD), (b) linguistic determinism (LD) (Section 5.3), and (c) media determinism (MD). MD, as discussed in Section 5.4.3, is an alternative term for TD when considering determinism from the perspective of the media [63].

5.1. Technological Determinism

Technological determinism (TD) is not a new concept, the term being used with reference to the socio-economic impact of the industrial revolution in the 19th century [64]. TD is a reductionist theory where technology determines the development of its social structure and cultural values. Karl Marx (1818–1883) argued that technological change is the primary driver for socio-economic developments, social relations, and organisational structures. The position espoused by Marx has become the accepted view and the notion that technological developments change society is pervasive [17]. The literature identifies multiple forms of technological determinism [18] including: (a) *hard* determinism, (b) *soft* determinism, and (c) technology as a neutral influence.

Hard determinism proposes that technological development is independent of the social context where: (a) technology regulates our societal activities and the meaning of society, (b) society is organised to meet the needs of technology, (c) the outcomes (resulting from technological developments) are beyond societies control (or) technology is autonomous and society has limited freedom to make choices regarding outcomes.

Soft determinism considers the socio-technological relationships and posits that while technology is a driver for social evolution, society can make socio-technological regarding the use of technology.

The ***neutral view*** is interesting as it proposes that technology (generally) has a "neutral influence on societal development". However, Mackenzie and Wajcman in [10] have argued that technology is neutral "... only if it's never been used before ...". Green in [65] has proposed the neutral view of technological development only "... if no one knows the purpose it may be either good or bad" (and) "... if one believes technology is neutral, one would disregard the cultural and social conditions that technology has produced...". We may consider the views expressed in [10,65] to support the observation that there is a relationship between DI and TD.

We defer further consideration and analysis of the *hard*, *soft*, and *neutral* determinist views to Section 5.5 where related research [19,21,66] has introduced the *rational actor*, *materiality*, *subversive rationalisation*, and *voluntaristic* theories.

5.2. Modern Technological Determinism

IS have developed into strategic systems in a broad range of organisational settings; however, the paradox at the heart of informatics results in *unexpected* and *contradictory* outcomes resulting from the adoption of DI and the impact of TD. Such outcomes are frequently experienced, even when applying well known and understood modelling tools (such as the Unified Modelling Language (UML) and systems analysis using Entity Relationship Diagrams (ERD) along with the well known and accepted forms of logical analysis and reasoning [67,68]. The contradictory outcomes may be viewed in terms of a *Pandora's Box*, a concept which originated in Greek mythology, in modern usage the term refers to: (a) *any source of great and unexpected troubles* (or alternatively) (b) *a present which seems valuable but which in reality is a curse*. We may view the *unexpected* and *contradictory* outcomes resulting from the impact of TD in terms of a virtual *Pandora's Box*.

5.3. Linguistic Determinism

Research has *linguistic determinism* (LD) which argues that language limits and determines human knowledge or thought processes (e.g., categorisation, memory, and perception) [63,69]. Hickman has noted that LD "...implies that people who speak different languages have different thought processes...". LD is relevant to social theory and the media which we introduce in Section 5.4.3. LD, while addressing determinism, also has relevance for human cognition, cognitive modelling, and the processing of data and information as discussed in [4]. This topic is beyond the scope of this paper but will be briefly addressed in Section 6 and in Section 7 where our proposed direction for research into ISD is set out.

5.4. Related Research

In this section we consider the diversity of the socio-technology-based concepts introduced with a focus on the impact (positive and negative) of determinism. There is a large body of published research addressing determinism under the general heading of TD. The research considered here is not intended to be a comprehensive survey, for exemplars of DT in multiple domains see: [8–10,19,21,27,58,63,66,70–84]. Additionally, the news media contain many references to topics which have a close relationship to TD including: robotics (https://www.bbc.co.uk/news/technology-52340651), electricity lusage (https://www.bbc.co.uk/news/technology-52331534), security and 'ransomware (https://www.thenational.ae/business/maze-ransomware-hits-global-it-services-giant-cognizant-1.1007714), and 5G networks and communications (https://www.thenational.ae/business/technology/).

Research has investigated the 'disruptive affects' of DI with 'online' applications and systems being identified as the primary drivers for the disruptive affects. While the disruptive affects are mainly felt in the 'online' world, there are also related challenges in the 'offline' world as discussed in Section 5.4.3. Determinism has been investigated in many domains and we consider such research under the following headings: (a) technology and society, (b) social theory and human computer interface, (c) social theory and the media, (d) the impact of social networking and electronic word of mouth, (e) security and privacy, (f) communications and data networks, (g) robotics in society, (h) education, (i) primary healthcare, and (j) financial services. Other heading may be used but we consider the headings to be appropriate for ISD which forms the focus of this paper.

5.4.1. Technology and Society

There is a large body of published research in both computer and social science studies where the relationship between technology and society is addressed and the "social shaping" driven by technology is introduced. Social theory and it's relationship to technology is considered in [8–10] with autonomous social shaping introduced in [19]. Social shaping resulting from the use of robotic systems is identified in [82]. Technology-driven social shaping is recognised in the literature along with TD as a societal theory [10]. The affects of technology as it relates to social change is discussed in [8–10], the general thrust of the research being: ICT is a principal driver in contemporary social theory and technology is seen as the "impetus for the most fundamental of social trends and transformations". Furthermore, "understanding the socio-economic role of technology is now central to social theory". Dafoe [19] has introduced "autonomous social shaping" and social shaping resulting from the use of robotic systems is identified in [82].

Wajcman [9] in a paper entitled "addressing technological change: the challenge to social theory" has observed that "many sociologists see technology as the impetus for the most fundamental of social trends and transformations" and "while there are a variety of social theories that proclaim the radical transformation of society all contain, at their core, claims about the technological and social impact". Wajcman identifies three pragmatic theories related to social change: (a) information society, (b) post-Fordism, and (c) postmodernity. The principal conclusion reaches is that the "information economy" (or) "knowledge economy" is the driver for both work and pleasure as " education, family relationships, and personal identities are seen as moulded by the pressures exerted and opportunities arising from the new technical forces".

Wajcman in [8] considers "life in the fast lane? towards a sociology of technology and time" in conflating the relationship between sociology, technology, and time (over which the impact is felt as we consider in Section 8.2. Time is an important consideration as evidenced by the historical relative speed of information dissemination [85]. Wajcman argues that the increasing pace of life is a significant factor in contemporary social theory and ICT is seen as the main drivers. This is a complex topic and Wajcman argues for increased research; however, the relationship to determinism and the influence of technology is clear.

Social informatics is introduced in [7]. In a paper entitled "Learning about information technologies and social change: The contribution of social informatics" Kling [70] considers social informatics as it relates to: (i) the social context and work processes, (ii) socio-technical networks, (iii) public access to information, and (iv) social infrastructure for computer support. In an analysis of research into information technology and social change Kling points to social informatics as a research field that studies the design and use of ICT along with the "consequences in ways that take into account their interaction with institutional and cultural contexts". The reference to *consequences* infers a negative impact resulting from TD.

While the consensus view of TD is negative, the results of TD may not always be negative. Technological development has realised many socio-technical and socio-economic benefits but it is recognised that there exists a significant potential negative societal impact following the adoption of DI. Barnes [86] has considered the societal impact of technology and the concept of TD. She has introduced the concept of *symptomatic development* in which "if something is symptomatic (of something else—particularly when it is negative) it is symptomatic of the negative affect". This recognises both the potential positive and negative societal impact of TD; furthermore, in stating "... particularly when it is negative ...", Barnes concurs with the commonly expressed view that TD is generally used as a 'negative' term.

5.4.2. Social Theory and Human Computer Interface

Barnes, in [86], investigates theories which explain the relationship between technological development and social change. In considering the history of the human computer interface (alternatively termed HCI) she argues that:

> *"rather than thinking of disinhibition as the revealing of an underlying 'true-self', we can conceptualise it as a shift to a constellation within 'self-structure', involving clusters of affect and cognition that differ from the 'in-person constellation ... the original inventors of this technology were influenced by theorists associated with the deterministic perspective". However, early HCI developers used methods that support a "social constructivist" view of technological development and later developments, in using software agents in new designs, "support a constructionist" approach.*

Considering the study reported in [86], from a socio-technological perspective, the *Social constructivism* and *Symptomatic development* theories inform and support the concept of TD along with the need for socio-technical ISD. We consider 'disinhibition' in Section 5.4.4 with the 'self-structure' and cognitive facets addressed in Section 6.

5.4.3. Social Theory and the Media

Language (verbal and written) forms an important medium of communication in the media. We have introduced determinist theory and TD (see Section 5) and LD (see Section 5.3). MD is applied when considering determinism and the media and, while the print media has traditionally influenced debate, the advent of 'online' media has increased the potential power media has to influence opinion in society.

MD addresses determinism from a philosophical and sociological position and considers the power of the media to impact society [87]. The media has a central role in social theory and social shaping; however, the media can utilise technology for both positive and negative purposes as identified in a paper entitled "One tweet does not a revolution make: Technological determinism, media and social change" where he discusses the problematic influence of MD in popular news media [79]. Hirst [79] discusses the problematic influence of MD in popular news media and identifies the concept of *soft technological determinism* as it relates to "journalistic practice and news discourse". He considers the coverage of the Arab Spring uprising and observes:

> *"many of the arguments then and now are suggestive of a form of TD tat is coupled with other underlying and little-investigated assumptions inherent in most forms of news practice and discourse ... the question of the influence of TD within journalism studies is a far from settled debate ... at best social media is a new battleground in the struggle for information control, at worst it can blind activists and commentators to reality"*.

Hirst [79], while arguing that MD "is a far from settled debate", supports the view that social media is a potential issue for control of information and this is reflected in TD.

5.4.4. The Impact of Social Networking and Electronic Word of Mouth

The power and influence of social networking platforms to dominate communication and access to information is ubiquitous and pervasive. The impact of such technologies can be seen in socio-technological, socio-economic, and security challenges which principally include:

- The inability to understand developing user patterns and the resulting societal outcomes;
- Due to the exponential growth (of the Internet and social networking) such applications are now pervasive with the power to reach many more more people globally. There is empirical evidence from press reports of *Subjective reinforcement* and *influence maximisation* following 'push' recommendations from social network platforms where news based on browsing history, expressed preferences, and historical use patterns merely reinforce current views without exposure to alternative views;
- Social networking platforms (e.g., Facebook (https://en-gb.facebook.com/), Twitter (https://twitter.com/?lang=en-gb), and TikTok (TikTok:https://www.tiktok.com/) etc.), while providing positive benefits, can all too easily result in negative outcomes for users, organisations, governments, and society generally.

TD is potentially socially and technically challenging; potential issues issues include: *experience*, *credibility*, *susceptibility*, and *ethical* challenges. There are potentially extreme negative impacts reflected in *disinhibition* [88] and *abuse* [89,90]. Online abuse is addressed by Lewis et al. [91] where "abuse directed at visible and audible women demonstrates that cyberspace, once heralded as a new democratic and public space, suffers similar gender inequalities as the 'offline' world". While clearly pointing to 'online' abuse related specifically at prominent women, the point regarding the use of technology to abuse and attack is well made along with the influence of TD.

The levels of abuse are exacerbated by *electronic word of mouth* (eWoM) systems [89,90] which provide 'online' forums and messaging services where users interact in cyberspace in 'real-time' in an electronic interactive conversation. Issues resulting from eWoM 'conversations' include *disinhibition* by users in the form of 'online' abuse (audible and visible) manifested in negative, threatening, or offensive opinions are posted in 'real-time' on social media without the inhibiting effect of 'face-to-face' interaction [88–90]. Consider the "online disinhibition effect" [88] where users may "self-disclose or act out more frequently or intensely than they would in person". This is a potentially complex topic and Suler [88] has identified six factors that interact to create the online disinhibition effect: (i) dissociative anonymity; (ii) invisibility; (iii) asynchronicity; (iv) solipsistic introjection; (v) dissocociative imagination; and (vi) minimisation of authority. Moreover, "personality variables" will influence the extent of disinhibition [88]. Suler concludes that:

> *Rather than thinking of disinhibition as the revealing of an underlying 'true-self', we can conceptualise it as a shift to a constellation within 'self-structure', involving clusters of affect and cognition that differ from the 'in-person constellation.*

In the thoughts of Suler and the reference to "self-structure and in-person constellation" there is a correlation with the observations of Barnes [86] and her references to a "true-self" and "a shift to a constellation within 'self-structure". There is a correlation with human cognition, the notion of 'self', and the concept of the *internalised* and *externalised* 'self' as discussed in Section 6 where the relationship to information, knowledge, and wisdom is addressed. We defer consideration of 'self' as discussed in [86,88] to Section 6 where cognitive processes are considered.

A feature of many applications and systems (including social network platforms and marketing applications such as Amazon (Amazon: https://www.amazon.co.uk/) is the use of recommender systems (RS) [92]. RS are generally context-aware provide 'push' recommendations based on browsing history and expressed preferences and historical search and purchase history. Web search engines and RS are among today's most ubiquitous, pervasive, and successful applications; for example, 'Google' (a noun) is also used as a verb (to 'google'—meaning to search using a web browser over the Internet). We are increasingly reliant on such technology to search for information, 'online' shopping, or when we stream videos [93]. This is an example of technology 'shaping' society on socio-technical and socio-economic levels where the influence of technology is reflected in TD.

5.4.5. Security and Privacy

There are many examples of instances where individuals and organisations have experienced economic loss due to security and privacy issues resulting from cybercrime (UK: https://nationalcrimeagency.gov.uk/what-we-do/crime-threats/cyber-crime), this is exemplified by the 'hacking' of social-networking platforms (lBBC: https://www.bbc.co.uk/news/technology-51424352). Threats from cyber-crime have increased exponentially and the scale and complexity of attacks is wide ranging and 'Off the shelf' tools (generally acquired using the 'dark web' (Dark web: https://www.broadbandsearch.net/blog/facts-about-dark-web) to commit cyber crime.

There is a distinction between traditional crime and and the international nature of cyber-crime in which the most common cyber threats include extortion using *social engineering* [94–96] including:

- Hacking including theft of social media and email passwords;
- Phishing: fraud using email (often with malicious attachments)to obtain information. Spear-phishing is a targeted attack designed to trick a specific individual; this method involves a strategy in which an email appears to come from a trusted contact and may include some personal information;
- Vishing: fraud using phone calls or voice messages to obtain information;
- Spear-phishing: a targeted attack designed to trick a specific individual. This method involves a strategy in which an email appears to come from a trusted contact, and may include some personal information to make the message seem more convincing;
- Malicious software: including 'ransomware' (BBC: https://www.bbc.co.uk/news/business-48661152) which is a growing threat to individuals and organisations;
- Distributed denial of service (DDoS) attacks: which can be driven by political and financial motives.

Society frequently forms interest groups with shared interests and while such groups are in the main beneficial (to both members and society) there are groups with malign and criminal intent. Soderberg [78] in a paper entitled "Determining Social Change: the role of technological determinism in the collective action framing of hackers" addresses the political engagement of hackers as "a prism" for examining the relationship between TD thinking and collective action. The concept of "collective action framing" is borrowed from social movement theory to describe how "hackers have appropriated notions of the post-industrial information society in their struggles against intellectual property laws and state censorship". Soderberg has studied the topic from the perspective of political engagement (which is not necessarily malign) of hackers as "a prism for examining the relations between TD thinking and collective action. He concludes that "Building on this comparison ... TD does not always lead to political resignation, but TD can also serve as a foundation for collective action". Security critical actions and reactions are a feature of social media; however, tweeting is both increasingly relevant and also time critical (Twitter hack: https://www.bbc.co.uk/news/technology-53428304). Processing tweets for cyber-security threat awareness is addressed in [97] where receiving timely and relevant security is introduced as a means of maintaining high levels of security for IT infrastructures.

The general response to 'cyber-crime' is responsive and the premature implementation of DI without an understanding of the potential risks only exacerbates problems with this approach; there is a need for a proactive approach to attempt to anticipate such threats. On a governmental level, law makers face legislative challenges and generally fail to keep up with socio-technological and socio-economic change driven by DI and TD. As with cyber-crime governments generally adopt a reactive approach and fail to effectively anticipate the potential risks. We consider cloud-based solutions and how a reactive approach in ISD may be implemented in Sections 7 and 8.

5.4.6. Communications and Data Networks

Communications is an field where DI is important on a socio-technological and socio-economic level with data transmission, bandwidth, cost, and latency being highly significant factors in the implementation and take-up of streaming services and in the development of cloud-based solutions. The development of 5G networks [98] (and the projected 6G and 7G) present opportunities for (a) significant increases in data transmission speeds and broadband width with lower latency and reduced infrastructure cost, and (b) increases in data transfer speed broadband width will enable the projected growth in the internet-of-things (IoT) and smart environments. We have considered these topics in [34] where we have introduced our fog computing model (see Figure 4) which models the architectural relationships in cloud-based solutions and latency. We consider this model in Section 8.1.

Such developments are relevant for all stakeholders as current technologies, which may become redundant as they are generally slower than 5G cellular networks, are not mobile and are more infrastructure intensive. Furthermore, there may be changes in telephone usage with landlines (often used only for data transfer with mobile communications being the principal mode of communication) becoming redundant with users using mobile technologies. However, there are potential societal problems for those without 5G connectivity which include the development of mobile near field communication (NFC) payment systems (Google Pay: https://pay.google.com/about/) and the possible issues in the availability of cash. These potential changes are determinist in nature and may result in significant potential socio-technological and socio-economic consequences for all stakeholders in society.

Turning to the impact of TD as it relates to the Covid-19 pandemic the prevalence of 'online' 'fake news' many examples of such posts exist; for example, "fake news" [99] claimed that 5G was responsible for the Covid-19 virus. This theory has been comprehensively disproved as these theories have been rejected by scientific experts in the World Health Organisation (WHO) and Full Fact (a UK-based independent fact checking charity) (Gov.uk: https://www.gov.uk/guidance/5g-and-coronavirus-covid-19) who state that 'viruses' cannot travel on radio waves or mobile networks. The Covid-19 virus is also spreading in many countries that do not have 5G mobile networks. However, the determinist nature of social media has resulted in a pervasive impact in propagating this false theory driven by social networking posts.

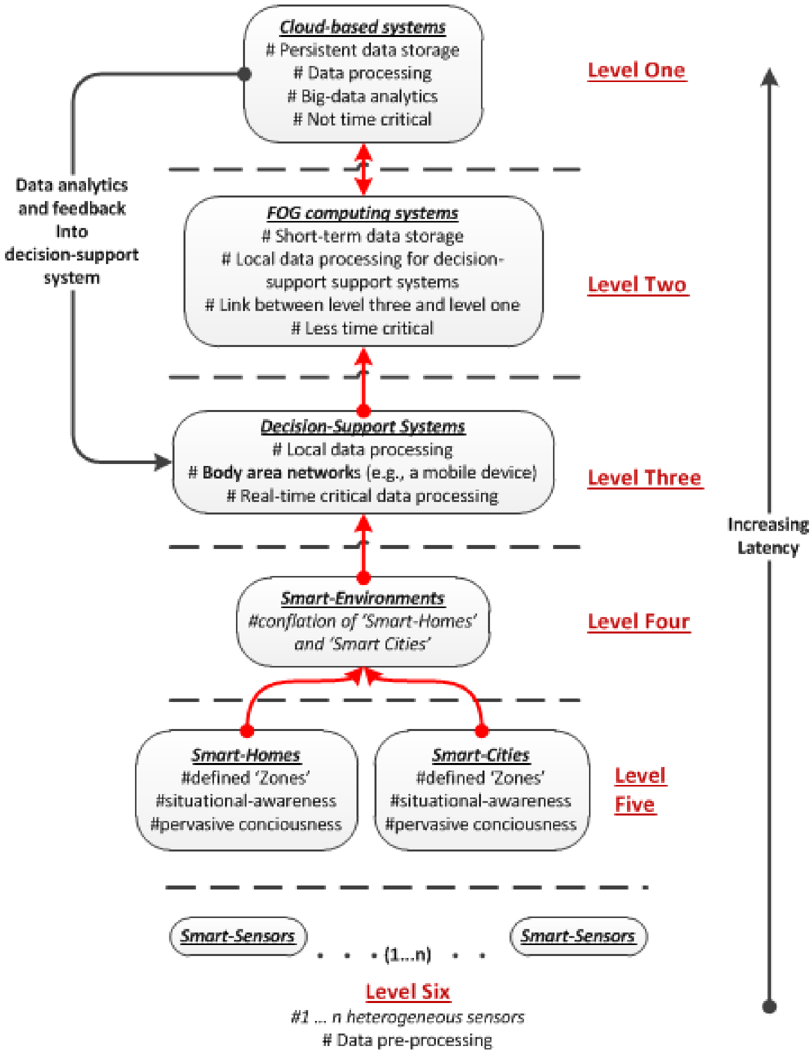

Figure 4. The Fog Computing Model (FCM): is a conceptual model showing the architectural relationships between heterogeneous 'smart-sensors', the 'smart-home' with data processing in a BAN, fog computing systems, and cloud-based systems. The model shows the deployment of a homogeneous system comprising data capture, computing, storage, and networking components along with decision-support systems. Source [34].

5.4.7. Robotics in Society

Robotics research has considered many facets and functions for robotic systems including socially assistive robots, humanoid robots, and autonomous robotic systems for use in domestic and disaster recovery scenarios. Sabanovic [82] considers robots in society and in an analysis of research addressing the social impact and acceptability of robotics concludes that "a linear, technologically determinist view of the interaction between robots and society is dominant in the field" and "the social impact of robotic technologies derives mostly from their technological capabilities and the aim is for society to accept and adapt to technological innovations".

Autonomous robotic systems have been developed for multiple domestic and disaster recovery functions as discussed in [42,100–104]. The research introduces intelligent sensor-derived data processing with autonomous coverage path planning (CPP) in working robots operating in an internal dynamic (static and moving obstacles) domestic environment and a similar dynamic external environment. Significant results have been reported for CPP in 'real-world' environments.

Huber et al. [83] in a paper entitled "Designing Adaptive Roles for Socially Assistive Robots: A New Method to Reduce Technological Determinism and Role Stereotypes" state that "social roles are a design option for robots that behave in accordance with user expectations" and conclude that experimental results "reveal basic role concepts and specific preference clusters in each user group". The empirically based clusters are suitable for the parametrisation and development of robots with adaptive social roles". There is empirical evidence (from the USA and Japan) [82] that demonstrates "a linear technologically deterministic view of the interaction between robots and society is dominant in the field". Additionally, Huber et al. have observed that "research in the field of social robots generally considers implementation of behaviours based on social roles to be important if long-term human-robot interaction (HRI) is to be realised".

The narrative relating to the attitude of society to robotic systems points to the conclusion that the social view (of robot technologies) and 'social shaping' is largely driven principally by the technological capabilities and is therefore technologically deterministic. A similar conclusion is drawn Huber et al. in [83] where the argument posited is that "social roles are a design option for robots that must behave in accordance with user expectations". Huber et al. observe that robots must meet (or exceed) the "stereotypical role behaviours" and dynamically provide roles that suit domestic living spaces to achieve long-term acceptance".

Seminal work has been reported in studies conducted by Prof Sheila Nirenberg [105,106]. Her work is based on human retinal research extended to robotic systems; the reported results are important both in technological terms but also on a societal level as the vision implemented in robots (albeit limited when compared to human vision) has important sociological and technical implications for both robotics and in treating human blindness.

We can conclude that robotics research is shaping society and technology can result being a mutual shaping framework for social robot design [83] with research (generally) based on the humanoid principle [82] and social shaping resulting from the use of robotic systems. Furthermore, reported results support the view that a technologically deterministic view exists in interactions between robots and society and, the social impact of robots is derived mainly from the technological capability.

5.4.8. Education

A fertile field for research has been the domain of higher (tertiary) education and related pedagogic systems with research addressing: (a) the traditional face-to-face approach (often termed: 'talk-and -chalk') [33], and (b) online technology driven pedagogic systems in higher education including blended learning and and distance education delivered textitanytime and *anywhere* [33,107].

Oliver, in a paper entitled "Technological determinism in educational technology research: some alternative ways of thinking about the relationship between learning and technology" [75] considers the relationship of technology to education and argues that research into the adoption of technology "frequently overemphasises the influence of technology and different positions are used to analyse the ways in pedagogic systems might be described as technologically deterministic". In the study four theoretical perspectives are proposed: (a) *activity theory*, (b) *communities of practice*, (c) *actor-network theory*, and (d) the *social construction of technology*. In considering the ways we may think about education and technology, the fact of TD is confirmed. Oliver concludes that the approach to TD requires research to build on the "alternative conceptions of technology" [75].

Hawkridge presents a study which addresses "the Big Bang Theory in Distance Education" [107]. He argues that empirical evidence of the benefits of 'online' distance education [33] and the availability of educational resources. Similarly, there is empirical evidence of critical appraisal of 'online' approaches to pedagogic systems with support for traditional methods. The existence of 'online' distance learning and blended learning can be traced back over many years to the *Open University, UK* (Open University: http://www.open.ac.uk/. The Open University (founded in 1969) has provided both traditional distance learning and 'online' blended learning support. The *UOC University, Barcelona* (UOC: https://www.uoc.edu/portal/en/index.html) has provided 'online' pedagogic systems over many years.

Kirkwood [108] notes that distinctions between "traditional campus-based universities and those dedicated to distance learning" are being eroded by the use of technology. He argues that notwithstanding the investment in technology, there is a lack of clarity of the practical significance. Going further, Kirkwood argues for research involving "joined up thinking" to integrate the multiple contextual factors that combine to influence how technology is used in practice. The study by Kirkwood, while raising questions regarding technology and TD confirms its existence and the resulting influence.

In considering the research into the relationship between pedagogic systems and technology the reported results are often conflicting and contradictory. However, a common thread in the research lies in the impact and use of the Internet and technologies with much of the research being based on subjective and empirical evidence as scientific research methods are often inappropriate. Current developments in pedagogic systems and the use of technology has raised significant issues including:

- The impact of the use of 'online' pedagogic systems is the subject of much conjecture and opinion;
- Access to Internet services and computing resources by students has been inconsistent: while many students benefit from 'online' pedagogic systems other students have been disadvantaged by socio-economic and socio-technical factors;
- Teaching staff have widely varying views on 'online' pedagogic systems as the use of technology often creates increased pressure on teachers [33];
- The variable impact (benefits and negative effects) of 'online' pedagogic systems vary across academic disciplines.

Research into education and technology has investigated the relationship between ontology, epistemology, and methodology within the context of designing multi-modal artificial intelligence (AI) technologies for collaborative learning. Cukurova [109] has considered this relationship in two case studies with a literature review where empirical research in the field (40 out of 46 studies) falls under the inductive methodology. The conclusion drawn is "Although, both deductive and inductive approaches are valuable for the advancement of the field ... the apparent lack of deductive investigations may lead researchers to fall into TD".

There is an extremely large body of published research addressing pedagogic systems including the developing field of AI. The research identified here relates to the pedagogic systems with social and technological factors. We may conclude that while there are undoubtedly both benefits and negative aspects to the use of technology in pedagogic systems, the resulting influence of determinism in the socio-technological context is clear.

5.4.9. Primary Healthcare

Research has considered the use of 'telemedicine' and video services along with nurse-led triage systems , the aim being to address the growing demand and the limitations in the availability of primary healthcare services globally [29–32,110]. Research and empirical evidence (personal and in the press) suggests that the there has been resistance to the implementation of telemedicine, electronic medical health records, and triage systems. However, the impact of the Covid-19 pandemic and the public health requirement to implement:

- *Social distancing* [111] (also termed physical distancing): which is a set of non-pharmaceutical interventions or measures intended to prevent the spread of a contagious disease by maintaining a physical distance between people; (and)
- Reducing the number of times people come into close contact with each other by controlling the *basic reproduction* (or *R*) number [112].

To realise social distancing while providing (albeit limited) primary healthcare services, remote triage systems and the use of telemedicine has been applied in the UK. In developing countries where limited healthcare provision is a feature, the benefits of 'telemedicine' and video services along with nurse-led triage systems has been shown to be effective. However, in developed countries, following the enforced use of remote triage systems and the use of telemedicine, empirical evidence suggest that there appears to be a realisation by both patients and healthcare professionals that: (a) the technological approach to the delivery of primary healthcare services has been generally positive, and (b) the technological approach has generally been accepted by patients and healthcare professionals. Furthermore, there is a realisation that a return to the 'status-quo' is unlikely. This is an example of determinism in action; however, research is required to validate the current technology-driven approach.

Turning to the TD impact on healthcare generally consider the measles, mumps and rubella (MMR) vaccine use-case. The MMR vaccine is given as part of the routine childhood immunisation program in the UK. A controversial study [113] claimed that there was a link between the MMR vaccine and autism. The study received high levels of media coverage which resulted in a significant reduction in the take-up of the vaccine and a large increase in the prevalence of the diseases in the UK with significant negative health outcomes in both the short and long term [113]. Subsequent studies have found no link between the MMR vaccine and autism and Wakefield's work has since been completely discredited (NHS: https://www.nhs.uk/news/medication/no-link-between-mmr-and-autism-major-study-finds/).

The MMR vaccine use-case demonstrates the potential negative impact of technology in the dissemination of information which is frequently "fake news" [99]. The Covid-19 pandemic has resulted in a similar flood of "fake news" as reported in the article "Social media firms fail to act on Covid-19 fake news" (BBC: https://www.bbc.co.uk/news/technology-52903680. The impact of the "fake news" applies to the traditional media but the pervasive nature of online reportage and social networking serves to exacerbate the impact which we may view in terms of TD.

5.4.10. Financial Services

High-frequency financial trading (HFT) systems [92,114], facilitate price efficiency by trading based on dynamic change in financial instruments in 'real-time', the result is the capability to buy and sell securities in milliseconds. There have been an existential change in the trading of securities in the financial markets over the past 30 years driven by changes in the regulatory framework, the HFT systems, and high-speed data networks. In a European Central Bank working paper (No: 1602-Nov 2013) "High Frequency Trading and Price Discovery" the conclusions are:

> *. . . the direction of buying and selling in high frequency trading predicts price changes over short horizons measured in seconds . . . (and) . . . in high frequency trading liquidity supplying orders are adversely selected . . .*

While HFT systems have created extremely fast and efficient financial trading; however, such systems have induced high levels of volatility [84] with self-perpetuating and uncontrolled stock-market falls in financial markets globally. Financial trading systems represent an exemplar of systems where the technology overtook the ability of human operators to fully understand the technology and the potential impact (on financial markets) [84]. The influence of TD with the disruptive impact of high frequency trading technologies is clear.

5.5. Counter Arguments

As we have discussed, TD may be viewed as a Pandora's box where the potential impact of DI is generally unknown and unforeseen. This was relevant to the DI in the industrial revolution and is arguably more relevant today given the dynamic nature of society driven by rapid socio-technological and socio-economic change. However, there are theories which argue (at least in part) against determinism and TD including the: (a) *rational actor* theory [21], (b) *subversive rationalisation* theory [66], (c) *voluntaristic* theories [21], (d) *materiality* theory [21], and (e) *inevitably thesis* [115].

In Section 3, we introduced the *hard*, *soft*, and *neutral* determinist views. There is a perceived correlation between the textitsoft, and *neutral* determinist views and the *rational actor*, *materiality*, *subversive rationalisation*, and *voluntaristic* theories.

The rational actor theory argues that the negative social affects may be outcomes that people deliberately intend to achieve (or) users might anticipate the medium's risks and take steps intended to ward off negative effects. The materiality theory proposes the conflation between the material and the social with the distinction between *determinism* and *voluntarism*. There are those who adopt the view that society and/or culture interacts with, and may even contribute to, the 'shaping' of technologies. However, a TD view argues that technology use is largely determined by the structure of the technology. Interestingly, an *inevitably thesis* has been proposed [115] which states that "once a technology is introduced (into society or culture) what follows is the inevitable development of the technology". This thesis has a clear determinist correlation where the adoption of DI and supports the TD theory.

Feenberg in [66] disputes the "rationality" argument by proposing in 1992 that "those who are today subordinated to technology's rhythms and demands will be able to control it and determine its evolution". This is termed "subversive rationalisation at it requires technological advances that can only be made in opposition to the dominant hegemony". Leonardi and Barley in [21] have investigated the *materiality* and *voluntaristic* theories to build a "better theory about technology and organising". Leonardi et al. have suggested that research often conflates the distinction between the "material and social" with the "distinction between determinism and voluntarism" and have identified four challenges that researchers must consider to effectively address technological change:

- The relationship of *technologies* and *materiality* (the quality of being relevant or significant) to TD;
- The range of technologies included in the research undertaken to better understand the socio-technical factors and TD;
- The study of the relationship between development and use (of IS) to understand how: (i) the practices of designers affect users, and (ii) how users use of systems can effect a systems analyst and designers conceptual view of systems [20] (a common conceptual model as discussed in [13,16]);
- The realisation that new technologies can result in different outcomes in different social contexts.

Janet Fulk [80] has introduced "The Social Influence Model of Technology Use" where the "explosion of new technologies has generated widespread controversy over their potential effects on the workplace". Fulk argues that current media-use theories fail to recognise a central premise of current organisation theory and behaviours occur in a social context which is far from neutral in its effects". In conclusion Fulk notes:

> *Once we assume an active and influential social context of media use, we then face the problem of specifying the social processes more precisely. An appropriate starting point is to examine existing theories of social relations in organizations with an eye to how their premises apply to media-use behaviour*.

In considering the research which addresses determinism and questions the validity of TD, we may draw the following conclusions: (i) while the counter arguments present an alternative determinist view, the consensus view in the press and research is that TD is an increasingly important and relevant factor in society generally, and (ii) research is required to support the notion that the outcome resulting from technological change is socially constructed.

6. Data Processing and Cognitive Modelling

In socio-technical ISD people form a central element in a systems analysis and human cognitive processing must be considered. Humans' view their 'world' through a unique perceptual filter and employ reasoning which enables decisions and conclusions to be reached based on sparse, imprecise, and incomplete data using learned knowledge and experience. A significant feature in how humans' 'view of their world' is cognitive dissonance [116] which describes a state where: (a) humans' display inconsistent thoughts, beliefs, or attitudes relating to behavioural decisions and attitudinal change, and (b) there is a difference between experience or behaviour and beliefs about what is true. Cognitive dissonance has a place in IS and ISD as it relates to users response to systems. The concept of 'self' is introduced in [88,117–123]. Barnes in [86], investigates theories which explain the relationship between technological development and social change and has observed:

> *rather than thinking of disinhibition as the revealing of an underlying 'true-self', we can conceptualise it as a shift to a constellation within 'self-structure', involving clusters of 'affect, and 'cognition' that differ from the in-person constellation ....*

Figure 5 models the notion of *self* which embodies the concept of *internalised* and *externalised* self [124]. The internalised and externalised self models human cognition and how humans' process information and generate experience and therefore knowledge. From Figure 5 we can see the externally generated stimuli and the internally generated stimuli.

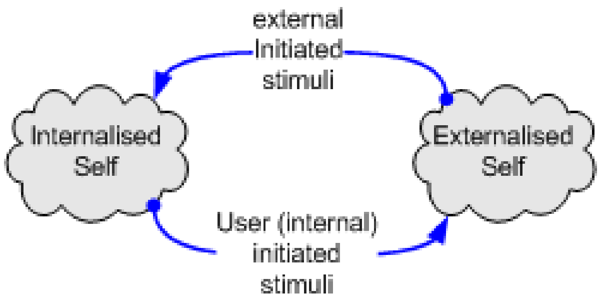

Figure 5. A cognitive model showing the notion of 'self' and the 'feedback-loop' that applies to human cognition and the generation of knowledge and experience. The internalized and externalized self models human cognitive processing and the human socio-technical and socio-economic 'view of their' world (source: [4]).

In Section 5.4.4 we have considered determinism as it relates to social networking and introduced the concept of 'disinhibition' where there are references to "self-structure" and "in-person constellation" [88]. These observations are correlated with [86] who has introduced the concept of a 'true-self' conceptualised as a shift to a constellation within 'self-structure'. The notion of 'self' with the the concept of the internalised and externalised self can be seen to have a relationship with human cognition and are relevant in machine cognition [125]. Furthermore, there is a perceived relationship to information, knowledge, and wisdom as addressed in [4] and the cognitive processes modelled in Figure 5.

In Section 2 we have noted that *information is power*. However, the relationship of information to power is generally misunderstood, what is important is knowledge and information provides a basis for the creation of knowledge and the traditional view states that Information is data processed. However, this view is limited as it fails to capture the true nature of information and knowledge as it applies in modelling 'real-world' human cognitive systems. We have considered data processing and extended the traditional view of data processed into information in [4] where we introduce data processing where *data* –> *CAPTA* –> *information* –> *knowledge* –> *wisdom*, Figure 6 models the process.

In Section 5.3 we have introduced LD which is a concept that considers the notion that language limits and determines human knowledge or thought processes (e.g., categorisation, memory, and perception) [63,69]. Humans express emotional response in semantic and linguistic terms [4,126,127]; therefore, in considering cognitive processes and ISD, emotional response (affective computing) [36] using linguistic and semantic analysis based on *Kansei* engineering and hedge algebras forms an important element. A detailed discussion on these topics is beyond the scope of this paper, for a detailed exposition on the topics see [128–131].

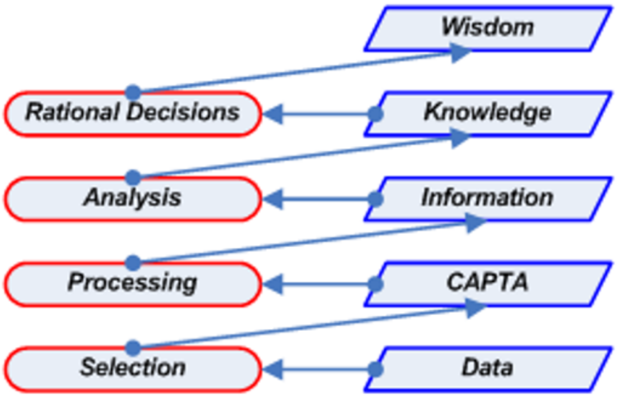

Figure 6. A conceptual model illustrating the progression of data processing from the raw data to wisdom (rational decision-support). Shown is the intermediate stage (CAPTA) [52] where an initial selection of relevant and useful raw data (termed *CAPTA* [52] is used.

Following our brief overview of cognition we conclude: (a) our extended view of data processing [4] addresses data processing into knowledge (and ultimately wisdom) where knowledge (and experience) can result in true power, (b) viewed from an organisational context, understanding human cognition and it's relationship to power forms an important factor in IS and ISD, (c) generating an understanding of users' attitudes to specific systems based on cognitive processing with text analysis can provide useful information in the ISD process as discussed in Section 7.

7. Discussion

In this paper we have considered informatics and introduced IS, ISD, and determinism driven by the impact of DI on both societal and technological levels where the impact can be both positive and negative. We have identified the paradox that lies at the heart of Informatics and IS which can result from the adoption of DI; the paradox relateing to the general concept of determinism with particular reference to TD in a societal context. Determinism is a challenge facing all stakeholders in IS including:

- *Systems analysts and knowledge engineers*: who investigate the organisational setting, create the requirements specification, and design he system;
- *Commissioning bodies*: generally the organisation who require and fund the design and development of a system;
- *Software engineers*: who build, test, and implement a system;
- *Stakeholders*: all those who have an interest in a system or application.

In considering determinism we have introduced TD, MD (an alternative term for TD when applied to the media), and LD which is relevant to social networking, security, and data processing including human cognitive processes. We have considered research which supports the concept of TD and also introduced research which contests (at least in part) the societal validity of determinism. While the counter arguments present alternative views of determinism, the consensus view is that TD is an increasingly important and relevant factor in the relationship between society and technology, as such, TD forms an important element in socio-technical ISD. Published research has proposed a number of theories to explain the (generally negative) relationship that exists between technology and society, the theories dating back over decades [19,21,66]. Theories proposed include hard, soft, and neutral determinism [19,21,66] where the *rational actor*, *materiality*, *subversive rationalisation*, and *voluntaristic* theories are discussed.

Allan Dafoe [19] has noted that TD is "predominantly employed as a critics term" which and has been used to "dismiss certain classes of theoretical and empirical claims". However, Dafoe argues for the autonomous 'social shaping' influence of technology noting that TD is a "valuable and prominent perspective". The *rational actor materiality*, and *subversive rationalisation* theories (which are potentially relevant from an ISD perspective) are arguably outdated given the pace and scope of technological development. However, TD (as proposed by Marx) has become the dominant and accepted view following the pervasive and highly dynamic nature of technology. In considering voices that argue against TD, there is a clear similarity between the *rational actor* theory and *voluntarism*. However, the development in technology (for example, the influence of social networking and the pervasiveness of mobile communications) has rendered the observations of Feenberg in [66] outdated. Leonardi and Barley [21] are sceptical regarding the influence of TD but agree with the observations of Feenberg that research is required. While such theories argue against TD, there remains a need for research to validate the theories.

Related research has identified two elements at work in determinism namely the technological and societal factors and, based on this discussion we may conclude:

- While the impact of TD can be felt on a technological level, the impact is relatively easily identified and the required updates implemented (albeit often after the event);
- From the related research considered, it is clear that the societal impact of DI represents a more significant challenge. Indeed, as noted in this paper, the paradox of TD and the Pandora's box that potentially may be opened may never be closed. Therefore, the impact of TD from the societal perspective is difficult to foresee and may never be corrected. Therefore, it is important to attempt to address this challenge at the ISD stage;
- There is a requirement to create a better understanding of the adoption of DI in 'real-world' systems (and) develop an ISD methodology capable of accommodating the increasingly dynamic socio-technological challenges for IS and address the potential challenges created by TD.

In Sections 8, 8.1, and 8.2 we set out our current research direction designed to create a socio-technical approach to ISD along with open research questions and proposed directions for future research. The challenges identified are non-trivial and potentially far reaching with the impact of DI being felt across all strata of society. This is exemplified by IS in 'real-world' computerised systems where there is a lack of understanding relating to societal issues as evidenced by the problems experienced by social networking platforms (https://www.theguardian.com/commentisfree/2018/aug/04/) (BBC: https://www.bbc.co.uk/news/technology-51511756). Ignoring the historical perspective of social network platforms and their publishing status [132], improper use of the platforms is reflected in *disinhibition*, *abuse*, and *subjective reinforcement* (based on expressed preferences and historical use patterns) or *influence maximisation* [133].

Turning to human cognition we have identified determinism in the form of LD. This topic, while addressing determinism, has relevance for human cognition, emotional response, [36], cognitive modelling, and the processing of data and information [4]. As discussed in Section 5.3, linguistics and semantics form an important component in human cognitive processing [4] and as such must be considered from an IS and ISD perspective. Additionally, cognitive dissonance (see Section 6) forms an important consideration in IS and ISD. In addressing education and AI [109] it has been argued that "both deductive and inductive approaches are valuable for the advancement of the field; it is argued that the apparent lack of deductive investigations may lead researchers falling into technological determinism" [109].

8. Directions for Future Research

Research into computer science, social science, and social anthropology is relevant to an understanding of how humans interact with, react to (both active and reactive), and use technology [11,86,109,134]. In considering the socio-technical aspects of IS and ISD, an understanding of how humans operate in the social context is essential [11,135], has considered social anthropology and the relationship to technology and has observed that:

> ... *the Standard View of technology underlies much scholarly as well as popular thinking*" and "*against the Standard View's exaggerated picture of technological evolution from simple tools to complex machines, the socio-technical system concept puts forward a universal conception of human technological activity in which complex social structures, non-verbal activity systems, advanced linguistic communication, the ritual coordination of labour, advanced artefact manufacture, the linkage of phenomenally diverse social and non-social actors, and the social use of diverse artefacts are all recognised as parts of a single complex that is simultaneously adaptive and expressive*.

Social anthropology and social science research pre-dates the current technology landscape. However, there is a clear correlation between the observations in [11] as they relate to the current technological landscape and the impact of determinism (including TD, MD, and LD) which can be seen in many applications and systems on both socio-economic and socio-technological levels. Accordingly, it is challenging to predict the potential impact of TD which can be summarised as:

> *The lack of an understanding of the potential affects (negative and positive) resulting from DI and the premature implementation of DI driven by a socio-technical imperative in which equal importance is given to the societal and technological components*.

The problems as they relate to determinism are well represented in the press and published studies. Social network platforms such as Facebook, Twitter, and TikTok are exemplars of applications where determinism has resulted in significant socio-technical issues as discussed in this paper. Given the potential challenges presented by determinism and the affects felt by organisations and individuals, from an IS and ISD perspective the important open research question is:

> *How to create a design methodology capable of accommodating the increasingly dynamic socio-technological demands of informatics while identifying the current impact of determinism and anticipating the potential future impact of TD as it relates to computerised information systems?*

Addressing the open research question requires an approach which utilised an iterative and agile method [136] incorporating socio-technical design as discussed in Section 3. We argue that such an approach can flexibly accommodate (or at least mitigate) the short and long term affects of determinism in our highly dynamic technology driven unpredictable world. We consider a potentially profitable (in research terms) direction for future research lies in the development of an approach to: (a) identify the opportunities in the systems analysis, design, development, and adoption on DI from a socio-technical perspective; (b) improve the understanding of how to identify the affects of DI; and (c) develop an understanding of the nature of determinism and what digital disruption means.

8.1. Cloud-Based Solutions

For organisations, cloud-based solutions (CBS) form an increasingly important and viable approach. We will investigate ISD in combination with a study to develop a "layered approach" using the fog computing model (FCM) shown in Figure 4 (see Section 5.4.6). The aim here is to address the needs of IS in CBS including fog and edge computing with the Internet-of-Things (IoT) [40]. Space restricts a consideration of the elements modelled in our FCM; for a detailed discussion on the FCM where the functions, technologies, and the six levels modelled in our FCM see [34]. In summary, the tiered approach adopted in the FCM can address latency, data processing, with *in memory* and *persistent* data storage [53] in CBS which are relevant to the development of IS. We aim to investigate the tiered approach and incorporate the results into our ISD development.

Peterson et al. [76] have proposed an interesting "overlay-based" to design, evaluate, and deploy geographically distributed network services and suggests four design principles: (a) *slice-ability*,

(b) *distributed control of resources*, (c) *unbundled management*, and (d) *application-centric interfaces*. It is argued in [76] "an overlay approach that supports these (four) design principles will facilitate the emergence of a new service-oriented network and architecture". A detailed exposition of the approach proposed by Peterson et al. can be found in [76]; however, we believe that this approach has potential benefits for the challenges presented by determinism and our research into ISD.

8.2. The Risk vs Time Relationship

As we have discussed in this paper, there is a relationship between adoption and an understanding of the theory and practice as this relates to the impact of DI. To understand the relationship between of theory, practice, and determinism we view the relationship for determinism (forthe social and technological context) from a *risk vs time* perspective in terms of Equation (1) which will result in a normalised result in the range $[0\ldots1]$ with (0) being low potential impact and (1) high potential impact. The equation is shown in Equation (1) :

$$I(a) = \prod_{s\,t}^{\infty} \left(\frac{R+T}{max} \right) \tag{1}$$

where $I(a)$ is a normalized quantitative measure of the overall the risk in the range $[0\ldots1]$, (s) is the social risk, (t) is the technological risk, (∞) is the time over which the risk is measured, (R) is the measure of the risk in the range $[0\ldots1]$, (T) is the measure of the time in which the risk is measured, (max) is the measure of the maximum risk for (s) and (t) where (max) is the maximum risk value for the $\sum(s+t)$. The Equation (1) will be developed and extended to implement context-awareness as discussed in [53] in ISD along with the proposed ISD architecture shown in Figure 7.

Our proposed approach is conceived as an approach to enable the implementation of the social and technology elements in intelligent ISD and will be based on the ISD architecture (see Figure 7). In the proposed architecture there are five principle interactive component modules: (i) data processing; (ii) the organisational structure; (iii) information system analysis and design; (iv) the staged testing strategy; and (v) the implementation and systems maintenance strategies. The component modules are briefly described in Figure 7 where the iterative interactions are between the component modules are shown. The component modules will be used at all stages of the SLC frmo the initial design and implementation to the maintenance and updating stages.

Research Summary

In Section 4.1 we have set out the RS in our proposed determinist context which sets out an hierarchical multi-factorial starting point for a systems analysis and implementation which includes:

1. The development of the proposed architecture with additional sub-functions required to address the needs of socio-technical ISD;
2. The development of an approach using multi-modal domain specific factors and parameters (contextual information [36]);
3. An approach designed to meet the demands of systems analysis and ISD including data collection, knowledge engineering, and the testing strategy;
4. Develop the RS to design and develop an approach with the capability to update and maintain a system over the SLC.

The research goal is to extend the ISD 'state-of-the-art' to accommodate the demands of determinism using a range of methods to develop an approach to ISD employing:

1. The application of context-awareness with context-matching [53] between (R) and (T) for the social and technology context;
2. Intelligent data processing implemented in a fuzzy rule-based approach [53] with affective computing using 2D valence emotion recognition based on intelligent context-awareness [137];

3. The analysis of context will use advanced analysis techniques including: the Semantic Web technologies [138–140] with linguistic and semantic approaches [93], *hedge algebras*, and *Kansei* engineering [126,129,130,141] in text analysis.

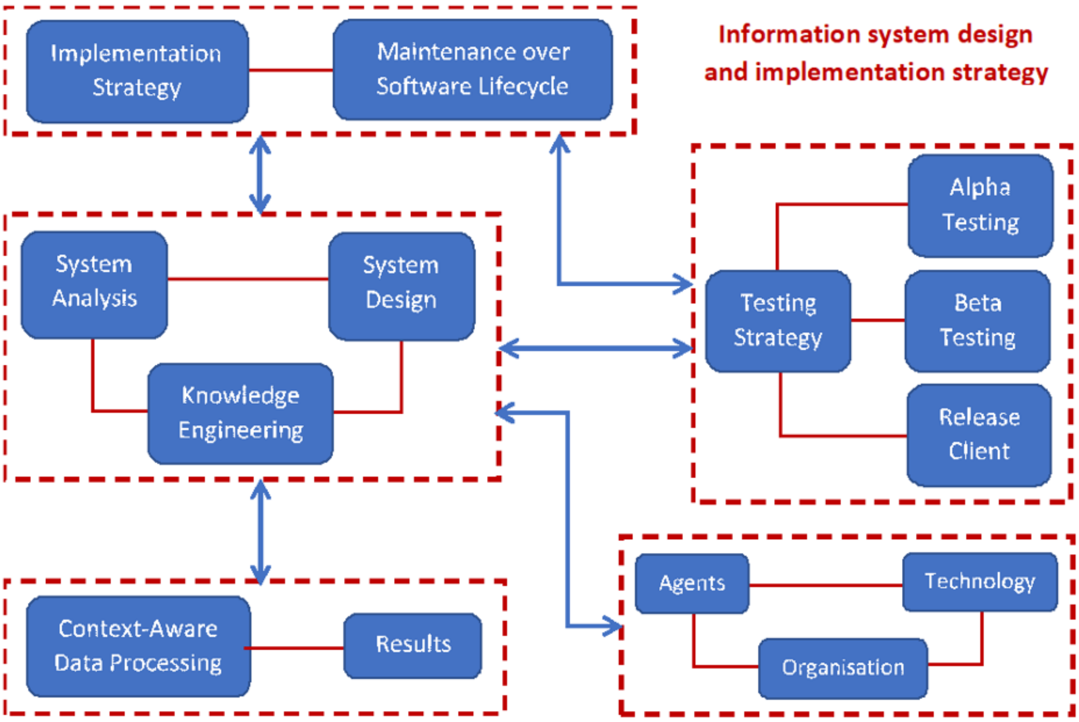

Figure 7. The ISD architecture models five interactive principle component modules: (i) intelligent context-aware data processing [53], (ii) the organisational structure including the socio-technical elements and the organisatonal culture [5,52], (iii) information system analysis and design including knowledge engineering using interactive and unobtrusive data gathering methods in the systems analysis, (iv) the staged testing strategy implemented over the software life cycle, and (v) the implementation and systems maintenance strategies designed to maintain and update the system over the software life cycle.

The proposed approach will employ a novel agile iterative method predicated on a fuzzy rule-based approach [53] with the traditional fuzzy sets theory [142] extended using intuitionistic fuzzy sets [143] and picture fuzzy sets [144]; this represents work in progress which we will report in a later paper . The "overlay approach" [76] provides interesting opportunities and, when used in concert with our FCM (see Figure 4 introduced in [34]), offers an interesting research ISD direction for socio-technical ISD. Future work will develop and implement the proposed approach based on an actual 'real-world' case-study which will be addressed in subsequent publications.

9. Concluding Observations

In this paper we have considered informatics, IS, ISD, and determinism along with the opportunities and challenges presented by paradox of TD which may be summarised as a lack of understanding relating to the socio-technical issues resulting from the adoption of DI as evidenced by the well documented problems such as Facebook and Twitter where improper use of the platforms is reflected in *disinhibition*, *abuse*, and *subjective reinforcement* or *influence maximisation* (based on expressed preferences and historical use patterns), and security violations.

The ubiquity of computerisation along with the development and adoption of novel computing paradigms has presented many opportunities and benefits for all stakeholders from an organizational and individual perspective. There are positive and negative aspects of determinism where TD is arguably more significant on the societal level and less so from a technology perspective, however, following the adoption of DI, the positive affects are seen relatively early while the negative affects become apparent over time. While the concept of TD has been questioned is has become an accepted 'real-world' reality. Informatics and IS are central to all stakeholders in computerised applications and systems; therefore, IS are vital in Internet applications. TD represents a significant challenge for all stakeholders (including designers and developers) of computerised systems.

The research introduced in this paper uses our previously developed (and tested) approach which is being developed and extended in the ISD domain based on the current work in progress. The proposed ISD method will employ intelligent context-aware data processing using our rule-based fuzzy systems approach incorporating linguistics and semantics in an ISD method that will accommodate currently known and understood methods of systems analysis and modelling (such as UML and ERD) which will form part of the approach to socio-technical ISD. The aim is to create an ISD methodology which will be accessible and will generalise to ISD in multiple diverse domains and systems. In future ISD, we must try to accommodate TD and the socio-technical elements while addressing the dynamic social structures that operate in the 'real-world'.

We suggest that our proposed direction for research will provide an approach capable of informing IS and ISD that will generalise to accommodate the diverse requirements of multiple domains and systems.

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