Socio-Technical Theory

Socio-technical theory is an organisational theory that conceptualises a given work or other system in view of its constituent social and technical subsystems, with the goal of achieving system success through joint optimisation.

By Roba Abbas (School of Business, University of Wollongong, Australia) & Katina Michael (School for the Future of Innovation in Society & School of Computing and Augmented Intelligence, Arizona State University, USA)

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Theory Factsheet

Proposed By: Trist & Bamforth, 1951

Parent Theory: General Systems Theory, Open Systems Theory

Related Theories: Actor Network Theory, Soft Systems Theory, Work Systems Theory, Work Systems Method

Discipline: Management and business studies

Unit of Analysis: Individual, work system, organisation, industry, nation, society

Level: Meso-level

Type: Theory for Design and Action

Operationalised: Qualitatively / Quantitatively

Introduction

Socio-technical theory originated in the 1950s at the Tavistock Institute in London (Ropohl, 1999), led by Trist and Bamforth (1951) and Emery (2016), resulting from industry-based action research focusing on coal mining (Fox, 1990) and labour studies in Britain (Ropohl, 1999). Built on an open systems foundation (von Bertalanffy, 1950), the theory promised a "*new paradigm*" (Trist, 1981:p42) that defied the dominant technological imperative at the time, in favour of an approach that perceived people as more than extensions to machines (refer to Table 1 for an overview of the initial view of the new paradigm i.e., socio-technical theory). The proposed socio-technical paradigm also deviated from the notion that people were dispensable to a perspective where individuals were considered as a "*resource to be developed*", encouraging collaboration, commitment and a risk-taking environment, as opposed to competition, alienation and minimal levels of risk taking respectively (Trist, 1981:p42).

Table 1: Adopted from Trist et al. (1981)

Old Paradigm	**New Paradigm**
The technological imperative	Joint optimization
Man as an extension of the machine	Man as complementary to the machine
Man as an expendable spare part	Man as a resource to be developed
Maximum task breakdown, simple narrow skills	Optimum task grouping, multiple broad skills
External controls (supervisors, specialist staffs, procedures)	Internal controls (self-regulating subsystems)
Tall organisation chart, autocratic style	Flat organisation chart, participative style
Competition, gamesmanship	Collaboration, collegiality
Organisation's purposes only	Members' and society's purposes also
Alienation	Commitment
Low risk-taking	Innovation

According to Pasmore et al. (1982:p1182), the socio-technical approach is a *"method of viewing organisations which emphasises the interrelatedness of the functioning of the social and technological subsystems of the organisation and the relation of the organisation as a whole to the environment in which it operates. Put simply, the sociotechnical system perspective contends that organisations are made up of people that produce products or services using some technology, and that each affects the operation and appropriateness of the technology as well as the actions of the people who operate it.*" Within this definition is the value-added notion, whereby the products and services produced are "*valued by customers (who are part of the organisation's external environment)*" (Griffith & Dougherty, 2001:p206).

Further simplified, Emery (1980) maintains that socio-technical research is about mutual benefits derived from the intersection of social and technical elements. This intersection emphasises a reciprocity between humans and machines, in which a process of dual shaping of the social and technical systems occurs (Ropohl, 1999:p59). As such, the socio-technical approach defines the social and technical dimensions, which are termed subsystems, that form a system of interest or broader system, known as a suprasystem. The theory stipulates that the success of the socio-technical system is a product of the interactions between these subsystems. Socio-technical theory emerged in response to dominant technocratic models that were technologically deterministic, ignoring human factors (Kling, 1980; Trist, 1981). These models were regarded as restrictive in their disregard for the social aspects within a system, particularly with respect to how the social subsystem interacts with the technical subsystem. As such the socio-technical approach was proposed to acknowledge the significance of society or the social aspects in the design, redesign and interventions affecting a system, whereby the aim of each subsystem would be to "*meet its own objectives, by using its own means, but is also in an interdependent relation with other subsystems*" (Bauer & Herder, 2009:p601). Design activities were originally completed in the context of a primary work system or organisational unit as the main units of analysis (Trist, 1981). Alternate units of analysis were also recognised in early socio-technical studies, external to the primary work system or the organisational boundary, acknowledging the macrosocial as a significant unit of analysis (Trist, 1981).

Support for socio-technical theory was initially underwhelming and it was not till the 1980s that a shift from the dominant "*technocratic and bureaucratic mode*" became apparent (Trist, 1981). This transition was encouraged in seminal work concerning social analyses in the technology realm (Kling, 1980:p62), which maintained that deviance from the "*technical determinist*" orientation was necessary in researching technologies. Kling's landmark study described the importance of prospective and speculative analyses in addressing the implications of emerging technologies, in view of "*the capabilities, potential benefits, and potential harm of new technical developments*", concluding that meaningful analyses of implications must incorporate social and economic factors, thereby avoiding sole reliance on technical aspects (Kling, 1980:p62). These sentiments were reiterated by Trist (1981:p9), who claimed that "*(t)he technological imperative which was still dominant throughout the eighties could be disobeyed with positive economic as well as human results... the best match would be sought between the requirements of the social and technical systems.*" Bijker (1997:p273) concurred that integration is required, claiming that "*all stable ensembles are bound together as much by the technical as by the social*", and as such should be treated as a single unit consisting of "*intimate social and technical links*". Since its introduction, socio-technical theory has diverged into various application areas.

Theory

Open Systems Basis

Socio-technical theory is built on the foundations of general systems theory and open systems theory (von Bertalanffy, 1950). An open system, as opposed to a closed system, can be defined as one in which there is flow ("*import*" and "*export*") and or interaction between components and the environment, resulting in the modification or evolution of system components (von Bertalanffy, 1950). Consequently, socio-technical systems inherit key assumptions, concepts, and characteristics from these parent theories. These inherited elements include concepts relevant to responsiveness to environmental factors and the key notion of "*equifinality*" in the achievement of a steady state (Trist et al., 2016; Herbst, 1974). With respect to the environment, the open systems perspective acknowledges that a system's success and / or survival is affected by the way it interacts with its environment, and its evolution and responsiveness to any changing conditions. This implies that environmental factors will influence the way the system behaves (Mumford, 2003), and therefore, to resolve complex issues, the dynamics between psychological, economic, technical, cultural, and political aspects need to be understood (Mumford, 2003). The application of open systems thinking within the socio-technical framework promotes not only the dual consideration of the social and technical elements, but also an awareness of "*present and future environmental demands*" (Pasmore et al., 1982:p1186). As to equifinality, this is expressed as a range of possible initial conditions for ensuring a steady state or equilibrium (Trist et al., 2016). Equifinality is an important notion when considering the operationalisation of the theory through (information) systems design, in that multiple designs could potentially achieve a steady socio-technical system state. A steady state refers to the ability of an open system to reach a time-dependent state of equilibrium, whereby the entire system and its components remain constant (von Bertalanffy, 1950).

Social and Technical Subsystems

The socio-technical approach distinguishes between various dimensions of a given system through the concept of a subsystem. Initial studies identified the dimensions of a socio-technical system as socio-psychological, referencing the people and denoting the human aspects; the technological, as referring to the artifacts or the things; and the economic, as representing the effectiveness of interactions between the human and technological resources (Trist et al., 2016). Current conceptualisations are concerned with three primary dimensions or subsystems: the social, technical, and environmental. In a general sense, the social subsystem refers to the human factors or elements present in a socio-technical system. In an organisational setting, the social subsystem comprises the individuals or people that constitute an organisation and the relationships, values, structure, work-related elements and associations that are delivered by organisational members (Trist & Bamforth, 1951; Emery, 2016; Jacobs, 1972; Bostrom & Heinen, 1977a; Pasmore et al., 1982). The technical subsystem refers to the physical and material flows within a transformation process, in addition to the tasks, control and maintenance functions, and when applied to the organisational setting, denotes the tools, techniques, skills, and devices that are required by workers to fulfil organisational objectives and tasks (Trist & Bamforth, 1951; Emery, 2016; Jacobs, 1972; Taylor, 1975; Bostrom & Heinen, 1977a; Pasmore et al., 1982). These subsystems collectively operate within a given environmental subsystem, which influences their function and the way in which they interact. The environmental subsystem is defined as the context, surroundings, and conditions within which the open socio-technical system operates and is situated, referring to both the internal and external environment (Emery & Marek, 1962; Cummings, 1978; Trist, 1981; Pasmore et al., 1982). According to the founders of the socio-technical school of thought, and in the context of the coal mining industry, the interactions between the social, technical and environmental systems are conveyed as follows: *"So close is the relationship between the various aspects that the social and the psychological can be understood only in terms of the detailed engineering facts and of the way the technological system as a whole behaves in the environment of the underground situation"*(Trist & Bamforth, 1951:p11).

Socio-technical perspectives of an organisation or work system are similarly comprised of distinct but interrelated social and technical subsystems, where a work system is a primary unit or department within an organisation that can be regarded and (re)designed as a socio-technical system consisting of interacting subsystems, within which subdimensions exist (Taylor, 1975; Bostrom & Heinen, 1977a; Bostrom & Heinen, 1977b; Trist, 1981). Within a work system, constructs such as structure, people, technology, and tasks exist and interact (Bostrom & Heinen, 1977a; Bostrom & Heinen, 1977b). This prevalent representation of a socio-technical system is centred on the assumption *"that the outputs of the work system are the result of joint interactions between these two (i.e., the social and technical) systems"*, and as such integration is necessary during the design or redesign process (Bostrom & Heinen, 1977a:p17). Other representations of socio-technical subsystems focus on defining the characteristics of the distinct social and technical subsystems in view of origins, control and situatedness among other aspects (Table 2), noting that the social and technical aspects *"point in different directions"*, and that the *"the strength of sociotechnical systems results (from) the integration of these two kinds of different phenomena"* (Fischer & Herrmann, 2011:p4).

Table 2: Adopted from Fischer and Herrmann (2011)

	Technical systems	**Social systems**
Origins	Are a product of human activity; can be designed from outside.	Are the result of evolution, cannot be designed but only *influenced* from outside.
Control	Are designed to be controllable with respect to prespecified performance parameters.	Always have the potential to challenge control.

Situatedness	Low: preprogrammed learning and interaction with the environment.	High: includes the potential of improvisation and nonanticipatable adaptation of behaviour patterns.
Changes	Are either preprogrammed (so that they can be simulated by another technical system) or a result of intervention from outside (so that a new version is established).	Evolutionary: gradual accumulation of small, incremental changes, which can lead to emergent changes (which, however are not anticipatable). There is no social system that can simulate the changes of another social system.
Contingency	Are designed to avoid contingency; the more mature a version is, the less its reactions appear as contingent.	The potential for change and evolution is based on contingency.
Criteria	Correctness, reliability, unexpected, unsolicited events are interpreted as malfunction.	Personal interest, motivation; in the case of unsolicited events, intentional malpractice may be the case.
Modeling	Can be modeled by describing how input is processed and leads to a certain output.	Models can only approximate the real behaviour and have continuously to be adapted.
Modus of development	Is produced or programmed from outside.	Develops by evolution that is triggered by communicative interaction.

Principles of Socio-technical Theory

There are two main principles of socio-technical theory, the first relating to the nature of interactions between the social and technical components in defining the degree of success of a system, and the second concerning the *"goodness of fit"* between the social and technical factors of an organisation (Trist, 1981:p10), which results in an optimum state for the suprasystem. This fit was formally termed joint optimisation, which fundamentally refers to equal consideration of the technical and human elements throughout the socio-technical design or redesign process (Emery, 2016; Emery, 1980; Trist, 1981), and entails achieving a "*best match... between the requirements of the social and technical systems*" (Trist, 1981:p9). Although varying interpretations of this principle exist (Mumford, 2003), joint optimisation references a process of reaching an optimum state in the interest of the overall system, rather than privileging or optimising one subsystem, as described by Trist et al. (2016:p7): "*Inherent in the socio-technical approach is the notion that the attainment of optimum conditions in any one dimension does not necessarily result in a set of conditions optimum for the system as a whole. If the structures of the various dimensions are not consistent, interference will occur, leading to a state of disequilibrium, so that achievement of the overall goal will to some degree be endangered and in the limit made impossible. The optimisation of the whole tends to require a less than optimum state for each separate dimension*."

The definition of optimisation was later enhanced to encompass sensitivity to environmental pressures in the pursuit of optimisation within an organisational setting (Pasmore et al., 1982:p1182). This is due largely to the open systems foundation (von Bertalanffy, 1950), whereby organisations are required to be flexible to accommodate variations in their environments, additionally implying that, in order to avoid "*organisational obsolescence*", joint optimisation should not be considered a static endeavour (Pasmore et al., 1982:p1189). Hence, socio-technical design for joint optimisation is very much an iterative and frequently evolving process. Another key point in this regard is that optimisation should be a mutual, rather than an independent, activity within the socio-technical system, to encourage the most favourable outcome for the given system, as explained by Trist (1981:p24): "*The technical and social systems are independent of each other in the sense that the former follows the laws of the natural sciences while the latter follows the laws of the human sciences and is a purposeful system. Yet they are correlative in that one requires the other for the transformation of an input into an output, which comprises the functional task of a work system. Their relationship represents a coupling of dissimilars which can only be jointly optimised. Attempts to optimise for either the technical or social system alone will result in the suboptimisation of the socio-technical whole.*"

Socio-Technical Design

The principles of the theory, specifically the principle of joint optimisation, are operationalised through a process of socio-technical design, redesign, or some other form of socio-technical intervention, depending on the unit of analysis in each project. Socio-technical design signifies the design or redesign of (information) systems achieved through stakeholder participation and incorporating interaction between people and (new) technologies (Herbst, 1974). Pasmore et al. (1982) note that socio-technical interventions should not assume technology as a constant where society would be expected to conform to technical demands. Instead, design and or redesign activities should determine the suitable configurations, options and interplay between the human and technical components that would allow for a steady, optimal state to be defined and achieved. Socio-technical studies in the mid-70s identify important requirements in this regard. For instance, Herbst (1974), using relevant concepts such as Wiener's (1980) cybernetics, Shannon and Weaver's (1963) communication theory and von Bertalanffy's (1950) open systems theory, explores the role of control mechanisms within an open environment and the function of control mechanisms in maintaining a "*steady state*". The open environment is also referred to by Herbst (1974:p21) as the "*variable environment*", necessitating a distinct approach to socio-technical systems design, where the role of learning within the organisation, the integration of a "*non-disciplinary*" approach, and the value of documenting a design sequence originating with the social system are documented (Herbst, 1974:p30). With respect to the social system, Herbst (1974) claims that when the social organisation needs have been mapped, it is possible to somewhat reverse engineer and work towards a conceptualisation of the required and supporting technological conditions. Other approaches to socio-technical design have been proposed, all of which guide a collaborative approach to problem solving and to achieving joint optimisation. That is, "*prolonged, patient and intense collaboration*" has long been regarded as key to socio-technical design (Trist et al., 2016:pxiii).

In operationalising socio-technical theory, various principles-based and other design models/approaches have been introduced. Regarding principles, Cherns (1976) presented nine socio-technical design principles, to serve as a design checklist. The nine principles are compatibility, minimal critical specification, the socio-technical criterion, organism versus mechanism, boundary location, information flow, support congruence, design and human values and incompletion. Collectively, the principles are not specifically aimed at the socio-technical designer, but rather at individuals within an organisation affected by a redesign, in addition to a specialist in the area. These principles were later revised (Cherns, 1987), to include compatibility, minimal critical specification, variance control, information flow, power and authority, the multifunctional principle, support congruence, transitional organisation, and incompletion of the Forth Bridge principle. While the original checklist (Cherns, 1976) included design and human values within the eighth principle, the revised list omits values as these are considered to support all the principles (Cherns, 1987) and as such cannot be represented as a distinct principle.

Socio-technical design, on the other hand, is defined by influential scholar Enid Mumford (2003:p262) as providing "*a new worldview of what constitutes quality of working life and humanism at work. It facilitates organisational innovation by recommending the removal of many elite groups and substituting flatter hierarchies, multiskilling and group decision-taking. It wants to replace tight controls, bureaucracy and stress with an organisation and technology that enhances human freedom, democracy and creativity.*" Mumford's prominent design approach ETHICS stands for Effective Technical and Human Implementation of Computer-based Systems, and is a model and philosophy that endorses user involvement and participation as key features throughout the socio-technical design process (Mumford, 1983; Mumford, 1993). A 15-step process was initially defined (Mumford, 1983). However, simplified versions of ETHICS are also available, such as the four-stage process later defined by Mumford (1993:pp 260-262), with the stages as follows: Mission and key task description - expressing what the department is trying to accomplish and the tasks required; Diagnosis of needs - defining effectiveness and job satisfaction (knowledge, psychological, efficiency and effectiveness, and job design) requirements, identifying challenges prohibiting the mission from being accomplished, and establishing future change needs; Information requirements - determining essential (highly desirable) and useful information and solidifying objectives for the new system; and Departmental and job redesign - employing socio-technical design principles to consider how redesign can take place in a manner that is sensitive to social and technological aspects.

An updated, six-stage version is also available in Mumford (2000:p132), with the stages as follows:

Diagnosis of needs - defining reasons and motivations for changing the current system, describing system boundaries, identifying core objectives/ purpose/ information needs/ tasks, gauging job satisfaction levels and efficiency, and determining the nature of future change; Setting of objectives - establishing unambiguous objectives pertaining to efficiency, job satisfaction and future change that are desired in the new system; Identifying solutions - recognising design alternatives, including socio-technical solutions, and partaking in discussion; Choice and deployment of solution - selecting and implementing a solution; Follow-up evaluation - evaluating the deployed solution; and Reporting - documenting theoretical and practical lessons.

Irrespective of variations amongst the various representations of ETHICS, the underlying premise is that "*ETHICS is intended to provide users who are not technologists with the means to control or influence systems analysis and design. The approach does this by involving them in the design processes and providing tools and techniques that assist an analysis of their needs and problems*" (Schuler, 1993:p259).

Other socio-technical design models and methodologies also exist. In the context of smart card innovation in Australia, for example, Lindley (1997:p168) proposes a socio-technical design process entailing phases such as systems exploration, systems analysis, initial design by joint optimisation, redesign and implementation, and evolution and redesign as an iterative process. Another model, suggested as a meta-design framework by Fischer and Herrmann (2011), focuses on meta-design at the meta, intermediate, and basic levels, allowing for the continuous adaptation and evolution of socio-technical systems within an environment, facilitated through participatory design processes. Davis et al. (2014) propose a hexagonal framework in which socio-technical systems are represented in view of six interrelated components; namely, goals, people, processes/procedures, culture, technology, and buildings/infrastructure that exist within an external environment. Furthermore, approaches that incorporate values into the design process have been proposed, such as value-sensitive design (Friedman, 1996; Himma & Tavani, 2008), privacy by design (Cavoukian, 2012), and democracy by design (Pitt, Dryzek & Ober, 2020), among others. More recently, numerous integrated co-design approaches have also emerged in the literature. For example, in the biomedical engineering field, a socio-technical, ethically aligned co-design methodology has been detailed, embedded within an existing engineering design process (Robertson et al., 2019). Additional design approaches that embody socio-technical notions are identified and reviewed by Baxter and Somerville (2011) and include soft systems methodology, human-centred design, contextual design, cognitive systems engineering and more.

Theory Updates/Extensions

Socio-technical theory has evolved from the traditional notions and principles defined above, primarily in response to altering organisational and technological environments and contexts, but with the basic philosophy remaining consistent (Davis et al., 2014). During the latter part of the 1980s and the early 1990s, socio-technical theory received considerably less attention due to the introduction of alternative approaches, namely, lean and business processes re-engineering (Baxter & Sommerville, 2011). Irrespective of its relative popularity, the transition in thought and application of socio-technical theory has reflected the introduction of technologies and corresponding industry applications within specific time periods. Davies et al. (2014:p4) succinctly document the shift in focus in socio-technical research, as follows: "*The emphasis has shifted from an early focus on heavy industry… to a gradual broadening of enquiry to advanced manufacturing technologies…through to office-based work and services (and to) the design of large scale IT projects.*" For further information, refer to Trist (1981) for an overview of the historical context, and developments at the work system, whole of organisation and macrosocial levels from the 1950s to the 1970s. Mumford (1983) also provides a detailed account of theory updates, and later an account of the evolution of socio-technical concepts including international work in the socio-technical space (Mumford, 2006), while Davis et al. (2014) have more recently offered an overview of the shift in focus in socio-technical thinking.

The evolution of socio-technical theory can also be reviewed in terms of the focus on socio-technical designs and interventions. For instance, over time socio-technical research has involved the integration of numerous perspectives, deviating from the original organisational focus. In the Information Systems and ICT fields, for example, Morris (2009) states that socio-technical systems literature can be grouped based on several dominant perspectives including, but not limited to, the social sciences, organisational sciences, engineering, and complex systems viewpoints. Each perspective determines the manner in which socio-technical research can be conducted. As such, Morris (2009) examines socio-technical systems scholarship based on these four perspectives, presenting the important considerations within each perspective. Additionally, Geels has focused on the dynamics of socio-technical systems in terms of transitions, transformations and reproduction in the context of sustainability using a multi-level perspective (MLP) (Geels, 2005; McKelvey, 2006;Geels, 2010;Verbong & Geels, 2010). Another emerging area is socio-technical design for public interest technology (PIT). This stream of socio-technical research offers a transdisciplinary perspective, operationalising socio-technical principles within an ecosystem setting and presenting a framework that documents technology design considerations (such as stages, context, environment, design activities), including the technology application environment, the explicit recognition of values through to situating various approaches that lead to the design of PIT (Abbas, Pitt & Michael, 2021).

Applications

Socio-technical theory has been applied in a range of disciplines, notably information systems (complex systems), organisational studies / business / management and engineering (Morris, 2009), among others, employing diverse qualitative and quantitative approaches and socio-technical design methodologies. Furthermore, socio-technical theory has been applied in multiple contexts and levels

(Griffith & Dougherty, 2001; Geels, 2005), ranging from micro to macro. That is, it could be applied to work systems within an organisation, to the entire organisation, through to "*macrosocial systems"* functioning at the societal level, such as sectors of industry (Trist, 1981:p11). The approach is not restricted to organisations but also accommodates other "*socio-technical phenomena"* (Trist, 1981:p11), although the focus of socio-technical theory has traditionally been at the work system, organisational or departmental level and on achieving economic, work-related and other outcomes. For early empirical applications, refer to Pasmore et al. (1982:p1181). While the application of the socio-technical approach to the design of work systems has been widely documented (Trist & Bamforth, 1951; Cherns, 1976; Cherns, 1987; Clegg, 2000; Alter, 2006; Alter, 2008; Alter, 2013; Eason & Waterson, 2013), studies also point to the need for extensions to the approach (Davis et al., 2014).

Recent studies and applications of the socio-technical approach have reviewed contemporary socio-technical frameworks to account for technological developments (Bednar & Welch, 2020), and to systematically explore socio-technical dimensions such as technology, task, actor and structure in order to identify research gaps in new application areas such as platforms and the platform economy (Kapoor et al., 2021). The transition of socio-technical theory from one discipline to the next has resulted in variable application of the original theory. For instance, in some disciplines it has been used to describe complex systems in general, while in other disciplines, socio-technical theory has been applied and operationalised in a range of empirical studies. Refer to the special issue by Griffith and Gougherty (2001) for an overview of the role, application and categories of research in engineering and technology management. A selection of texts is also provided below.

Table 3: Selection of texts

Area	Reference
Theoretical contribution/evolution	Appelbaum (1997) Geels (2004) Pasmore (1995) Sony & Naik (2020)
Design-related	Adman & Warren (2000) Becker (2007) Doorn (2013) Hirschheim & Klein (1994) Jones, Artikis & Pitt (2013) Patnayakuni & Ruppel (2010) Pitt & Diaconescu (2016) Whitworth & De moor (2003)
Application in practice	Bourazeri & Pitt (2014) Chai & Kim, 2012 (2012) Herrmann et al. (2004) Kling & Courtright (2003) Molina (1990) Ryan, Harrison & Schkade (2002) Sawyer, Allen & Lee (2003)

Limitations

From a theoretical and philosophical perspective, the socio-technical approach was promising in its deviation from technological determinism and its emphasis on joint optimisation of the social and technical subsystems. Ideally the socio-technical approach leads to mutually beneficial outcomes. However, according to critics, the theory initially failed to live up to its potential. For instance, Kelly (1978), in an analysis of applicability, maintains that there are inherent flaws within socio-technical theory, one of which is related to the joint optimisation notion. The author questions whether earlier and founding socio-technical studies did in fact achieve jointly optimised socio-technical systems, claiming that activities privileged the social system (Kelly, 1978:p1084). This resulted in the technical system being somewhat overlooked, as it had "*not been altered in any of these cases as part of a sociotechnical intervention"* (Kelly, 1978:p1086). Pasmore et al. (1982:p1181) reiterated these concerns in an article that reviewed early socio-technical studies from both theoretical and practical (experimental) perspectives. The authors analyse the evolution of the theory and over 130 related experiments, concluding that only a minimal number of experiments entailed the redesigning of technology. Rather, the focus in most of the studies was on "*rearranging the social system around an existing technology in order to approximate joint optimisation*" (Pasmore et al., 1982:p1185). It was explained that optimisation was not a product of finding a suitable match between the social and technical subsystems but rather with independently adapting the social subsystem to support technology (Pasmore et al., 1982:p1195). Technology was thus considered as a constant, and, as such, Pasmore et al. (1982:p1200) believed that greater interest in technological development was required within socio-technical studies. Related to this point, Coiera (2007:S99) cautions against an overly critical approach to technology, to avoid an "*anti-technology*" perspective, which in turn will result in limited application of core socio-technical principles.

With respect to socio-technical design, further weaknesses have been exposed using a critical information systems lens (see Stahl (2007) for an overview). Mumford (2003) has also reported on the implementation, power and participation-related limitations of socio-technical design and the ETHICS approach more specifically. While stakeholder participation and consultation are regarded as critical to socio-technical design success and the achievement of joint optimisation, participation can also have an undesirable effect in cases where consensus cannot be achieved (refer to Fok et al. (1987) for further information regarding this point), resulting in an inability to reconcile competing and divergent stakeholder interests and an intensification of the gap between stakeholders and their varying interests. Furthermore, limitations of Bostrom and Heinen's seminal work (1977a; 1977b) have been documented, with early studies maintaining that certain claims, such as the requirement to alter designers' perspectives of an organisation (this was regarded the primary reason for MIS failures), were unsubstantiated (Langefors, 1978). Early critiques also propose the Infological approach as an alternative socio-technical framing to address these issues of perspective, advocating instead for user empowerment through inclusion in design initiatives in addition to the need for new types of analysts or designers to support socio-technical design (Bostrom & Heinen, 1977a). More recently, there has also been a call for contemporary socio-technical analysis given the progress in technologies, namely from the perspective of ecological, financial, and socio-technical sustainability (Bednar & Welch, 2020). Other studies, such as that of Davis et al. (2014:p2), have also expressed the need for further extensions to the socio-technical approach, noting that scholars "*engaged in socio-technical thinking need to extend their conceptualisations of 'systems', apply the core ideas to new domains reaching beyond the traditional focus on new technologies, and, at the same time, become involved in predictive work*".

Concepts

Work System (Concept): A primary unit or department within an organisation that can be regarded and (re)designed as a socio-technical system consisting of interacting subsystems, within which subdimensions exist. (Trist & Bamforth, 1951)

Social Subsystem (Concept): The individuals or people that constitute an organisation and the relationships, values, structure, work-related elements, and associations that are delivered by organisational members. More generally, the social subsystem refers to the human factors or elements present in a socio-technical system. (Trist & Bamforth, 1951)

Technical Subsystem (Concept): The tools, techniques, skills, and devices that are required by workers to fulfil organisational objectives and tasks. More generally, the technical subsystem refers to the physical and material flows within a transformation process, in addition to the tasks, control and maintenance functions. (Trist & Bamforth, 1951)

Environmental Subsystem (Concept): The context, surroundings, and conditions within which the open socio-technical system operates and is situated, referring to both the internal and external environment. (Emery & Marek, 1962)

Open System (Concept): A system where there is flow ("import" and "export") and or interaction between components and the environment, resulting in the modification or evolution of the components. (von Bertalanffy, 1950)

Steady State (Concept): The ability of an open system to reach a time-dependent state of equilibrium, whereby the entire system and its components remain constant. (von Bertalanffy, 1950)

Equifinality (Concept): The range of possible initial conditions for ensuring a steady state within an open system, noting that when applied to socio-technical design, multiple design options may achieve a steady state. (Trist et al., 2016)

Joint optimisation (Concept): The degree of fit between the social and technical subsystems, resulting in an optimum state and benefits for the overall socio-technical system. (Emery, 2016)

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