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A CASE FOR SYSTEMS THINKING AND SYSTEM DYNAMICS

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1 Introduction

The title of this paper is too brief to be quite accurate. Perhaps with the following subtitle it does not promise too much: a review of systems thinking that considers its unique history and influences, paradigms and methodologies, and presenting a case for the system dynamics methodology as the best tool for the most diverse range of problem situations.

Systems thinking is a way of thinking that focuses on the relationships between the parts forming a purposeful whole. Its intellectual integrity draws from a number of fields and influences including philosophy, sociology, organisational theory, feedback thought, and a reaction against the method of science. Aspects of these influences have been examined.

Systems thinking can be practiced in more than one way. A collection of methodologies representative of both sides of the main hard/soft divide within the paradigm have been evaluated including soft systems methodology, systems engineering and analysis, operations research, organisational cybernetics, interactive planning, and organisational learning. Each has been considered in terms of its advantages and disadvantages and most appropriate applications.

Completing the list of system methodologies is a special case in the instance of this paper— system dynamics. System dynamics is concerned with building computer models of complex problem situations and then experimenting with and studying the behaviour of these models over time. Often such models will demonstrate how unappreciated causal relationships, dynamic complexity, and structural delays may lead to the counter-intuitive outcomes of less-informed efforts to improve the situation. System dynamic models make room for soft factors such as motivation and perceptions so that problem spaces can ultimately be better understood and managed.

A case is made as to why systems thinking in general and system dynamics in particular represent a choice of first resort for the broadest range of problem spaces. In brief, the argument is they boast the best tool set, they have the best intellectual credentials, and they are best suited to contemporary business and social situations.

2 Systems Thinking History and Influences

Humans have always been a part of systems but for the most part there was no realisation of the actuality of systems. Primitive societies accepted their role in a divinely given order of things without too much contemplation, and adjusted themselves as circumstances required. With industrialisation, political, economic and social systems became more noticeable but no more easy to grasp. "A search for orderly structure, for cause and effect relationships, and for a theory to explain system behaviour gave way at times to a belief in random, irrational events" [6, p. 1-1].

However, philosophers and sociologists have attempted some explorations.

In the early nineteenth century, the German Idealist philosopher Georg Hegel (1770 – 1831) conceived of an enormously broad, holistic fashion of thinking in which there was room for everything— logical, natural, human, and divine. Hegel believed that the truth about reality could not be grasped by studying phenomena in isolation; rather, a higher, more abstract philosophical vantage point was needed.

Although likely unappreciated and unintended at the time, Hegel's dialectic also contains a key systemic construct— a negative feedback loop. The tension between thesis and antithesis, between the desired and the actual, eventually forces a new state of affairs, the synthesis [20, p. 71].

Writing around the turn of the last century, the French sociologist Emile Durkheim (1858 – 1917) carefully and critically absorbed the ideas of the French sociologist Auguste Comte (1798 – 1857) and other contemporaries such as Herbert Spencer (1820 – 1903), particularly accepting the notion that the scientific viewpoint was the best from which to study social reality. However, Durkheim did not believe that scientific reductionism or "an analysis of the parts which existed in the social organism and the role they performed was adequate as an end of sociological analysis" [1, p. 44]. Instead, he felt that causal analysis (why) of social phenomena was required in additional to functional analysis (what). For example, the study of a social formation needs to take account of the social and historical forces that bring it into being and allow it to operate. Any such group, though not necessarily superior to its individual parts, is different from them and demands an explanation on the level peculiar to it. That is, the whole is more than just the sum of it parts [9, pp. 22 – 26].

If a common thread can be said to run through the work of this small collection of social theorists, it may be that each saw value in using biological and mechanical metaphors to understand social phenomenon. At a period in European history dominated by industrialisation, positivism, and evolutionism, it seems only logical that similar threads became woven into their writings. Even though the overly scientific and rigorous methods they advocated are at some odds with softer, current versions, the underlying systemic understanding shows itself as an idea of some age and magnetism.

In more modern times organisational theorists have also contributed to the field of systems thinking particularly through open systems theory: a way of thinking that recognises the dynamic interaction of the system with its environment in which inputs are transformed by some internal process and made into outputs.

Influential in early open systems theory was the US sociologist and Harvard professor, Talcott Parsons (1902 – 1979). He advocated a structural-functionalist approach to analysing social systems, an approach built upon the biological metaphor and that focuses on the concepts of holism, interrelationships between parts, structure, functions, and needs [1, p. 50].

Parson's writings have been criticised as being too conservative and avoiding or being unable to explain change and dysfunction in social systems [11]. More able to do this was a contemporary of Parsons, Robert Merton, who believed that the structural-functionalist approach was valuable because it required the viewer to examine the consequences of social action, that is, its latent functions, rather than relying solely on superficial manifest functions. Even so, less fully developed in Merton's theory was an explanation of why dysfunctions might continue. It may be that Merton had not stepped back far enough to see these dysfunctions as ongoing issues, particularly if he accepted Vilfredo Pareto's (1848 – 1923) equilibrium proposition:

His view of society was that of a system of interrelated parts which, though in a continual state of surface flux, were also in a state of underlying equilibrium, in that movements away from the equilibrium position were counterbalanced by changes tending to restore it. [1, p. 47]

That is, deviations from the norm are mended by the system. The feedback theory underlying Pareto's model of society is premised on the mechanical, rather than the biological, metaphor and herein may lay a reason why dysfunctions continue in spite of a Pareto system's innate search for equilibrium. The mechanical metaphor assumes that any deviation from the norm will feed back into the system and be invariably acted upon by certain rules. Yet, in any system composed of decidedly unmechanical humans this feedback may be indeed be handled in this way, or it may just as likely be misinterpreted or arbitrarily ignored.

To more formally define the feedback that Pareto talks of we might say that it is a process through which an action (an event or piece of information) passes through a series of causal relationships to eventually affect the original action.

Examples of virtually fully developed concepts of feedback thought can be found in the inventions and writings of the ancient Greeks while many of the most influential machines of the Industrial Revolution employed some form of automatic regulation [17].

It is interesting to note that after a long hiatus, there was a sudden explosion of feedback inventions in Europe at the time of the Industrial Revolution. Mayr [17] believes that technical and economic factors alone do not adequately explain this sudden burst of interest in automatic regulation. In fact, the same interest had a much wider cast as the writings of some of the philosophers and sociologists discussed already demonstrate. It would seem that at a point in time marked by great social, economic, and political uncertainty, largely brought about by fundamental technological changes, people at all levels were searching for meaningful stability and structure.

Given that feedback thought has a history of many centuries and was being used intuitively and elegantly, if unknowingly, in many fields, it is perhaps surprising that its self-awareness is only relatively recent. Richardson [20] believes that Rosenblueth, Wiener, and Bigelow's 'Behavior, Purpose, and Telelogy' (1943) was the first published work to link human systems with the engineer's concept of feedback. In this article, the authors make the distinction between non-purposeful behaviour, which is basically random, and purposeful behaviour, which is directed towards some goal. If signals from the goal modify the action in the course of the behaviour, then feedback is happening.

In *Cybernetics, or Control and Communication in the Animal and the Machine* (1948), Norbert Wiener expanded on the theme, in the process coining the word cybernetics, being a metaphorical application of the Greek kubernetes, meaning steermanship. Wiener and his colleagues had applied the concept during World War II looking for ways to develop and refine devices for the control of gunfire.

Traces of holistic thinking can therefore be found in many areas of study. Yet from an early stage each discipline had been using holistic thinking to cope with its own elements of complexity and had tended to use a language unique to its environment, meaning that the systems movement was late in gaining a degree of self-awareness. It was not until the late 1940s that the organismic biologist Ludwig von Bertalanffy appreciated that the parallel ideas in various disciplines could be generalized in a systems theory.

As a biologist von Bertalanffy was interested in the nature of life but noted that an organism's constituent physico-chemical processes did not explain all there was to know. Never a vitalist, von Bertalanffy suggested that a return to the organismic biology that preceded the invention of the microscope was a more fruitful avenue of thought. That is, organisms should be studied as irreducible, whole systems, contrary to a central tenet of the method of science that advocated reductionism.

From the 1950s, von Bertalanffy shifted his focus from the biological sciences to the methodology of science. He was concerned that scientific endeavour was following too faithfully one of its own rules:

Modern science is characterized by its ever-increasing specialization, necessitated by the enormous amount of data, the complexity of techniques and of theoretical structures within each field. Thus science is split into innumerable disciplines continually generating new subdisciplines. In consequence, the physicist, the biologist, the psychologist and the social scientist are, so to speak, encapsulated in their private universes, and it is difficult to get word from one cocoon to the other. [23, p. 30]

Despite this fragmentation, von Bertalanffy noticed that there existed a certain parallelism of general cognitive principles in fields such as chemistry, physics, biology, and sociology, made all the more striking by having developed independently in each [23, p. 31]. If this underlying isomorphism could be captured and made known then a tool would be at hand to reunify science and to move it forward more quickly. With the publication of two influential articles in 1950, 'The Theory of Open Systems in Physics and Biology' and 'An Outline of General Systems Theory', von Bertalanffy introduced the tool he had conceived for the task— general systems theory (GST).

However, the generality of an analytical framework such as GST is both a weakness and a strength:

- Weakness: by taking a holistic view, general systems theory takes away the comfort of mastering details and means understanding relationships instead of absolute facts. However, the relatively vague, initial totality is transitory. As a general understanding of the overall system is attained, the focus of study can then narrow to the analysis of details, but with a broader understanding in mind.
- Strengths: if we study the parts of a system alone, we will lack essential knowledge of the whole; and if we study the overall entity without comprehending its makeup, we will lack a fundamental awareness. General systems theory is a coherent way of resolving the parts-versus-whole dilemma.

Being aware that the word 'paradigm' can be easily misused, GST could be called a paradigm shift. According to Kuhn [15] paradigm shifts occur when the prevailing normal science is unable to answer those questions left in the too-hard basket. The reductionist method of science had certainly not dealt adequately with all the difficult problems it had been presented with, but then neither has systems theory. The reason lies in each, in their purest paradigmatic form, being suited to particular tasks. This theme of selecting the right tool for the job at hand recurs when we come to consider specific ways of practicing systems thinking.

3 The Systems Thinking Paradigm and Methodologies

The systems community is no more immune to paradigm or methodological racism than any other. In fact, Midgley [18] talks of paradigmatic wars and caustic sniping between the different schools of system thought, with the two dominant combatants being hard and soft systems thinking. The literature generally supports the distinction between the two on the basis of their most-suited problem contexts:

- Hard systems thinking is best applied to well-defined, goal-oriented, quantifiable, and real-world problems. Examples would include systems analysis and engineering and old-style operations research
- Soft systems thinking is best applied to ill-defined, fuzzy problem spaces, usually made this way because of the unpredictability of people, uncertainty, and other cultural considerations. Examples would include soft systems methodology and soft operations research.

Hard systems thinking predates its soft relation and retains traces of its origins in World War II logistical and scientific support of military operations. In peacetime the paradigm found purpose in government and industry.

But in less predictable times, hard systems thinking was found wanting when it was applied to problems a good deal softer than its 'home' disciplines of engineering and defense economics, mainly because precise objectives were not so easy to pin down [2, p. 141]. Something else was needed to analyse softer, ill-defined problems.

Enter soft systems thinking.

Before soft systems thinking had properly settled itself, however, its methodological and epistemological foundations were being challenged. Around 1990, two main areas of concern had arisen:

- "That the interpretive theory underpinning soft systems thinking is inadequate for understanding and acting in social situations where there are inequalities in power and economic relations" [4, p. 79].
- That soft systems thinking practised too rigorously paradigm incommensurability, refusing to accept that any of the tenets of hard systems thinking might have value.

Enter, this time, critical systems thinking, a research perspective embracing three fundamental commitments: critical awareness, emancipation, and methodological pluralism.

In essence, critical systems thinking argues that practitioners be just that— critical. It accepts that no single paradigm or methodology is best in all circumstances and that an informed judgment needs to be made based primarily on the nature of the problem space being addressed.

In this light, a literature review of a representative range of systems thinking methodologies has been conducted. The methodologies include soft systems methodology, operations research, organisational cybernetics, interactive planning, organisational learning, systems analysis, systems engineering, and system dynamics. Each was critiqued from a critical systems thinking viewpoint of selecting the most appropriate methodology for the issue at hand.

However, not all authors accept that, when faced with a particular problem, we are free to choose an appropriate methodology from within a certain paradigm: "paradigms cannot be like spectacles that we can change when necessary" [19, p. 452].

If we take the critical systems thinking view that methodological pluralism is an attainable concept, then a valid question to ask at this point is which is most appropriate in certain circumstances? Research since the early 1990s at the University of Hull in the United Kingdom has been directed at this question. Using the principles of critical systems thinking as a basis, total systems intervention (TSI) is a meta-methodology that:

uses a range of systems "metaphors" to encourage creative thinking about organisations and the difficult issues their managers have to confront. These metaphors are linked by a framework (a "system of systems methodologies") to various systems approaches, so that once agreement is reached about which metaphors are most relevant to an organisation's concerns and problems, an appropriate systems-based intervention methodology (or set of methodologies) can be employed. Choice of an appropriate systems methodology will guide problem management in a way that ensures that it addresses what are found to be the main concerns of the particular organisation involved [5, p. 322].

The system of system methodologies is typically that proposed by Jackson and Keys [14]. The authors define a matrix made up of the two essential dimensions of any problem space: the nature of the people who are the would-be problem solvers, described using the language of industrial relations; and the environment or context of the problem.

The value of Jackson and Keys matrix is that it "helps get inside methodologies and to assess the fundamental assumptions that they hold about the nature of social reality" [3, p. 129] so that the best tool for the job at hand can be used. For example, if the problem context is seen to be one in which there are differing opinions that might still allow consensus (pluralist), and none of the participants seem to have the whole picture (systemic), then a methodology based on systemic-pluralist assumptions is the most appropriate, for example soft systems methodology or interactive planning.

However, Jackson warns those using the system of systems methodologies to be critically aware of their particular choice since "the aim is... [also] to reveal the particular strengths and weaknesses of available systems approaches and to make explicit the consequences, because of the assumptions each makes about systems and the relationships between participants, of using any of these" [13, p. 664]. That is, the system of systems methodologies should not be used slavishly.

As meta concepts, critical systems thinking and total systems intervention have been criticised for following too closely the functionalist's predilection for classifying things like 'insects on pins in shirt boxes'. If we take this criticism to an absurd end then we might not classify or organise anything. Therefore, in reviewing the collection of systems methodologies here, a more productive line of thought has always been held: at a time characterised by increasing detail and dynamic complexity, paradigm blindness is wasteful. Instead, problem solvers and thinkers need to be practised in the art of scanning for ideas— greedy almost in looking for concepts, visions, tools or paradigms that make sense to them, at this time, and in their organisations.

4 Conclusions

Humans need help; help in coping with the information overload made possible by technology; help in dealing with the new dynamic complexities of the shift to knowledge economies; and help in compensating for those human attributes that often mean we do not act to our own best advantage.

The argument of this paper has been that systems thinking has the historical intellectual integrity and practical application to provide this help.

Systems thinking offers an opportunity to become more fully aware, to make informed decisions that extend beyond our otherwise bounded rationality, and to view problem spaces in their proper context. It does this by taking a worldview opposite to the atomised simplicity or specialised decomposition that Laszlo [16] criticises. Breaking a whole into its parts is analysis, through which we gain knowledge. Building parts into wholes is synthesis, through which we gain understanding. Through this understanding it becomes possible to achieve change that truly address the root causes of problems, rather than simply hoping that it might do so.

Systems thinking also fosters a collective understanding of a problem situation. Many of the tools of systems thinking, such as causal loop diagrams, rich pictures, or system archetypes, are visual rather than verbal descriptions. "A systems diagram is a powerful means of communication because it distils the essence of a problem into a format that can be easily remembered, yet is rich in implications and insights" [10, p. 6].

Yet, systems thinking is not as widely practised as these points might suggest it should be.

Systems thinking does not provide the linear quick fix needed in many political and organisational settings. In these situations, action, any action, is mistaken for achievement so that a problem deferred or shifted is a problem solved. Systems thinking forsakes the quick fix for hopefully the right fix.

Furthermore, the counter-intuitive and sometimes painful solutions offered by systems thinking can be hard to sell:

There are no utopias in social systems. There appear to be no sustainable modes of behavior that are free of pressures and stresses. But many modes of behavior are possible and some are more desirable than others. The more attractive behaviors in social systems seem possible only if we act on a good understanding of the dynamic behavior of systems and are willing to endure the self-discipline and short-term pressures that will accompany the route to a desirable future. [8, p. 23]

These are issues that are not insurmountable and more widespread systems thinking is possible, however, the remedy may still be incubating. Systems thinking is being incorporated into the curriculum of a small but significant number of primary and secondary schools in the United States, Australia, Europe and some other places. Not necessarily as a topic in itself, but as a tool for understanding and teaching other subjects [12]. A systems view that has been absorbed at this much more fundamental level has the opportunity to innately influence the thought processes of future decision makers and has a greater chance of finding a ready ear in a systems-aware community.

It is interesting to note that where the philosophy of systems thinking has been adopted in K-12 education, system dynamics has been chosen as the practical implementation. The reason for this partnering likely lies in the rich and democratic tool set provided by system dynamics.

The tool set is rich in that various vendors offer intuitive software applications built upon system dynamic credentials that can create models at different points along the qualitative—quantitative spectrum. The user determines the level of detail. More generic, shrink-wrapped microworlds can also help people appreciate the subtle tenets of causal relationships, and show how they might be mapped into different environments [21].

Meanwhile, the tools are democratic in that the knowledge required to drive them need not rest solely in the hands of guru-like modellers. In fact, actively involving stakeholders in the system dynamics process is a critical success factor. Moreover, the system dynamics modelling package STELLA is being widely used in American primary and secondary schools, and even the more advanced iThink product contains just four fundamental building blocks.

For all this, systems dynamics can be difficult to learn, with its history in engineering and computing possibly dissuading some people.

Of course, system dynamics is not the only way of practicing systems thinking. Yet, it is the case of this paper that when compared to a representative sample of other systems methodologies, system dynamics has a number of advantages.

Methodologies such as operation research, systems analysis and systems engineering can be called systematic rather than systemic because of the methodical way they decompose a problem and then comprehensively address each component. Therefore, they are ways of dealing with detail rather than dynamic complexity, with jigsaws rather than chess games. There is nothing intrinsically wrong in taking this approach if, for example, a meta-methodology such as TSI, points to it.

Each of the methodologies considered in this paper, except system dynamics, lack an important final step. While soft systems methodology, organisational learning, and interactive planning may produce a conceptual solution that is both desirable and feasible, in moving the solution 'into production' there still exists an unknown quantity because the solution has not really been tested. Forrester [7] has criticised this leap of faith in many methodologies.

Still, no model, not even the best system dynamics model, can perfectly predict the future. Nonetheless, simulation means our store of incomplete knowledge is at least reduced:

Simulation speeds and strengthens the learning feedbacks. Discrepancies between formal and mental models stimulate improvements in both, including changes in basic assumptions such as model boundary, time horizon, and dynamic hypotheses. [22, p. 37].

Maybe the essence of this paper is captured by John Sterman's appeal at the end of his new text book on systems thinking and system dynamics:

Be humble about what you know and listen to your critics. Strive always to make a difference. And have fun [22, p. 901].

Few other ways of thinking offer this provocation.

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