ISSN 0961-8309

Volume 46(2), Winter 2025

SYSTEMIST

The Publication of
The UK Systems Society

Published by UK Systems Society

Registered Office: Waterloo cottage, Silver Street, Chew Magna, Bristol BS40 8RE

Registered Charity, No: **1078782**

Submission of Material

Where possible all material should be submitted electronically following the policies and guidance on UKSS web site https://systemist.uk/for-authors and written using *Microsoft Word* using Times New Roman typeface and 12pt size, n.b. only main headings at 14 pt size, figures and tables in a format that is legible if reduced by 50%. All materials must conform with the Harvard (APA) referencing system. A title page must be provided and should include the title of the paper, author name(s) and affiliations, corresponding author, address and abstract of 100-250 words and a max of 5 key words
Material published in the journal does not necessarily reflect the views of the Society o the editors. Responsibility for the content remains with the author(s) as does the copyright for that material and the responsible for obtaining any necessary permissions including ethical requirements. Systemist is published under Creative Commons (CC-BY) Licence. Full details may be seen on the UKSS/journal website. The Editor reserves the right to select submitted material and to make amendments where necessary.

Contents pages

Editorial

This edition includes 4 papers. It is a mixture of conference papers that were and papers that were not presented. Two of the papers, one by Gary Evans and the other by Frank Stowell were not presented at the conference, but were listed in the programme, hence their inclusion here. In both cases there were good reasons why the papers were not presented. In one case it was because of an unexpected family event prevented the author from presenting the paper and the other was a case of simply running out of time. This was the first ‘in person’ conference we had held for some time which inspired a great deal of interaction, we simply ran out of time. It was outside of term and estates had to lock up! An indication of the success of having an ‘in person’ conference perhaps? The other papers were delivered at the conference but there are some outstanding papers but too late for this edition. The edition provides an opportunity for members to read at their leisure and make direct contact with the authors to follow up any matters raised.

I have already raised the matter of UKSS membership – by newsletter which was also placed on-line for members to read and digest. The key point to absorb is that we increased, for the first time in several years, the membership fee but this is coupled with the opportunity for members to attend the next conference scheduled for September 2026 at no cost to members. Depending upon the success of this policy that idea might be extended. However, as I am sure you realise manging the Society and its commitments have to be paid and without a reliable income to cover our commitments, we are duty bound to suspend activities. The fate of the Society and its associated responsibilities is in your hands

Volume 46 No.2, 2025

Frank Stowell
School of Computing,
Faculty of Technology,
University of Portsmouth, Lion Gate
Portsmouth PO13AE, UK
(frank.stowell@port.ac.uk)

Soft Systems Inquiry and the significance of thinking 'above and below' the line

Abstract:

This paper is written for those with knowledge of soft methods of inquiry and of the philosophy underpinning them. While Soft Systems Methodology is associated with the pioneering research undertaken at the university of Lancaster, paradoxically an unintended consequence of that programme is that the ideas underpinning this work have been neglected. This paper is concerned with the fundamentals of soft systems thinking, which I consider relevant to all soft inquiries. First, I reflect upon ideas that underpin a soft inquiry, second, I return to Checkland's notion of 'above and below the line' as the means of exploring the complexities of soft inquiry. I then expand upon this idea highlighting its importance for progressive 'soft' systems practitioners and researchers.

Key Words: Soft Systems, Above and Below the Line, Soft Systems Methodology, Appreciative Inquiry Method; Action Research; Phenomenology.

Glossary Where I have put *soft* in italics (or inverted commas) it is to highlight '*soft'* systems as its theoretical[1] concept. When I refer to SSM, Soft is in upper case because it is known by its mnemonic, SSM and in full as Soft Systems Methodology, a collective noun. System with a capital on its own is a noun (its complex meaning is discussed within the text). *System* then refers to something that is not fixed and immutable but an opinion; imagined. *Soft systems* inquiry is our attempt at trying to understand such complexity. Figures 1 and 2 are used as reference points throughout the paper.

Authors Framework of ideas

The intellectual position I have taken in this paper can be broadly described as phenomenological[2] because, I believe, it provides the theoretical basis of *soft* systems. I have limited my reference to philosophical ideas to those directly relevant to the point being made[3]. I differentiate between Soft Systems Methodology (the methodology) and '*soft*' systems inquiry (the inquiry) to emphasise that despite the importance of SSM there are other

[1] By this I mean as a metaphysical phenomenon – as we imagine something to be
[2] Husserl 1859-1938
[3] It is important to note phenomenology in this paper refers in terms of it as method, see Husserl, 2002, Pure Phenomenology, Its Method and Its Field of Investigation; also Kant, Critique of Pure Reason 2003; Gadamer Truth and Method 2004.

possibilities for 'inquiries' based upon *soft* systems ideas. The passionate reader will doubtless fill in any vacuum with their own research and opinion. These are mine.

The purpose of this paper

This paper is written for practitioners/theorists/researchers that are familiar with *soft* systems and s*oft* system inquiry and are interested in the ideas that support it. I refrain from reworking accounts of Soft Systems Methodology (SSM[4]) to focus upon aspects that a serious *soft* systems intellectual might find thought-provoking. My task is two-fold; first, to remind the reader of the theoretical implications of employing *soft* ideas to explore a situation of interest and second, through this surface the practical implications. I will begin by summarising what, for me, characterises a soft systems inquiry. To do this I will revisit the notion of 'above' and 'below' the line, (as indicated in Figure 1 below) and stress the importance of this idea, which is a feature often overlooked in the practice. For example, in Soft Systems Methodology (SSM) Mode 1, which is the most graphic representation of the methodology, Checkland draws a line separating the 'real world' from the 'systems thinking' world see figure 1 below). In SSM Mode1we see activities one and two and then five six and seven represent activities undertaken in the so-called real world. Activities 3 & 4 in the systems thinking world. In this section I will explore what the separation between the two areas of concentration are as this is a difficult intellectual and practical undertaking. I expand upon the notion of 'above and below the line' and consider the implications of time on this idea. For the purposes of this paper figure 1, below, will serve as a visual representation of above and below the line, and provide a reference point for the reader.

[4] In addition to the many journal publications of SSM a useful text of its application, see Checkland and Poulter 2006.

What is a *Soft* systems inquiry?

The first point to make is that *soft* systems thinking and practice differ, both philosophically and practically, from General Systems Theory and Cybernetics (see Bertalanffy,1973; Checkland, 1999). An inquiry grounded in *soft* systems ideas prioritises structured discussion about possible and desirable actions for change, rather than attempting to define in advance what that change must be. In this way, the inquirer is released from viewing the situation solely through the lens of a formal model and is instead guided by a flexible framework rooted in *soft* systems principles.

The utility of a *soft* systems inquiry lies not in producing a definitive description of the world, but in generating representations of how a situation is perceived by those who are concerned with it. *Soft* systems inquirers do not treat the area of concern as a collection of objective concrete entities. Rather, they recognise that a problem situation owes its 'existence' as much to the interpretations and imaginations of observers as to any independent external reality. Conceptualising something as a system gives it a communicable 'shape' that can be shared, explored, and debated with others. Crucially, this shape is not assumed to be a description of the real world itself; it is an interpretation—an intellectual construct that reflects the participants points of view.

‘*Soft*’ systems inquiry, ‘Opinion’ and Boundary

The value of a *soft* approach lies in its explicit acknowledgement of subjectivity and social interaction. By articulating and debating these systemic ‘shapes’, participants collaboratively build a shared picture of the situation—one that may be accepted, modified, or challenged. This intersubjective process guards against accusations of solipsism by situating individual interpretations within collective dialogue. In essence, s*oft* systems inquiry represents a conscious recognition of subjectivity and its role in shaping what is taken to be real.

This acknowledgement of subjectivity marked a significant departure from traditional systems thinking rooted in the natural sciences, with their emphasis on objectivity (see Checkland interview with Stowell, 2013). As Bertalanffy suggested, science itself is a conceptual construct that reproduces limited aspects of experience within formal structures (Bertalanffy, 1973 p.233). While systems thinking aspires to consider situations in their wholeness, it is neither possible nor desirable to account for the entire world and all its interpretations. Inevitably, decisions must be made about what the system of interest is (its shape), what is included and what lies outside it. This introduces the concept of boundary (see Checkland, 1999, p.174; q.v. Midgley 2000; Ulrich,1994, p.191).

Boundaries define the scope of concern and are selected by the inquirer in dialogue with participants. They reflect what is judged to be relevant, meaningful, and actionable. A *soft* systems inquirer must therefore accept that any account of the ‘real world’ is grounded in the subjective experiences of those involved. As Checkland observes, given the nature of human beings, ‘…*we are concerned not with problems as objective entities, but with perceptions of problems*…’ and inevitably, a plurality of such perceptions will exist (see Checkland 1999, p.238).

Our perceptions of the world are gained from our experience of our ‘surrounding world’, the Lifeworld[5], which is meaningful in a specific way for each of us and emphasises the importance of participation so that the differences can be highlighted. Contrary opinions can make finding out what is at the heart of the situation difficult so we must anticipate resistance from some. How a *soft* systems investigator addresses differences of opinion is challenging

[5] Husserl, *Cartesian Meditations 1991,* p.136 & *The Phenomenology Reader* pp’s. 151-174

and it is easy for them to find themself in a 'Catch 22'[6] absurdity and a return to the 'safety' of applying techniques that they have used in the past. Soft inquiry provides ways for the inquirer to look at the 'problem' situation as a whole. A '*soft*' inquirer should be aware of the differences of opinion in any situation and be careful to adopt an approach that recognises the importance of different opinions and how this might be embraced in a constructive way. Methods/methodologies such as SSM and the Appreciative Inquiry Method (AIM) offer a framework for participants to highlight and 'discuss' their differences by setting up a cycle of learning that can lead to actions for change (Stowell 2013b).

'Above and Below' the line and Spaciotemporality

The framework of ideas behind SSM and AIM transforms some of the intellectual concepts into practical applications. A soft inquiry promotes a cycle of learning and the exploration of ideas that participants raise during the inquiry. It is important that a *soft* inquiry facilitates discussion and debate, as Flood reminds us '…participation is central to soft systems thinking and action research' (e.g. see Flood, 2010. pp's. 270-284). It helps us avoid 'digging the same hole deeper'.

In SSM mode1 Checkland clearly suggests a distinction between actions of above and below the line (Fig 1 above, & see Checkland 1999, p.163). This distinction, I believe, is important to all soft inquiries. By above' the line Checkland means 'real world thinking' (RW) and below the line as 'systems thinking' world (ST or TW). What he does not discuss is the importance of what we might call spaciotemporality[7]. Our situation of interest has both a temporal and special relevance to the participants, accordingly, to enrich understanding I think it helpful to highlight the time horizon to be considered when discussing the manifestation of the problem.

For example, Stowell describes a case in a manufacturing company where a newly appointed export contracts manager joined a long-running project; the project had been developed into one of participation and of shared ownership over several months before he arrived. Known for a forthright management style in his previous company, he entered group meetings

[6] Joseph Heller's 1961 novel Catch-22, Vintage Books

[7] Relating to both time and space – e.g. see Patocka, 2016 pp's.160-161for discussion on time space and motion. And 2012 'Ideas', pp164-167

apparently assuming he could reorganize the project. Unaware of the established culture in his new organisation, he adopted an approach that was inappropriate and ultimately cost him his job (Stowell, 2014, p.16). By criticising the project, he inadvertently challenged the integrity of staff who had shaped and owned it over several years. Though experienced, he was new; he neither projected himself into their culture nor they into his. Lacking this mutual empathy, they saw him as belonging to an alien culture whose behaviours were unfamiliar and held no vicarious meaning for them. His power was grounded in a culture unrecognized and undervalued in his new environment. The episode illustrates how the late addition of someone, out of harmony with the accumulated thinking developed over time, can lead to unfortunate consequences.

Our imaginary 'line' then is not just a separation between observing and thinking it also represents our view and experience of the past and our anticipation of the future. In the 'real world' such a division is sometimes muddled.

'Temporality'[8] , the imaginary line and the value of PEArL

I am suggesting that we consider the relevance of our timeframe as we consider the system'[9] of interest. Are we thinking of the present time or the situation as it once was or how we would like it to be. In that respect I am meaning time in the everyday sense, of days, weeks, years, decades and so on. I am suggesting that we accept that our knowledge of the 'real' world arises from our experience of it, it follows then that a relationship exists between the moment we first encounter something and the experience we accumulate of, or about it. When we describe someone as having expertise, we implicitly attribute an element of time. Consider a motorist: we call a driver experienced because they have driven over a period of time, while someone new to driving we consider to be inexperienced; it is in relation to a particular 'thing', over time. Our imaginary line is, therefore, not simply a boundary between observing and thinking, it also represents our view of the past and our anticipation of the future. In practice this division is often blurred. For instance, in the simultaneity of social evolution and how we view the world now compared to how we once saw it, reminds us that personal reflection always draws upon experience yet our attempt to understand something occurs within a particular timeframe.

[8] See Gadamer, 2004, pp's.119-125

[9] Systems perspective – model of the whole entity.

I do not intend to enter into a philosophical discussion of time or memory; that is work for experts in those fields. My concern is how our lived experience informs our thinking about a situation. As experiences merge, the past progresses into the present and shapes our ‘now’. I refer to time here in Bergson’s (1971) sense of duration, rather than Heidegger’s framing and the fundamental nature of Being. Bergson’s notion of duration captures how past experience flows into present consciousness. In this practical sense, our line should be taken not merely as a separator of ‘real’ and ‘thinking’ worlds, but as marking a temporal dimension as well. Churchman reminds us that ‘*…according to Kant, an inquiring system capable of observing the world must have a built -in space time framework*’ (Churchman, 1971, p.106). Similarly, Vickers speaks of the flux of events and ideas, acknowledging that things change over time, as does our perspective. (1983, pp’s.13-14 & p55).

What we hear and see holds different meanings at the moment of experience. How we grasp what is said or observed depends on our life experience; each object of our attention may carry many meanings, and the act of perception may itself generate meaning. Our opinions change with time. For this reason, it is sensible to reflect upon the temporal horizon within which we choose to treat a ‘problem’. Fossil fuels, for example, are viewed differently now than in the nineteenth and twentieth centuries. The horizon is a choice, consciously or unconsciously, made by the inquirers. We must ask whether the ‘problem’ exists independently (a priori) or emerges only through later interpretation (a posteriori). Is it an independent entity, or one defined within a timeframe determined by its contemporaneity or by those who frame it? At the start of any inquiry, I suggest that participants agree on the timeframe over which they consider the problem to have arisen.
In real-world studies, the mnemonic PEArL (see Table 1 below), now part of the Appreciative Inquiry Method[10](see fig 2 below), has proved useful not only for understanding the character of a participant group but also for highlighting the period over which a problem has emerged.

P Participants	Who is Involved in the activity, Why are they involved? What is their role in the activity? Who is excluded and why? Are there any transitory participants, if so, why?

[10] PEArL Champion and Stowell 2007; AIM and PEArL, see Hart, 2015, p.73; Stowell 2015; Stowell and Welch 2012 p.56 & p.180, 2012.

E- Engagement;	How are the participants involved? Can you identify the boundary between ‘P’ and non ‘P’? What methods are used to engage participants? What are the environmental influences in which an activity takes place? E.g. passage of time
A- Authority; Formal authority associated with activity.	What are the environmental influences? What embedded authority do the tools for engagement have? Why were they chosen? and what influences the outcomes?
r- relationships;	What kind of informal power or commodities (Stowell 2014, Stowell and Welch 2012, pp.116–118) do people use to influence others (Examples include the use of gender, sociability, and verbal skills)

Table 1, PEArL

The value of PEArL[11] early in an inquiry is that it allows facilitators—and, where appropriate, participants—to surface underlying mindsets and reflect upon the ‘experience[12]’ of participants. At the start of a soft inquiry, in this case using AIM, we can begin by using ‘PEA’ from PEArL; P: Participants and ask: who is involved, and why? What are their roles? Who has been excluded, and for what reasons? Are there transitory participants, and if so, why are they involved at this time? We then turn to E: Engagement and ask: how will participants engage? Is the boundary between ‘P’ and ‘non-P’ clear? What environmental influences shape the engagement? What is the passage of time over which the ‘problem’ arose? Then A, what is the formal authority associated with the activity. For instance, should our participant group include only those with direct experience of the issue, or also those without practical experience but possessing other insights, (experience and expertise.) For example, in a study of changing weather patterns, should we rely solely on scientists, or should we also consider historical accounts, farmers observations, Mariners logs, and other sources that may enrich what scientists tell us? Who decides upon the makeup of the

[11] For a discussion of PEArL including why ‘r’ is lower case see, Stowell 2012**.**

[12] Experience in terms of experience of the situation or of the nature of the situation

participants and why? This exercise can help establish the context of the inquiry. Helping us as we move on to the notion of 'above and below' the line.

Thinking 'above and below' the line

Soft systems inquiry has been described as 'theory in practice'. We are imagining the so-called 'Real World' (RW) in terms of it being above an imaginary line separating it from the 'Thinking World' (TW) which we imagine as being below the line. The 'Thinking World', is an intangible world that is immanent and restricted entirely to the mind or a given domain; it is internal and subjective, '*The objective validity that is to be attached to any value cannot be separated from our temporal engagement with life. Values are not simply given or imposed from on high but are produced as part of the human process of explicating the meaning of history*' (Dilthey, 2002, p.249). However, asking a practitioner to engage in an intellectual exercise of separating the 'Real World' from the 'Thinking World' is likely to be met with skepticism. A practical way of doing this is to ask the participants to put to one side any thoughts they have about 'something' and look at it with a fresh pair of eyes. Husserl refers to this as Epoché (Husserl, 1991, p.57) but in practice it requires some form of intellectual gymnastics to be able to separate thinking about things as perceived and thinking about how they appear[13]. For some practitioners the purpose of this part of the inquiry is sometimes 'by-passed', although understandable, it is a mistake.

We are not asking participants to reflect upon the philosophical relationship between the RW and TW we are asking them to be aware that the meaning we attach to something or to an event is created from the culture or social setting and the timeframe in which it exists. The language we use to explain it is abstract. While we are thinking about the RW from a practical interpretation we are also asking participants to consciously separate this from the so-called TW.

Images and their Representation

When thinking 'above the line' we are asking inquirers to consider 'what is the essence' of the 'system' of interest. (I do not intend to labour this complex philosophical point, but for

[13] Patočka, (2016, p.123) highlights the intellectual problem of separating thinking about things as perceived thinking how they appear.

those interested see Kant, Schopenhauer and latterly Stang, 2024[14] for example). I am asking the inquirers to see (and agree) what is this '**System'** that concerns them, how shall we describe it, what would happen if it ceased to exist? This is more exacting than reflecting upon the 'Ws'[15] that might be behind an opinion (often so poorly applied). We are asking the participants to express what this **system** is[16] that concerns them. AIM helps to initiate this conversation through the development and discussions around individual systems maps leading to an agreed Composite Map, it generates a cycle of learning. Stowell (2012) suggests some practitioners might view the 'Real world' objectively, which they substantiate with facts that can be investigated through the use of a model or measured by observation. For example, an accountants view of the 'real world' of an organisation might be explained through the use of spreadsheets and data but, as Capra (2003) reminds us, while organisations are designed for specific purposes such as making money, they are also communities of people who build relationships and interact (ibid, pp's.85-88).

I am not convinced looking at the world through an actuarial lens[17], is in the spirit of a soft systems inquiry. Such an approach begins from the assumption that the world is described through *'… systemically ordered thinking concerned with …. well-structured problems in which desirable ends can be stated'* (Checkland 1983, p.667). I concede a 'hard' approach used, in conjunction with a suitable *soft* systems method, could help gain greater understanding.

Representing the thoughts/opinions of participants is the starting point of any soft inquiry, yet how can individuals unfettered views be expressed? In SSM mode 1 (Fig 1 above) it was the Rich Picture (RP) that participants were encouraged to use as a means of surfacing and discussing the situation of concern. In AIM discussion and debate is embedded around individual 'Is' and 'Ought 'Systems maps (Fig 2 below). Both approaches provide a means of participants to engage in the process. SSM and AIM are designed to encourage discussions about the situation of concern. In SSM it is concerns in the 'real world' and in AIM it is

---

[14] Positive noumena – see https://philosophy.stackexchange.com/questions, also see Stang, (2024), Kant's Transcendental Idealism.
[15] WELTANSCHAUUNGEN WORLD VIEW, OUTLOOK ON LIFE, PHILOSOPHY. SEE DILTHEY 1980.
[16] Note the change from System to *system* to emphasise something the participants think exists into the recognition that is an opinion or 'imagined' to exist see Checkland 1999, p.238.
[17] Churchman refers to an engineering philosophy (ibid, 1968, p180). For the dedicated see Churchman 1968 Chapters 11, 12, 13 &14.

encapsulated by expressing 'what IS the case' of the situation of concern. In some respects, AIM emphasises the importance of discussion between participants as it is designed to generate a debate around each diagram (systems map); the inquiry cannot usefully progress without this stage.

Fig.2. (with acknowledgement of Stowell and Cooray presentation O/R conference 2021)

Articulating the situation of interest in a *soft* inquiry

In AIM (fig 2 above) we invite participants to reflect upon the situation of concern through the use of Venn diagrams that are then discussed (debated) between the participants[18] (Appreciate, Articulate and Clarify). This is in contrast with the traditional modes of inquiry where it is not uncommon to use some form of structured or unstructured interview, or questionnaires. In both cases what transpires is written down, usually, by the inquirer and for questionnaires these are usually analysed by the setter. There are obvious weaknesses here in that the 'interpretation' of the inquirer or note-taker may seep into the account. On the other hand, in a soft inquiry, we are attempting, with participants, to gain understanding of the

[18] It should be clear by this time about the importance of reflecting upon the make-up of the participant group – see PEArL above.

'essence' of the 'system' we are investigating. What we are asking is, what is this '*System*'[19] and what has it been created to do? We attempt to do this by the engagement with the stakeholders (see Fig 2 and PEArL Table 1 above). We should be aware that the language in which this is expressed has embedded within it a meaning (intentionally or in fulfillment). The 'listener' then selects from these utterances, something which has meaning for them. For this reason, language, verbal or written, is unlikely to be value free. How then can a situation of interest be safeguarded from the persuasive views of those that are engaged in an inquiry? As Kant says most of our judgements are synthetic and a posteriori (Seung, 2009, p.9). Our recollection of a situation is subjective not an apodictic description. For this reason, we need to think of what this 'thing' is we are trying to describe. Husserl reminds us, *'… We can absolutely not rest content with mere words*, i.e. with a merely symbolic understanding of words such as we first have when we reflect on the sense of the laws for 'concepts', judgments truths…*we must go back to things in themselves*[20]' (2008, p.168). Husserl is reminding us that we are subject to the influences of 'opinion' and to disengage we should look for the 'essence' of the thing we are observing. But if we take Husserl's meaning on first sight it appears to be an unattainable task. Kohl, engages with this thought, when he says **'…***When we represent the existence of things in themselves we go beyond mere possibility because we posit a nonspatiotemporal constitution of objects whose existence we already know (synthetically) through sensible intuitions, and because we know (analytically) that what appears in spatiotemporal form must have some constitution that is not appearance'*(Kohl 2015). In other words, we cannot completely shed the influence of our experiences. I resist, once more, engaging in a philosophical discussion about the influence of past experiences upon the way we view the present, but we should recognize that our experiences have an effect on the way that we view a situation and we should attempt to shed its influence, else it will be difficult to avoid retreading the same path that created the problem, (e.g. Stang, 2024) let's call it associative functioning (Husserl, 2008, p.187). Our challenge is how can we reduce this effect as we carry out our inquiry.

[19] '*System*'as agreed by participants, it is based upon <u>their</u> shared experience. See above the difference between System and *system* and discussion below

[20] Things in themselves. We cannot know about something without first experiencing it therefore we cannot know things in themselves, ony phenomena. Stang 2024; and Khol, 2015 provide a valuable discussion on the 'problem' of separating what we already know from a purely conceptual representation of existence.

In SSM mode 1 we are encouraged to use a Rich Picture (RP). Checkland describes the process as building up the richest picture as possible of the situation in which there is perceived to be a ‘problem’. This ‘picture’ should, as far is possible, be created without imposing a structure upon it, this includes restricting (or eliminating) the use of legends (see Checkland 1999, pp’s165-166; Stowell and Welch, 2012 pp’s.14-15). This stage of SSM mode 1, emerged as a cartoon-like picture in which a third party would see it as a value free representation of the situation. Some inquirers found this stage difficult and others impossible. There are examples where the RP takes the form of a story board, resembling those associated with motion picture composition, often these pictures include words to assist the viewer in their appreciation of the ‘problem’ situation. Such representations fly in the face of Checkland’s original intention. In Systems Thinking Systems Practice (ibid, 1999) he says that if the inquirer has digested the ideas behind the methodology this is no longer a necessary stage. But, I suggest, this is the nub of the difficulty. In my experience, it is digesting the ideas that lie behind SSM that provides the greatest struggle for many (Stowell 2025 provides an interesting discussion about this difficulty). The point of a RP is a means of eliminating the meanings embedded in language[21].

A RP is to encourage the participants to create an expression of the problem situation. With the assistance of those involved the idea was to produce a visible ‘picture’ of the situation of interest. The difficulty is that there are few examples where captions or ‘guidance’ are absent from the picture. This is not to say that the symbols used are in themselves without inbuilt meaning, but adding words and arrows compounds the problem. In SSM mode 2 this feature is less emphasised because of the reliance that the practitioner has internalized the basic principles underpinning soft systems. Perhaps as the ‘purity’ of the idea behind a RP has faded this stage should be seen more as an agenda for discussion, emphasizing the Lockean idea of the ‘association of mind’, than an unassailable pictorial representation of it.
AIM encourages participants to produce systems maps of what they think ‘IS ’the case, which is then debated by the group as a whole. This is a way of exchanging ideas about the situation as it is perceived to be, before moving on to produce and share Maps of what the participants think Ought to be the situation. The expectation is that by exchanging opinions of

[21] See Husserl, 2008, p.168. It would be remiss not also to refence Derrida’s critical scrutiny of Husserl’s use of ‘signs’. Important as they are these ideas this is not the place to do justice to them and I limit the discussion to the way that two soft approaches address situations of interest, within the umbrella of soft systems.

'What IS the Case' will generate discussion and create, in the context of philosophical hermeneutics (and a nod to Locke?), is what Gadamer referred to as a fusion of horizons (Gadamer, 2004 p.304). He says '…When a translator interprets a conversation, he can make mutual understanding possible only if he participates in the subject under discussion…' (ibid, p.389)[22]. In so doing the participants embark upon a voyage of discovery of the other participants imagination of the situation of interest. The discussions between the participants creates for each of them a cerebral picture as they, in turn, present their Systems Map to other participants.

The central point that emerges from this discussion is the importance of engaging with participants and through that engagement create a cycle of learning. In SSM mode 1 the inappropriate use of a Rich Picture or if it is absent in SSM mode 2 can easily deny the participants this important aspect of *soft* systems inquiry. In AIM the expectation is that the participants observations, as depicted in their Systems Map, will be enriched through discussion and free exchange of views with the other participants. As an aside, we should be aware of the influences of individuals or groups in this process[23] as it is not unknown for a participant or group to try to persuade others to their point of view rather than enter into the spirit of an exchange of ideas. It is the task of the facilitator to be aware of the possibility that such power may be being exercised. A valuable part of the AIM process, as indicated above, is the mnemonic PEArL, that can help the facilitator and, where appropriate, the participants with their awareness of this possibility (e.g. Hart, 2014 pp's.178-179; Cooray 2010, p.214; Cooray, and Stowell, 2017, pp.'s 99-100).

Communicating the problem as 'above the line'. Summary of Discussion so far

In depicting, what for the participants, is the situation of concern we find that in SSM Mode 1, relevant systems are first identified and then defined in relation to an agreed set of problems. Within AIM, these problems are instead represented by the outer subsystems

[22] Gadamer (2004) explains the concept of horizon in this way; '…*To acquire a horizon means one learns to look beyond what is close at hand- not in order to look away from it but to see it better, within a larger whole and in truer proportion*' p.304.

[23] The impact of the use of 'power' should be recognised e.g. see Checkland and Poulter 2006, p.91; Checkland, 2000, pp's. 25-26, Stowell 2020). Also see Hart 2014 below

collectively agreed by participants and depicted in the composite map in terms of 'what IS the case'. Addressing these issues while maintaining coherence with the underlying conceptual framework can be challenging.

AIM makes a clear distinction between problem identification and problem exploration by asking participants to think in terms of what **is** the case then what **ought** to be the case. The issue that motivates the inquiry is continuously debated and refined as participants develop and cluster their ideas around a central question. Plenary discussions of individual maps serve not only to surface differing perspectives but also to test the ongoing relevance of the original problem statement. As a result, it is common for the group to revise—or even replace—the initial question as new insights emerge.

Applying SSM Mode 1 (and to a degree Mode 2) some practitioners process the 'problem themes through a structured, sequential approach, this is a mistake. SSM is not a recipe but an iterative process of gaining understanding. This is easily lost by those new to soft inquiry and have not internalised the thinking behind soft systems ideas. The cycle of learning is also prominent in AIM as it treats the issue formulation as fluid and cyclical. The central question is revisited whenever the developing understanding of the situation requires it, sometimes leading to the reformulation of the initial question or issue.
Moving on to thinking below the line.

Systems Thinking 'below' the line and outcome

We now use our imaginary 'line 'as the means of drawing attention to the separation between what we have decided to be problem's and how we might tackle them. But what do we mean by using **Systems** Thinking below the line? Paraphrasing Checkland, he asks at the end of the expression stage (above the line) what are the names of notional systems that seem relevant to the problem (ibid, 1999, p166). He reminds us that the choice of notional systems will represent a particular outlook of the problem situation. A similar point was made earlier by Churchman who said that '…*whether or not something is a system is regarded as a specific choice of the designer*.' (Churchman, 1971, p.42). It is a subjective choice and will relate to the outlook of the inquirer, it is the explicit choice of the designer. But how do we close the circle between recognizing the importance of subjective experience and taking it into account in a practical sense?

In SSM Weltanschauung (W) is offered to practitioners as a means of putting the choices into an intellectual framework, but this is often done in an uninformed approach without the care that Dilthey's ideas merit (for a useful discussion of 'W 'see Makkreel, 2016). From a practitioner's point of view, I feel that Gadamer's interpretation has much to offer, he suggests that understanding can be achieved only by reference to the Weltanschauung in which that understanding is taking place (see Gadamer, 2004, p.293). He underlines the point that our understanding is based within the context in which the phenomenon is experienced, its space and time. Unlike Dilthey and Heidegger he says that there can be no final interpretation of reality because new life-worlds or world pictures will cause future interpreters to see and experience the world differently (see McIvor, 2018).

The main point I take from Checkland's thinking about the 'line' is to ask the participants to separate their past experience of similar situations and focus on the problems yielded by our exploration of above the line (this is why I use System and *system*). In SSM Mode 1, we consider problem themes and in Mode 2, we consider the situation uncovered by our intervention through, Analysis One, Two and Three (Checkland 2000, pp's. S25-26; Checkland and Poulter 2006, pp's.27-38). In AIM this is undertaken through the discussions between participants, first above the line relating to 'What **is** the case' and then, below the line, 'What **Ought** to be the case', thus creating a cycle of learning. As the process of inquiry develops, in the case of both SSM and AIM, as indicated earlier the inquirer should be aware of the influences that some participants have on the outcome, some can be very persuasive. I have found the application of PEArL during the study offers useful insights into the dynamics of the participant group. For example, Hart reports that during the field research, *'.…from the first, participant D was at pains to establish his credentials and his knowledge about the issue. …The impression given was that he wanted to remain in control and manage this potential challenge to his position by asserting informal authority, exercising this as a commodity of power in his relationship with the researcher. Noting this propensity at an early stage was useful in that the researcher was then more alert to the potential relationship and authority issues in the group of participants…'* (Hart, 2014, p.123).

As we continue our thinking below the line, we now think of what had emerged as 'problems' as the participants contemplate 'systems' that they deem relevant to these themes. In AIM this is represented by the agreed maps of 'what **Ought** to be the case'. This is achieved by asking the participants to suspend their thinking about previous experiences of similar situations and focus their thinking about the 'problem themes' and what notional systems are considered relevant to them.

The outcome of this discussion (in AIM) is to take the 'Oughts' above the line and consider them, and their impact, within the context of the 'real world'. This stage is similar to the process in SSM Mode 1 and Mode 2 with the outcome being to consider actions for change and, as agreed in stage 1 of AIM, what '**is**' and then what **'ought'** to be the case.

Summary and conclusions

Critics of *soft* approaches frequently argue that these methods take longer than traditional problem-solving techniques. This is true, but the difference is explained by the fact that, in traditional methods, the problem is taken as given, whereas in both SSM and AIM the problem itself is subject to inquiry. SSM Mode 1 separates a problem surfacing followed by conceptual modelling, while AIM integrates these activities continuously. In both approaches, however, the effort invested in negotiating and representing the issue—whether as a RP in SSM or through iterative mapping in AIM—provides a robust basis for collaboration. By establishing clarity and shared understanding early, the inquiry avoids downstream confusion and misalignment, ultimately reducing the risk of failure and enhancing the coherence of the overall project. When embarking upon an inquiry time spent in discussing and reaching an accommodation about the situation of concern and agreeing the key issues is fundamental to *soft* inquiry. It should be remembered that we are seeking to understand the situation in its fundamental state, what is it? We should also be aware of the influence of the method of inquiry adopted, Churchman asks '…*what an inquiring system would be like which did not function according to the basic principles of its own design*[24]*...*' (Churchman,1971, p.249). In other words, beware that the method employed does not in itself, predicate an outcome. Applied in the manner intended, *soft* systems

[24] It should be noted that Churchman is considering the influence that each of the philosophers might have upon inquiry. In this case he is considering how Hegels ideas might shape inquiring systems. However, the point he makes is a valuable one for all approaches to inquiry.

methods/methodologies of inquiry should avoid this ‘trap’. *Soft* systems practitioners should encourage non-judgmental participation by highlighting the intersubjectivity ‘trap’ (‘*fore-conception’* and ‘*readinesses*’).

Finally, as a summary of the cycle of learning of a *soft* inquiry I include Checkland’s diagram of SSM, that I think can serve as guidance to other *soft* methods of inquiry. The similarities between SSM and AIM are deliberate as AIM acknowledges its roots and philosophical direction to the evolution of SSM. AIM is an interpretation of the ‘process’ of a *soft* systems inquiry. For example, the selection of models in AIM is the outcome of the discussions about the Systems Maps between participants. For SSM the purposeful activity systems are based upon a declared world view. Both arise from the results of the above and below the line activities.

Figure 3 Checkland’s Cycle of learning

References

Bertalanffy, L. von. (1973) General Systems Theory, Penguin Press, Bungay, Suffolk, Great Britain.
Bergson, H., (1971), Time and Free Will, George Allen & Unwin, New York
Capra, F., (2003) The Hidden Connections, Flamingo, Harper Collins, London.
Champion, D. (2007) Managing Action Research: The PEArL Framework, Systemic Practice Action Research 20:455–465DOI 10.1007/s11213-007-9070-8
Checkland P.B., and Poulter, J., (2006) Learning for Action, Wiley, Chichester
Checkland P.B., (2000), Soft Systems Methodology: A Thirty-Year Retrospective, Systems Research and Behavioural Science, 17, S11-S58 2000, John Wiley and Sons

Checkland, P.B. (1999) Systems Thinking, Systems Practice, a Thirty-Year Retrospective, Chichester: Wiley.
Checkland, P.B. (1983), *Systems Thinking, Systems Practice, a Thirty-Year Retrospective*, Chichester: Wiley.
Churchman, C. West (1971) *The Design of Inquiring Systems*, Basic Concepts of Systems and Organizations, New York: Basic Books
Churchman, C.West, (1968), *Systems Approach*, Dell Publishing Co Ltd, New York USA
Cooray, S. (2010), End User Driven Development of Information Systems: Revisiting Vickers Notion of Appreciation. *PhD Thesis*, Portsmouth: University of Portsmouth.
Cooray, S. and Stowell, F.A. (2017), Virtual Action Research for Virtual Organisations? *Systemic Practice and Action Research*
Dilthey. W. (2002) *The Formation of the Historical World in the Human Sciences: Selected Works, Volume III:* The Formation of the Historical World in the Human Sciences, Princeton University Press, Oxfordshire UK
Dilthey. W. (1980), A Hermeneutic Approach to the Study of History and Culture Martinus Nijhoff Philosophy Library *Dilthey's Philosophy of World*-Views.
Flood, R.L., (2010) The Relationship of 'Systems Thinking' to Action Research, *Systemic Practice and Action Research*, Springer, pp's.269-284, Pub. On-line 23 March 2010
Gadamer, H.G. (2004) *Truth and Method* (2nd ed.), New York: Continuum
Hart, P., (2014), Investigating Issues Influencing Knowledge Sharing in a Research Organisation using AIM, *Unpublished Thesis*, University of Portsmouth
Hart, P., (2015), Recognising Influences on Attitudes to Knowledge Sharing in a Research Establishment: An Interpretive Investigation, *International Journal of Systems and Society*, July-Dec 2015, Vol2, No.2, pp's. 68-87
Heller, J. (1961) Catch-22, Vintage Books.
Husserl, 2002, Edmund Husserl: Founder of Phenomenology, '*in*', *The Phenomenology Reader*, Ed D. Moran and T. Mooney, pp's, 57-151, Routledge, London.
Husserl, E., (2012), *Ideas*, Routledge Classics, Oxford, United Kingdom
Husserl, E., (2008), *Logical Investigations, Vol 1.*, International Library of Philosophy, Routledge, London and New York.
Husserl. E., (1991), *Cartesian Meditations*, Kluwer Academic Publishers, the Netherlands
Husserl E (1964), *The Phenomenology of Internal Time-Consciousness*, Indianna University Press
Kant. I., (2003), *Critique of Pure Reason*, Dover Philosophical classics NY,
Kohl, M., (2015) Kant on the Inapplicability of the Categories to Things in Themselves, *British Journal for the History of Philosophy*, 23:1, 90-114, DOI: 10.1080/09608788.2014.978838
Makkreel. R., (2016) Wilhelm Dilthey, *Stamford Encyclopedia of Philosophy*, Thgen Metaphysics research Lab
Midgley, G. (2000), *Systemic Intervention*, Kluwer Academic/ Plenum Publishers, New York
Patočka, J., (2016), *The Natural World as a Philosophical Problem*, Ed I. Chvatik and L. Ucnik, trans E. Abrams, Northwestern University Press, Evaston, Illinois.
McIvor, D.W., (2018), Weltanschauung, *International Encyclopedia of the Social Sciences*.Encyclopedia.com. 8 Sep. 2018, <http://www.encyclopedia.com>.
Seung. T.K. (2009), *Kant. A Guide for the Perplexed*, Continuum, London
Stang, N. F., (2024), Kant's Transcendental Idealism, *The Stanford Encyclopedia of Philosophy* (Spring 2024 Edition), Edward N. Zalta & Uri Nodelman (eds.), URL = <https://plato.stanford.edu/archives/spr2024/entries/kant-transcendental-idealism/>.
Stowell, F.A. (2020) Power in Organisations, A Soft Systems Perspective, *Systemic Practice and Action Research*, Springer.
Stowell, F.A. (2015), What is Organisational Inquiry in the 21st Century? *International Journal of Markets and Business Systems, Vol. No1*, Inderscience Enterprise Ltd.
Stowell, F.A. (2014), Organisation and the Metaphor Commodity, *International Journal of Systems and Society*, July-Dec 2015, Vol, No.2. pp's.12-20
Stowell, F.A. (2013), Peter Checkland Interview, *International Journal of Information Technologies*

and Systems Approach, 6,(2), 53-60, July-December 2013

Stowell, F.A. (2013b), The Appreciative Inquiry Method – A Suitable Framework for Action Research? *Systems Research and Behavioural Science,* Volume 30, Issue 1 pp15-30, Jan-Feb 2013.

Stowell, F.A., and Welch, C. (2012) *The Managers Guide to Systems Practice, Making Sense of Complex Problems,* Chichester: Wiley.

Ulrich, W., (1983,1994) *Critical Heuristics of Social Planning*, Haupt, Bern.

Vickers, G. (1983) *Human Systems are Different* Harper and Rowe, London

Saminda Deshan Wattuhewa (1) and Nalika Danthasinghe (2)
School of Computing,
University of Portsmouth,
Portsmouth, Hampshire, UK
(saminda.wattuhewa@port.ac.uk)
(2) College of Creative Arts, Technology and Engineering,
Buckinghamshire New University,
High Wycombe, UK
(nalika.danthasinghe@bnu.ac.uk)
Corresponding Author*: Saminda Deshan Wattuhewa (saminda.wattuhewa@port.ac.uk)*

Developing the Curriculum – Examples and Benefits of Cross-Disciplinarity

Abstract

Contemporary UK higher education is under increasing pressure to graduate individuals capable of addressing complex and interconnected global challenges. This paper explores the cross-disciplinary imperative for curriculum planning as a strategic response to such demands and evolving policy landscapes. It examines how integrating seemingly unrelated subject disciplines, such as computing and design or art and engineering, can nurture comprehensive problem-solving competencies and enhance student engagement. By moving beyond traditional disciplinary boundaries, cross-disciplinary approaches support innovative pedagogies that emphasise critical thinking, adaptability, and situational awareness when addressing complex problems. Furthermore, empirical evidence suggests that such curricula can significantly improve graduate employability by developing highly valued transversal competencies, while also promoting inclusivity through multiple learning pathways [24][18]. This paper argues that the incorporation of cross-disciplinarity is not merely an enhancement but a necessary transformation for future-proofing higher education, ensuring its continued relevance and capacity to drive innovation within an increasingly dynamic societal landscape. Importantly, the paper extends the theoretical discussion by engaging more deeply with systems pedagogy literature, demonstrating how systems thinking provides both a conceptual foundation and practical methodologies for effective cross-disciplinary curriculum design.

Keywords: cross-disciplinary curriculum, systems pedagogy, systems thinking, higher education, graduate employability, transversal competencies, critical systems thinking, curriculum transformation.

INTRODUCTION

The landscape of UK higher education is undergoing a profound transformation, driven by the dual pressures of global complexity and evolving economic demands. The traditional model of siloed disciplinary education, while effective in developing deep specialised knowledge, is increasingly insufficient for preparing graduates to address the multifaceted "wicked problems" of the twenty-first century, including climate change, public health crises, and digital transformation. These challenges do not respect disciplinary boundaries, and their solutions require the integration of knowledge, perspectives, and methodologies from diverse fields. In response, a significant pedagogical shift is gaining momentum through the strategic integration of cross-disciplinarity within curriculum design.

This paper argues that cross-disciplinary curriculum development is no longer a niche pedagogical experiment but a fundamental necessity for the future of higher education. It represents an essential strategy for cultivating graduates who are not only knowledgeable in their chosen fields but also adaptable, innovative, and capable of addressing complex problems. By deliberately breaking down the silos that have long characterised academic structures, universities can create learning environments that reflect the interconnected nature of the modern world. Such environments can enhance student engagement, foster critical transversal competencies, and strengthen graduate employability. This paper explores the theoretical foundations of cross-disciplinary education, examines its practical application through illustrative and verified case studies, and discusses its broader implications for institutional practice and national policy. In doing so, it positions cross-disciplinary curriculum development as a key component of a resilient and forward-looking higher education sector.

THEORETICAL AND CONCEPTUAL FRAMEWORK

The movement towards cross-disciplinary curricula is grounded in a rich theoretical framework that challenges traditional epistemologies and advocates a more holistic and integrated approach to knowledge. Key concepts from systems thinking, constructivism, and the scholarship of integration provide the conceptual foundation for this pedagogical shift.

Systems thinking: Foundational principles

At its core, cross-disciplinarity aligns with the principles of systems thinking, which propose that the world is composed of complex and interconnected systems whose properties cannot be fully understood by analysing their components in isolation. A purely disciplinary approach often results in what Peter Senge [21] described as "functional silos", where specialists in one area lack the perspective required to understand how their work influences, or is influenced by, other parts of the system. When applied to curriculum design, a systems-oriented educational model suggests that students must learn to recognise both the "whole" and the "parts". It encourages them to identify patterns, understand feedback loops, and appreciate the dynamic relationships between different domains of knowledge. A cross-disciplinary curriculum therefore represents a direct pedagogical application of systems thinking, designed to equip students with the cognitive tools needed to analyse and address complex systemic problems, a need highlighted in the work of Meadows [11].

Systems pedagogy: Deep theoretical foundations

The integration of systems thinking into educational practice has evolved into a distinct pedagogical approach with its own theoretical frameworks and methodological principles. Systems pedagogy represents more than the application of systems concepts to education. It fundamentally reconceptualises the teaching and learning process itself as a complex adaptive system [9][10].

The systems approach to education, as articulated in foundational work spanning several decades, treats the educational process as an organised whole comprising interdependent inputs (learners, teachers, curriculum, and resources), processes (teaching strategies, learning activities, and analysis), outputs (learning outcomes, competencies, and values), and feedback mechanisms (evaluation and continuous improvement) [20]. This conceptualisation shifts pedagogy from being merely goal directed to being systematically integrated, where all components, including objectives, content, methods, and evaluation, function as coherent elements within a larger system [19].

Contemporary research on systems thinking pedagogy reveals its catalytic potential for transforming curriculum and classroom dynamics. Recent studies demonstrate that teachers who engage with systems thinking as pedagogy, rather than solely as curriculum content, report fundamental shifts in their professional practice [7]. The implementation of systems mapping as a central pedagogical activity enables both educators and students to visualise complex relationships, identify leverage points for intervention, and develop sophisticated problem-solving capacities. This approach promotes a culture of "becoming" in which collective learning challenges traditional expectations and positions all participants as capable academics [7].

Critical systems thinking and pluralistic methodologies

Building upon foundational systems principles, critical systems thinking (CST) offers a more sophisticated framework for addressing the pluralism inherent in cross-disciplinary education. Michael C. Jackson’s work on critical systems practice provides a multi-perspectival and multi-methodological approach that is particularly relevant to curriculum design [5][8]. Jackson’s EPIC framework (Explore, Produce, Intervene, and Check) offers a structured process for:

1. Exploring problem situations from multiple systemic perspectives
2. Producing intervention strategies that recognise the variety of systems approaches
3. Intervening flexibly while remaining responsive to emerging insights

4. Checking progress through evaluation and reflection on the approaches used

This framework recognises that different educational contexts and challenges require different systems methodologies. Some situations call for "hard" systems approaches focused on optimisation and efficiency, while others require "soft" systems methods that accommodate multiple perspectives and contested meanings. In other cases, critical approaches are needed to address power dynamics and emancipatory concerns [8]. The pluralism inherent in CST aligns closely with the demands of cross-disciplinary curriculum development, where diverse epistemologies, pedagogical traditions, and stakeholder interests must be reconciled.

The Viable Systems Model in educational organization

Stafford Beer's Viable Systems Model (VSM) provides another important systems perspective for understanding how cross-disciplinary educational initiatives can be organised and sustained [1][6]. The VSM proposes that viable systems, whether biological organisms or social organisations, share common structural features that enable adaptation and survival. Applied to higher education, the VSM helps institutions design cross-disciplinary programmes that balance:

1. Operational autonomy (individual disciplines and departments)
2. Coordination mechanisms (programme leadership and integration structures)
3. Control functions (quality assurance and alignment with institutional mission)
4. Intelligence gathering (environmental scanning and stakeholder engagement)
5. Policy formulation (strategic direction and identity)

The VSM's emphasis on recursive structures, where each viable system contains viable subsystems and is itself part of a larger viable system, helps explain how cross-disciplinary programmes must operate simultaneously at multiple organisational levels. A cross-disciplinary degree programme functions as a viable system nested within the viable system of a faculty or school, which in turn is nested within the viable system of the university [6]. Understanding these nested relationships helps curriculum designers anticipate structural barriers and develop appropriate governance mechanisms.

Systems thinking in curriculum development: Process and content

Recent scholarship distinguishes between systems thinking as curriculum content and systems thinking as a pedagogical process, a distinction that is particularly important for cross-disciplinary education [7][13]. As content, systems thinking encompasses concepts such as feedback loops, emergence, boundaries, and interconnections, which represent knowledge that students must acquire. As a pedagogical process, systems thinking shapes how learning environments are structured, how teaching is conducted, and how assessment is designed.

The application of systems thinking to curriculum development recognises that curricula themselves are complex systems embedded within broader educational, economic, and societal systems [12][16]. Effective curriculum development must therefore account for:

1. Multiple stakeholder perspectives (students, faculty, employers, professional bodies, policymakers)
2. Dynamic feedback mechanisms between curriculum design, implementation, and outcomes
3. Emergent properties that arise from the interaction of curriculum components
4. Boundary judgments about what knowledge is included or excluded
5. Systemic interventions required at organizational, human, and technological levels

This systems perspective on curriculum development aligns closely with contemporary calls for educational transformation. It enables curriculum designers to move beyond linear and mechanistic models towards adaptive and responsive approaches that can accommodate rapid change while maintaining coherence and quality [16].

Constructivism and connectivism

The pedagogical rationale for cross-disciplinarity is strongly supported by constructivist learning theories, which suggest that learners actively construct their own understanding and knowledge through experiences and interactions [15]. When students from different disciplines collaborate, they are required to negotiate meaning, reconcile different terminologies and conceptual frameworks, and co-create new shared understandings. This process fosters a deeper and more robust form of learning than can be achieved through the passive reception of information within a single discipline.

In the digital age, connectivism [22] extends this perspective by emphasising that learning occurs within networks of connections. A cross-disciplinary curriculum intentionally creates and leverages these networks, connecting not only people but also ideas, data, and tools from diverse fields. This mirrors the way knowledge is generated and applied in the contemporary professional world. Such an approach also aligns with the application of psychological theories to educational practice by moving beyond domain-specific knowledge and supporting the development of domain-general capabilities such as analytical, creative, and practical intelligence [23].

The scholarship of integration

Ernest Boyer's seminal work *Scholarship Reconsidered* [2] provides a foundational argument for valuing different forms of scholarly activity beyond traditional research. He introduced the concept of the "scholarship of integration", which he defined as the work of making connections across disciplines, placing specialised knowledge within a broader context, and illuminating its significance. This framework legitimises the intellectual work involved in cross-disciplinary curriculum design. It reframes such work not as a dilution of disciplinary rigour but as a distinct and valuable form of scholarship that generates new insights and creates meaning. A curriculum built on this principle teaches students to become integrators themselves. They learn to synthesise information from multiple sources, translate concepts across disciplinary languages, and construct comprehensive frameworks for understanding complex issues.Together, these frameworks, enriched through engagement with systems pedagogy literature, provide a compelling rationale for embedding cross-disciplinarity within higher education. They shift the focus from what students know within a single field to what they are able to do with their knowledge in a complex and interconnected world. The systems perspective, in particular, offers both philosophical grounding and practical methodologies for designing, implementing, and evaluating cross-disciplinary curricula at scale

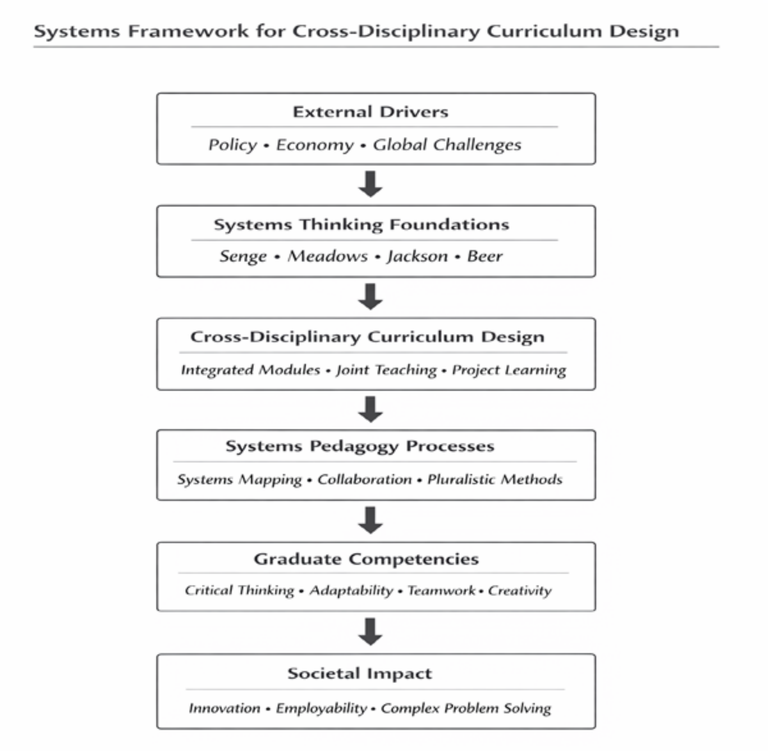


Figure 1. Systems framework for cross-disciplinary curriculum design

Figure 1 illustrates the conceptual framework proposed in this paper. The model integrates systems thinking foundations with cross-disciplinary curriculum structures to demonstrate how systems-oriented pedagogy can develop graduate competencies suited to complex societal challenges. External drivers such as policy priorities, economic demands, and global challenges create the need for curriculum transformation. Systems thinking provides the theoretical foundation, while cross-disciplinary curriculum design operationalises these principles through integrated and collaborative learning environments.

CONTEXT AND METHODOLOGY

This paper focuses on the contemporary UK higher education sector, which operates in a dynamic and demanding environment shaped by policy, economic, and societal expectations. The analysis adopts a conceptual approach, drawing on existing scholarship and secondary data from two documented initiatives to illustrate how cross-disciplinary curriculum design and institutional support can be implemented in practice. Rather than reporting primary empirical findings, the paper uses these cases as illustrative examples to connect theoretical frameworks with real-world implementation, offering transferable design principles and practice-oriented insights. The generalisability of the discussion is therefore limited. The intention is to provide analytically informed reflections that may support curriculum innovation and policy development in comparable contexts.

Policy landscape

Government bodies and funding councils increasingly emphasise graduate outcomes, employability, and the role of universities in driving economic growth and innovation. The focus on "levelling up", developing a high-skill economy, and addressing national strategic priorities, for example in artificial intelligence, green energy, and life sciences, creates a strong incentive for curricula that produce versatile and adaptable graduates.

Economic pressures

Employers across all sectors consistently call for graduates with strong "T-shaped" profiles. These graduates possess deep disciplinary expertise, represented by the vertical bar of the T, combined with broad cross-cutting skills, represented by the horizontal bar. These transversal competencies, including critical thinking, communication, collaboration, and creativity, are best cultivated in environments that require students to engage with diverse perspectives and methodologies [3].

Global challenges

As outlined in the introduction, the scale and complexity of global challenges require collaborative and interdisciplinary responses. Universities are positioned as key institutions for developing the human capital required to address these issues, making cross-disciplinary education a matter of social and civic responsibility.

Methodological approach

This paper adopts a case study approach with a conceptual methodology. It synthesises existing literature and theoretical frameworks with an analysis of two documented examples from the UK higher education sector. The approach has two purposes. The first is to establish the theoretical and pedagogical foundations of cross-disciplinary education by drawing on established scholarship, particularly within systems pedagogy literature. The second is to illustrate its practical application and benefits through carefully selected examples. The case studies are chosen for their illustrative value, demonstrating successful models for integrating design and data science and for addressing complex urban sustainability challenges. This approach relies on secondary data and published reports. Consequently, the generalisability of the findings is limited to the specific contexts examined.

DISCUSSION OF FINDINGS AND CASE STUDIES

The true value of cross-disciplinary education is most evident when examining its implementation. The following two case studies, both verified and documented, illustrate how universities are successfully breaking down disciplinary silos in order to create transformative learning experiences. These initiatives reflect the systems-oriented curriculum framework illustrated in Figure 1 and demonstrate how theoretical principles of systems pedagogy can be operationalised in real educational settings.

Case study 1: The University of Edinburgh's Design Informatics Programmes

The University of Edinburgh has established itself as a leader in data-driven innovation, demonstrated through its integration of data science across various disciplines. This is particularly evident in its Design Informatics programmes, which bring together the College of Art and the School of Informatics.

Curriculum Structure: Students in design programmes are required to take modules in data literacy, programming fundamentals, and data visualisation. Conversely, computer science students are introduced to principles of user experience (UX) design, ethics in artificial intelligence, and creative problem-solving methodologies. The curriculum is project based and culminates in a capstone project in which interdisciplinary teams of students collaborate to solve a real-world problem.

Systems Thinking in Practice: This programme exemplifies several principles of systems pedagogy.

The curriculum structure reflects Beer's VSM concept of operational autonomy balanced with coordination, where individual disciplines maintain their identity while contributing to an integrated whole. The project-based learning approach operationalises systems mapping and visualisation by requiring students to identify stakeholder relationships, trace feedback loops, and understand emergent properties of their design solutions [11]. Students develop systems thinking capabilities through iterative cycles of problem framing, intervention design, and evaluation, reflecting the EPIC framework of critical systems practice [8].

Strengthened Outcomes Data: This integrated approach yields significant benefits, particularly in terms of graduate outcomes. Publicly available data for the School of Informatics indicates that approximately 90 percent of graduates achieve a positive destination, either employment or further study, within six months of graduation [26]. Graduates from the Design Informatics programmes are highly sought after, with job titles including User Experience (UX) Designer, Product Manager, System Analyst, and Artificial Intelligence Specialist, as advertised on programme websites [27]. Furthermore, the wider Creative Informatics programme that supports this cross-disciplinary work has demonstrated substantial economic impact. It has contributed £33.1 million in Gross Value Added (GVA) to the Scottish economy and supported the creation of 45 spin-out companies [25].

Example Project: A typical capstone project involves a team developing a data-driven solution, such as a mobile application designed to promote sustainable consumer behaviour. The design student leads the user research and interface design, the computer science student develops the back-end architecture and data processing algorithms, and the business student designs the market entry strategy and business model. This collaboration encourages students to develop a shared language and mutual respect for each other's disciplines. They learn to ground creative ideas in empirical data and to develop technology that is intuitive, ethical, and aesthetically effective. From a systems perspective, students also learn to recognise how different components of the system, including the user interface, data processing, and business model, interact to produce emergent behaviours that cannot be predicted by examining components in isolation.

Case study 2: UCL's Bridging the Gaps: Sustainable Urban Spaces

To address complex urban sustainability challenges, the UCL Bridging the Gaps: Sustainable Urban Spaces (BTG) programme provides a robust real-world example of interdisciplinary collaboration. Funded by the UK Engineering and Physical Sciences Research Council (EPSRC), the programme was designed to initiate and support research collaborations across disciplinary boundaries [14].

Program Structure: The BTG programme initially focused on building relationships between the

UCL School of the Built Environment, Engineering Sciences, and Mathematical and Physical Sciences. It later expanded to include additional faculties. The core aim of the programme was to fund novel research partnerships addressing challenges related to sustainable urban spaces.

Systems Thinking Framework: The BTG programme explicitly adopts systems thinking principles in its organisational design and intervention methodology. The programme structure recognises the nested and recursive nature of viable systems. Individual research projects operate autonomously while being coordinated through programme-level governance, which itself functions within UCL's broader research strategy [1]. The programme's emphasis on building relationships across disciplinary boundaries operationalises the systems pedagogy principle that learning occurs through networks of connections between people, ideas, and methods [22].

Learning Process: The programme created structured opportunities for researchers from different disciplines to collaborate on complex urban sustainability problems, with each participant contributing methods and perspectives from their own field. This design reflects problem-based and project-based learning principles and demonstrates a systems-thinking orientation by encouraging participants to consider interdependencies across the built environment, engineering, and physical sciences domains. In doing so, it operationalised the scholarship of integration by fostering shared conceptual frameworks, supporting the translation of disciplinary insights into collaborative projects, and generating lessons that could inform both curriculum development and institutional strategy [2].

Critical Systems Practice in Action: The BTG programme demonstrates several stages of Jackson's EPIC framework. The exploration phase involved identifying sustainable urban spaces as a boundary object around which multiple disciplines could organise their inquiry. The production phase developed intervention strategies that recognised the plurality of relevant methodologies, including quantitative modelling, qualitative case studies, and participatory design. The intervention phase provided resources and organisational support for collaborative work while maintaining flexibility to respond to emerging insights. The checking phase evaluated both project outcomes and the collaborative processes themselves, generating transferable lessons regarding the enabling conditions for interdisciplinary work [14][8].

Benefits and Outcomes: The programme successfully fostered new research collaborations, demonstrating that interdisciplinary work can be both feasible and beneficial when appropriate structural support is provided. It offers a model for creating the conditions necessary for interdisciplinary collaboration and provides valuable insights into how the associated barriers can be mitigated. This example therefore offers a strong foundation for policy recommendations by demonstrating that strategic funding and institutional support are critical for successful cross-disciplinary initiatives. Importantly, the programme also shows that systems thinking approaches can scale from individual learning contexts to institutional and even sector-wide interventions.

Synthesis: Systems Pedagogy in Cross-Disciplinary Practice Both case studies illustrate how abstract systems pedagogy principles can be translated into effective cross-disciplinary programmes. They demonstrate the practical application of systems mapping, boundary critique, stakeholder engagement, and pluralistic methodologies. They also show how curriculum structures can embody systems principles by balancing autonomy and integration, enabling feedback loops between theory and practice, and fostering emergent capabilities that extend beyond individual disciplinary competencies. Most importantly, they reinforce the central systems pedagogy argument that learning environments must be designed as adaptive systems if they are to prepare students for complex and uncertain futures [9][12].

IMPLICATIONS FOR PRACTICE AND POLICY

The success of cross-disciplinary initiatives such as those described above carries significant implications for both institutional practice and national higher education policy. The systems pedagogy perspective gives particular weight to these recommendations by emphasising the need for systemic rather than piecemeal interventions.

For university practice

Structural Flexibility: Universities should implement flexible timetabling, credit structures, and progression rules that allow students to take modules beyond their home department. Institutions should also support joint appointments, shared centres, and seed funding that make cross-disciplinary programmes administratively viable. From a Viable Systems Model perspective, institutions must design coordination and control mechanisms that support cross-disciplinary work without imposing rigid centralisation [1][6].

Faculty Development: Institutions should provide professional development opportunities in co-teaching, team facilitation, and the assessment of integrated project work. They should also explicitly recognise cross-disciplinary curriculum design and teaching within promotion, workload, and reward frameworks. Faculty development should include exposure to systems thinking methodologies and their application to curriculum design so that educators can develop as sophisticated systems practitioners [5][13].

Pedagogical Innovation: A shift towards problem-based, project-based, and team-based learning is essential. Assessment methods must also evolve beyond traditional examinations and essays to include group portfolios, public presentations, and client-based project evaluations that capture the full range of competencies developed [28]. The integration of systems mapping and modelling tools into curriculum delivery provides powerful pedagogical mechanisms for making complexity visible and manageable [7][11]. Furthermore, interdisciplinary courses have been shown to positively influence the development of key skills such as teamwork, confident exploration of ideas, and the development of relevant ethical and professional perspectives [3].

Systems-Oriented Curriculum Design Tools: Institutions should adopt systematic frameworks for curriculum development that embed systems thinking principles. The Systems Education Matrix and related tools provide structured approaches for designing curricula that balance disciplinary depth with integrative breadth, ensure appropriate progression, and maintain alignment between learning outcomes, teaching methods, and assessment [4].

For national policy

Funding and Incentives: Government and funding bodies should create dedicated funding streams to encourage and support the development of cross-disciplinary programmes, similar to the EPSRC’s support for the UCL Bridging the Gaps programme. Funding models should recognise the higher coordination costs and longer development timelines associated with cross-disciplinary initiatives while also incentivising institutional changes required for sustainable implementation.

Policy Recognition (TEF): Quality assurance frameworks such as the Teaching Excellence Framework should explicitly recognise and reward institutions that demonstrate excellence in fostering interdisciplinary education and developing transversal skills. Although the TEF criteria are broad enough to accommodate interdisciplinary approaches, making this dimension more explicit would provide a stronger incentive for institutional change. Assessment criteria could include indicators of systems thinking capability development and cross-disciplinary integration effectiveness.

Systems Thinking in National Strategy: National education strategy should explicitly recognise systems thinking as a core graduate capability alongside digital literacy and global citizenship. Such recognition would legitimise the institutional investments required to embed systems approaches throughout curricula and would provide a coherent framework for sector-wide transformation [17].

Cost-Benefit Considerations: Although structural changes and faculty development require initial investment, long-term cost-benefit analysis supports this transformation. Graduates from these programmes demonstrate high employability and contribute significantly to the economy, as illustrated by the Gross Value Added generated by the Creative Informatics initiative [25]. Policy should also address potential barriers, including the complexity of managing diverse student cohorts, by providing resources for dedicated interdisciplinary programme management and systems-oriented curriculum development capacity.

Limitations

This paper has several limitations that should be acknowledged. First, the analysis relies on secondary data and published reports rather than primary empirical research, which limits the depth of insight into the specific mechanisms through which cross-disciplinary curricula achieve their outcomes. Second, only two case studies are examined, both from research-intensive UK universities. These may not be representative of the broader UK higher education sector, including post-1992 institutions, specialist colleges, or institutions with different resource profiles. Third, the UK-specific focus of the policy discussion may limit the transferability of the recommendations to other national contexts with different higher education governance structures. Finally, as a conceptual paper, the arguments presented here require further empirical validation through longitudinal studies that track the outcomes of cross-disciplinary programmes across diverse institutional settings.

CONCLUSION

This paper has argued that cross-disciplinary curriculum development represents a necessary transformation for UK higher education, grounded in robust theoretical frameworks and supported by evidence from existing practice. By engaging deeply with systems pedagogy literature, it has been demonstrated that systems thinking provides not merely a metaphor but a sophisticated set of conceptual tools and practical methodologies for designing, implementing, and sustaining effective cross-disciplinary education.

The systems perspective explains why cross-disciplinary education is increasingly important. Contemporary challenges are systemic in nature and require graduates who can think systemically, work across disciplinary boundaries, and intervene effectively in complex situations. It also clarifies how cross-disciplinary education can be achieved through organisational structures that balance autonomy and integration, pedagogical processes that make complexity visible and manageable, intervention strategies that respect methodological pluralism, and assessment approaches capable of capturing emergent system-level competencies.

The case studies from Edinburgh and UCL demonstrate that these theoretical principles can be successfully operationalised. They show that cross-disciplinary programmes can produce strong graduate outcomes, generate significant economic impact, and support meaningful transformation in educational practice when they are designed with systemic intentionality and supported by adequate institutional commitment and resources.

As UK higher education navigates an uncertain future characterised by rapid technological change, evolving workforce demands, and pressing global challenges, the importance of cross-disciplinary and systems-oriented education will continue to grow. Institutions and policymakers who embrace this transformation, grounded in the traditions of systems pedagogy, will be better positioned to fulfil the broader societal mission of higher education. This mission includes preparing graduates not only for the world as it exists today but also for the complex and interconnected world they will help to shape.

The transition towards genuinely cross-disciplinary and systems-oriented higher education requires sustained commitment, strategic investment, and cultural change within institutions. However, as this paper has demonstrated, the theoretical foundations are well established, the methodological tools are available, and the evidence of success is increasingly clear. The central question is therefore not whether this transformation should occur, but how effectively and how quickly it can be implemented.

DECLARATION OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper. Data Availability Statement

Data sharing is not applicable to this article, as no new data were created or analysed in this study.

AUTHOR CONTRIBUTIONS

Saminda Deshan Wattuhewa: Conceptualization, Writing – Original Draft, Writing – Review & Editing. Nalika Danthasinghe: Conceptualization, Writing – Review & Editing.

ACKNOWLEDGEMENTS

The authors wish to acknowledge any individuals, institutions, or funding bodies that supported this work.

References

[1] Beer, S. (1979). The heart of enterprise. John Wiley & Sons.

[2] Boyer, E. L. (1990). Scholarship reconsidered: Priorities of the professoriate. The Carnegie Foundation for the Advancement of Teaching.

[3] Corbacho, A. M., Minini, L., Pereyra, C., Lorieto, A., Basile, M., & Zabaleta, I. (2021). Interdisciplinary higher education with a focus on academic motivation and teamwork diversity. International Journal of Educational Research Open, 2, 100032. https://doi.org/10.1016/j.ijedro.2021.100032

[4] Davidz, H. L., & Nightingale, D. J. (2008). Enabling systems thinking to accelerate the development of senior systems engineers. Systems Engineering, 11(1), 1–14. https://doi.org/10.1002/sys.20081

[5] Elsawah, S., Ho, A. T. L., & Ryan, M. J. (2022). Teaching systems thinking in higher education. INFORMS Transactions on Education, 22(2), 66–102. https://doi.org/10.1287/ited.2021.0248

[6] Espejo, R., & Reyes, A. (2011). Organizational systems: Managing complexity with the Viable System Model. Springer.

[7] Goode, G. S., & MacGillivray, L. (2023). The construction of systems thinking pedagogy during a professional development institute. Journal of Pedagogical Research, 7(4), 275–302. https://doi.org/10.33902/JPR.202318879

[8] Jackson, M. C. (2019). Critical systems thinking and the management of complexity. John Wiley & Sons.

[9] Jones, P. H., Bowes, J., & Decker, D. (2018, October 23–26). On the design of systems-oriented university curricula [Paper presentation]. RSD7: Relating Systems Thinking and Design 7, Turin, Italy. https://rsdsymposium.org/on-the-design-of-systems-oriented-university-

curricula/
[10] Khanna, V. K., Kumar, A., & Verma, R. (2019). Role of systems approach in education. Journal of Education and Practice, 10(21), 94–98. https://doi.org/10.7176/JEP/10-21-12
[11] Meadows, D. H. (2008). Thinking in systems: A primer (D. Wright, Ed.). Chelsea Green Publishing.
[12] Nguyen, N. C., & Bosch, O. J. (2013). A systems thinking approach to identify leverage points for sustainability. Systems Research and Behavioral Science, 30(2), 104–115. https://doi.org/10.1002/sres.2144
[13] Papakitsos, E. C. (2016). The application of systems methodology to curriculum development in higher education. Higher Education Research, 1(1), 1–9. https://doi.org/10.11648/j.her.20160101.11
[14] Paskins, J., Bell, S., Croxford, B., Haklay, M., & Julier, S. (2012). Crossing disciplines to address urban sustainability. Sustainability: The Journal of Record, 5(2), 112–118. https://doi.org/10.1089/sus.2012.9961
[15] Piaget, J. (1970). Genetic epistemology (E. Duckworth, Trans.). Columbia University Press.
[16] Rahdar, R., London, M., Lin, Y., & Jiang, H. (2023, July). Systems thinking applied to higher education curricula development [Paper presentation]. 33rd Annual INCOSE International Symposium, Honolulu, HI, United States. https://commons.erau.edu/publication/2088
[17] RISE Programme. (2021). Applying systems thinking to education. Research on Improving Systems of Education (RISE). https://riseprogramme.org/publications/applying-systems-thinking-education/
[18] Riva, E., Meyer, H., Logan, F., & Neal, A. (2025). Humanising higher education through interdisciplinary student-devised assessments. Humanities and Social Sciences Communications, 12(1), 1196. https://doi.org/10.1057/s41599-025-05513-4
[19] Sanders, M. (1971). A systems approach to the teaching-learning process (ED050033). ERIC. https://eric.ed.gov/?id=ED050033
[20] Selvik, J. T., Abrahamsen, E. B., & Moen, V. (2022). Conceptualization and application of a healthcare systems thinking model for an educational system. Studies in Higher Education, 47(9), 1872–1889. https://doi.org/10.1080/03075079.2021.1946034
[21] Senge, P. M. (1990). The fifth discipline: The art & practice of the learning organization. Doubleday.
[22] Siemens, G. (2005). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning, 2(1), 3–10.
[23] Sternberg, R. J. (2008). Applying psychological theories to educational practice. American Educational Research Journal, 45(1), 150–165. https://doi.org/10.3102/0002831207312910
[24] Striolo, A., Jones, A., & Styan, C. (2023). The effectiveness of an interdisciplinary postgraduate-taught program in terms of employability. Education for Chemical Engineers, 45, 1–10. https://doi.org/10.1016/j.ece.2023.06.006
[25] Terras, M., Osborne, N., McDonald, C., Henderson, D., Pirie, E., & Tyndall, A. (2024). Creative Informatics final report. Zenodo. https://doi.org/10.5281/zenodo.12575157
[26] University of Edinburgh. (2024). Careers, employability and alumni. School of Informatics. https://informatics.ed.ac.uk/study-with-us/careers-employability-and-alumni (Accessed 2 March 2026)
[27] University of Edinburgh. (2024). Design Informatics MSc. School of Informatics. https://study.ed.ac.uk/programmes/postgraduate-taught/803-design-informatics (Accessed 2 March 2026)
[28] University of Edinburgh. (2024). Design Informatics MA. Edinburgh College of Art. https://study.ed.ac.uk/programmes/postgraduate-taught/821-design-informatics (Accessed 2 March 2026)

Jonathan Lee, John Crawford and Cris Hasan
Jonathan Lee 27041541@student.gla.ac.uk
University of Glasgow

Operationalising a Just Transition to Net Zero In Cities: Is There an Optimal Balance Between Top-Down and Bottom-Up Approaches?

Abstract

Transitioning to a just and sustainable society is an urgent and potentially existential problem. Devolving power allows for a nimble and experimental approach, where local knowledge can tailor solutions to an area's unique strengths and challenges. However, excessively compartmentalising decision-making potentially separates actions from their effects and impedes the sharing of resources and ideas. Understanding which scale of devolution yields the best trade-off between these effects is therefore an important step in making a just transition. To answer this question, a bespoke variant of the multispecies NK model was constructed, with the key innovation that its critical parameters were tuned using real data from the city of Glasgow. Simulation results show that highly devolved systems are unable to function effectively except in very simple problem landscapes. Conversely, the non-devolved system performs poorly in all but the most complex landscapes, only becoming one of two viable options at the point of maximum complexity. These results suggest that modestly devolved systems made up of 3 or 6 decision bodies are likely to strike an optimal balance between the costs and benefits of devolution and are better suited to engaging with systemic change than the un-devolved status quo.

Introduction

The United Nation's 2024 Sustainable Development Report found that just 16% of Sustainable Development Goals were on track to reach their 2030 targets (D. Sachs et al., 2024). Relatedly, a study of 1500 climate policies enacted worldwide found that just 63 were successful at reducing emissions (Stechemesser et al., 2024). They found that many of the most successful policies were components of bundles of policies designed to be implemented simultaneously – the relationship between the policy and its effect was not isolatable from the wider system. This is in tension with what Morçöl describes as the Newtonian beliefs embedded within present government systems (Morçöl, 2005), which aim to model the world as a series of mostly linear relationships which, with sufficient information, can be reliably manipulated.

Mueller also argues that present government systems are not well suited to controlling the complex system of society (Mueller, 2020), using as examples policies which, although promising in theory, performed poorly in practice. They argue that the difficulties posed by non-linearity and emergent behaviour mean that the expectation governments have of their ability to control society with policies is unrealistic. They advocate for the adoption of more agile and responsive strategies which accept and embrace policy failure as a means of learning and exploring solution space.

The principles of socio-technical design (Cherns, 1976) display a similar pessimism against structures being prescribed from the top down. Observations from industries led them to conclude that a system must be designed in an ongoing and participatory manner, since all members have unique insights and, should the system not fulfil its goals, the capacity to work around it in undesirable ways.

Viewing government through this lens, the devolution of power seems highly desirable. Moving decisions closer to their point of affect allows citizens to participate and contribute relevant information more easily. This information flow is also faster, which enables a greater sensitivity to successes and problems, enabling faster responses.

Prior work has also found that citizens in democracies are more trusting of local government (Mueller, 2020), which is valuable in a system which more visibly incorporates experimentation and failure.

However, these same principles imply an upper limit to the level of useful devolution. In a later work revisiting the principles (Cherns, 1987), the author relays a situation where a machine and its operators were separated by a wall and therefore placed into separate management boundaries. Similar disjoints occur in governing. Kramer describes an incident surrounding the redevelopment of a disused industrial building (Kramer, 2017). Public consultation was limited to residents of a specific area, whose boundary was a major road adjacent to the building. As a result, the poorer area on the other side of the road was not invited to discussions surrounding a potentially valuable asset within convenient walking distance.

Collaboration between areas regarding shared assets and issues can also present problems. Analysis of the Lisbon Metropolitan Area (Gonçalves et al., 2023) observed that efforts to encourage collaboration between municipalities through an intermunicipal entity largely failed, since municipalities were unwilling to act unless measures were directly in their interest. Ultimately, deadlocks around transit in the area were only broken by removing relevant powers from the municipalities and granting them to the entity.

Subdivision of this nature is also conceptually in conflict with the holistic nature of systems thinking, and risks eroding the ability to effectively engage with society as a connected system. This tension between manageably small partitions and the loss of holistic understanding was explored in study by Ethiraj and Levinthal (Ethiraj & Levinthal, 2003). They discuss a real-world example of this tension in the form of Intel designing a computer chip. In attempting to break the problem into tractable pieces, the engineers lost their understanding of the overall problem, forcing them to ultimately redesign the chip. They examined this problem of modularity further with theoretical modelling work, and concluded that attempting to over-divide a complex system led to more severe problems than under-dividing it.

The works discussed suggest that there are major potential benefits to devolution, but also that excessive devolution can cause problems which minimise or even outweigh these benefits. The question is therefore:

What level of government devolution will perform best at the finding, sharing, and implementation of the drivers of socio-environmental change?

This paper examines this question in the context of Glasgow using a modified version of the NK fitness model. The spatial nature of democratic constituencies is utilised to allow elements within the model to be associated with physical locations and the demographic properties of their inhabitants.

Methodology

The NK fitness model is a process for creating configurable rugged fitness landscapes (Kauffman & Weinberger, 1989). A landscape consists of *N* nodes, each of which contribute to the overall performance of the model based on their own state (typically either 0 or 1) and the states of *K* other nodes chosen at random when the model is initialised. Although the model (and fitness landscapes generally (Wright, 1932)) originated in the field of evolutionary biology, it has been applied extensively to other fields, such as safety assessment (Liu et al., 2022; Meng et al., 2024), and has also been examined mathematically (Jian Zhang et al., 2000; Weinberger, 1996). After Levinthal popularised the model's use in management science (Levinthal, 1997), it has enjoyed extensive use there, especially in the context of multinational corporations (Khodzhimatov et al., 2022, 2023; Rivkin & Siggelkow, 2002). Typically, the landscapes generated are explored using a "hill-climbing" algorithm, which examines the effects of change the state of a single node and adopts the change if it yields an improvement to overall fitness.

The model has accumulated many variants, including a multispecies variant (Kauffman & Johnsen, 1991), where *S* landscapes are independently generated and then connected together in a manner similar to the *K* connections of the original model; increasing the number of states each node can be in (Bull, 2022); or multi-objective variants where there are *M* separate fitness scores (Aguirre & Tanaka, n.d.; Cosson et al., 2022), each of which is contributed to by some subset of the landscapes nodes. Researchers have also modified the algorithm exploring the landscape to examine concepts such as self-interested management and the effects of diversity within organisations (Baumann et al., 2024; Hankins et al., 2023; Rivkin & Siggelkow, 2002).

The interactions between nodes within the model make a natural allegory to the conflicts that emerge between policy choices, which has been explored extensively in the context of management studies (Levinthal, 1997; Rivkin, 2000). Similarly, the usage of multi-species variants to explore companies within an economic system or departments within a multi-national corporation is prevalent within the field (Celo & Lehrer, 2022; Khodzhimatov et al., 2023).

The model used in this study was derived from the models discussed above; it interpreted policies as the nodes within an NK model, and devolved areas as species within the multispecies variant. Multiple objectives were incorporated, to represent the challenges of implementing multi-objective sets of goals such as the Sustainable Development Goals or Glasgow's own *Thriving Definitions*, which were developed as a means of guiding the city towards a just transition (Hjelmskog et al., 2023).

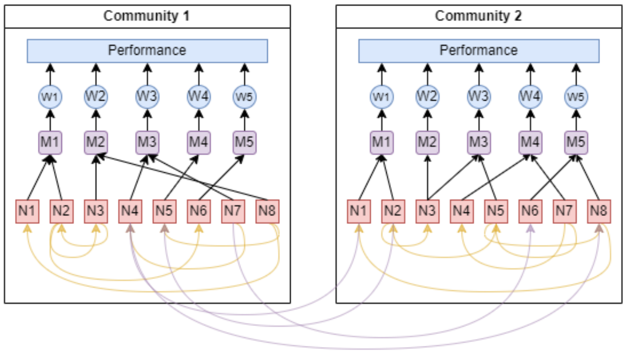


Figure 1: A diagram showing the components of each community within the simulation. Policies (red squares) contribute towards goals (purple rounded squares), based on their own state and the state of other policies which interact with them (purple and orange arrows). Overall performance is an average of goal performance, with each goal weighted by how much the community prioritises it (blue circles).

Figure 1 shows a simplified version of the model's structure. Each area of the city is represented as a species within the wider NK landscape. Red squares represent nodes in the model and are allegorical to policies. These make a fitness contribution to some number of goals (the rounded rectangles) based on their own state and the states of any nodes with arrows leading to them (representing policy interactions). Each goal takes the average of these combinations. These are then aggregated, weighted by a unique priority score (the circles) for each goal, to calculate the overall fitness of the area. The performance of the model is the average of these fitness's.

Prior work has raised concerns about the NK models role as an "artifact", whose inclusion inherently shapes the results of a study (Mckelvey et al., 2013). In response to this, and with the goal of increasing the potency of the models' findings, an effort was made to derive the key parameters of the model from actual data pertaining to the city of Glasgow. This was achieved by first assigning each species within the model a distinct contiguous area of the city, allowing it to be associated with demographic data from that area and related to other species in the model using connectivity analyses of the city. Several examples of this are discussed below.

Typically, the connections between nodes in a multispecies NK model are controlled by two parameters, one for connections between nodes within a species, and one for connections between nodes from different species. The researcher defines the extent to which species are linked to each other.

The model utilised in this paper instead receives a single parameter representing the number of policy side-effects, and assigns the connections between internal and external nodes via a random process weighted by a "connectivity matrix". This matrix an estimation of ease of travel between each pairing of DataZones (small census areas) within the city, and is calculated using nuanced travel-time estimates combined with demographic data for the area, such as rates of car ownership and estimated travel budget.

To represent budget-constrained policy plans more accurately, the nodes of the model were modified to have multiple states, each with a larger financial cost than the last, whose contributions to performance were configurably correlated. Areas had a finite budget at their disposal. The budget was split evenly between areas, but the total budget reduced the more areas were present in the model to simulate the cost of additional administrative overhead.

Existing socio-economic inequalities were integrated into the model by designating some of each area's goals essential, meaning that they represented basic needs such as health and physical safety. The nodes contributing to these essential goals were then assigned starting values based on the Scottish Index of Multiple Deprivation (SIMD) (*Scottish Index of Multiple Deprivation 2020 V2*, 2021) scores for the area. Performance scores were penalised for areas whose essential goal performance did not exceed a minimal threshold. Relatedly, heterogeneity was incorporated into the model in the form of areas having reduced sensitivity to these thresholds during decision-making, proportional to the variance of SIMD scores within them. The logic for these systems was derived from survey work conducted in cities across Europe, which found that citizens were only concerned about broader environmental goals once they felt secure in their own essential needs being met

(Kaufmann et al., 2024).

Results

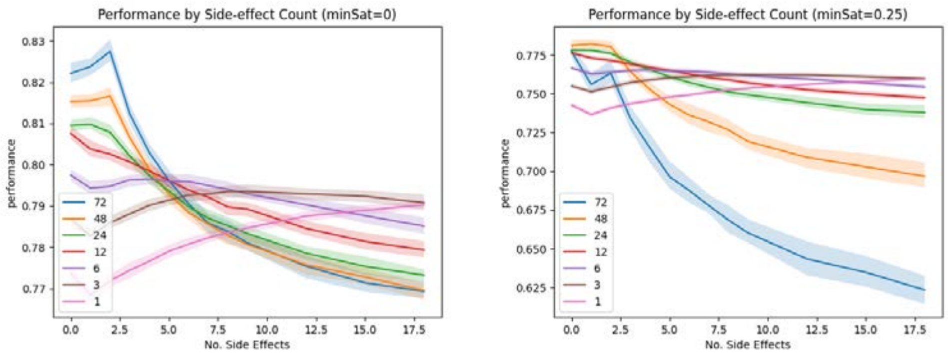
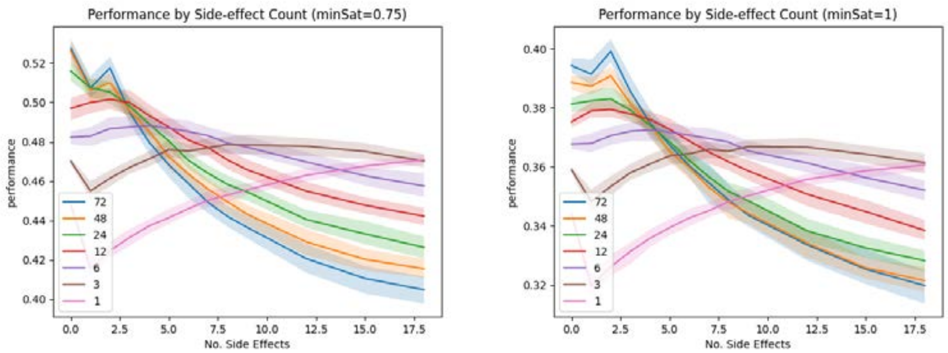


Figure 2ABCD: Plots of performance from different levels of policy side-effects. Lines within plots represent scenarios where the city is divided into that number of equally sized regions. Each plot is of a simulation with a different minimum value that essential goals must exceed for an area to avoid a fitness penalty.



Figures 2ABCD compare performance across several devolution scenarios. The Y axis marks average area performance across 101 simulations, the X axis the number of side-effects each policy was assumed to be affected by. Different figures represent variations of other parameters such as the threshold for critical goals and the level of correlation between the fitness contributions of a given policy's states.

The overall trend is best described as an inversion. As the number of side-effects increases, the optimal level of devolution becomes one with fewer, larger areas. Other parameters shift and stretch this inversion, potentially moving its extremes outside of the study area.

Both the status quo scenario of no devolution and the largest level of devolution examined (72 areas), are rarely optimal for any significant part of the explored space. For both, the next level of devolution (three areas and 48 areas respectively) outperform them in almost all contexts.

The six-area scenario is reliably the least sensitive to the number of side-effects, with relatively small decreases across the values explored for all parameter combinations. However, this means that the scenario is only the optimal solution for a small number of moderate side-effect estimates, typically between five and eight.

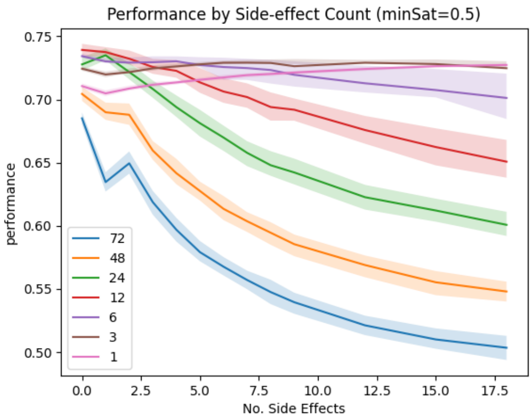


Figure 3: An alternative parameter set including correlation between the node states fitness contributions.

Figure 3 shows the results from an alternative parameter combination. Here, partial correlation is enforced between the states of each node, meaning that as a node's state is changed, it's fitness contribution changes more predictably. This shifts the pattern of inversion far to the left, outside of the possible range of parameters.

The optimal level of devolution switches between the four lowest devolution scenarios studied (twelve, six, three, and one areas). The un-devolved scenario still never decisively becomes the optimal choice. Although it is no longer the most consistent, the six-area scenario is still one of the best-performing, and yields a comparable average performance to the three and one-area scenarios.

To summarise, although parameter combinations frequently change which level of devolution performs optimally, they rarely cause either extreme to do so.

Conclusions

The results support the conclusion that Glasgow can engage with multi-objective goals more effectively if devolved into several semi-autonomous bodies. Although the exact number cannot be confidently derived due to parameter uncertainty, either three or six areas would be likely to yield superior performance to the status quo in almost all circumstances.

The model demonstrates behaviour similar to those observed in a previous NK study (Ethiraj et al., 2008) which generated a modular system and then constructed variably modular control systems to preside over it, with the ultimate finding that, although both over-modularising and under-modularising caused reduced performance, the consequences of over-modularising were more severe.

Given the sensitivity displayed towards the parameters explored by the researchers, further exploration of parameter space would improve confidence in the model's findings. Analysis of other cities using the same methodology would yield useful comparisons. Finally, any attempts to establish evidenced or data-driven values for additional parameters in the model would help to increase its authority.

References

Aguirre, H. E., & Tanaka, K. (n.d.). Insights on properties of multiobjective MNK-landscapes. *Proceedings of the 2004 Congress on Evolutionary Computation (IEEE Cat. No.04TH8753)*, 196–203. https://doi.org/10.1109/CEC.2004.1330857

Baumann, F., Czaplicka, A., & Rahwan, I. (2024). Network structure shapes the impact of diversity in collective learning. *Scientific Reports*, *14*(1), 2491. https://doi.org/10.1038/s41598-024-52837-3

Bull, L. (2022). Nonbinary Representations in the NK and NKCS Models. *Complex Systems*, *31*(1), 87–101. https://doi.org/10.25088/ComplexSystems.31.1.87

Celo, S., & Lehrer, M. (2022). How much lateral collaboration is optimal? Insights from computer simulations of MNEs as complex adaptive systems. *Journal of World Business*, *57*(3), 101289. https://doi.org/10.1016/j.jwb.2021.101289

Cherns, A. (1976). The Principles of Sociotechnical Design. *Human Relations*, *29*(8), 783–792. https://doi.org/10.1177/001872677602900806

Cherns, A. (1987). Principles of Sociotechnical Design Revisted. *Human Relations*, *40*(3), 153–161. https://doi.org/10.1177/001872678704000303

Cosson, R., Santana, R., Derbel, B., & Liefooghe, A. (2022). Multi-objective NK landscapes with heterogeneous objectives. *Proceedings of the Genetic and Evolutionary Computation Conference*, 502–510. https://doi.org/10.1145/3512290.3528858

D. Sachs, J., Lafortune, G., Fuller, G., & Lablonovski, G. (2024). *Sustainable Development Report 2024*.

Ethiraj, S. K., & Levinthal, D. A. (2003). Modularity and Innovation in Complex Systems. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.459920

Ethiraj, S. K., Levinthal, D., & Roy, R. R. (2008). The Dual Role of Modularity: Innovation and Imitation. *Management Science*, *54*(5), 939–955. https://doi.org/10.1287/mnsc.1070.0775

Gonçalves, J., Pinto, P., & Santos, M. (2023). Who and how decides when and where? Drifts and deadlocks in metropolitan governance. *Urban Research & Practice*, *16*(3), 374–393. https://doi.org/10.1080/17535069.2022.2033308

Hankins, K., Muldoon, R., & Schaefer, A. (2023). Does (mis)communication mitigate the upshot of diversity? *PLOS ONE*, *18*(3), e0283248. https://doi.org/10.1371/journal.pone.0283248

Hjelmskog, A., Toney, J., Scott, M., Crawford, J., Hasan, C., Winterbottom, J., & Meier, P. (2023). *Thriving Glasgow Portrait - a Shared Vision for a Healthy, Equitable and Sustainable Future*.

Jian Zhang, Thompson, R. K., & Wright, A. H. (2000). The computational complexity of N-K fitness functions. *IEEE Transactions on Evolutionary Computation*, *4*(4), 373–379. https://doi.org/10.1109/4235.887236

Kauffman, S. A., & Johnsen, S. (1991). Coevolution to the edge of chaos: Coupled fitness landscapes, poised states, and coevolutionary avalanches. *Journal of Theoretical Biology*, *149*(4), 467–505. https://doi.org/10.1016/S0022-5193(05)80094-3

Kauffman, S. A., & Weinberger, E. D. (1989). The NK model of rugged fitness landscapes and its application to maturation of the immune response. *Journal of Theoretical Biology*, *141*(2), 211–245. https://doi.org/10.1016/S0022-5193(89)80019-0

Kaufmann, D., Wicki, M., Wittwer, S., & Stephan, J. (2024). Democratic discrepancies in urban sustainable development. *Nature Sustainability*, *7*(11), 1409–1418. https://doi.org/10.1038/s41893-024-01425-4

Khodzhimatov, R., Leitner, S., & Wall, F. (2022). *Interactions Between Social Norms and Incentive Mechanisms in Organizations* (pp. 111–126). https://doi.org/10.1007/978-3-031-16617-4_8

Khodzhimatov, R., Leitner, S., & Wall, F. (2023). *Controlling Replication via the Belief System in Multi-unit Organizations* (pp. 359–370). https://doi.org/10.1007/978-3-031-34920-1_29

Kramer, R. (2017). Designing for and against Symbolic Boundaries. *City & Community*, *16*(4), 369–373. https://doi.org/10.1111/cico.12267

Levinthal, D. A. (1997). Adaptation on Rugged Landscapes. *Manage. Sci.*, *43*(7), 934–950.

Liu, Z., Ma, Q., Cai, B., Shi, X., Zheng, C., & Liu, Y. (2022). Risk coupling analysis of subsea blowout accidents based on dynamic Bayesian network and NK model. *Reliability Engineering & System Safety*, *218*, 108160. https://doi.org/10.1016/j.ress.2021.108160

Mckelvey, B., Li, M., Xu, H., & Vidgen, R. (2013). Re-thinking Kauffman’s NK fitness landscape: From artifact & groupthink to weak-tie effects. *Human Systems Management*, *32*(1), 17–42. https://doi.org/10.3233/HSM-130782

Meng, X., Li, H., Zhang, W., Zhou, X.-Y., & Yang, X. (2024). Analyzing ship collision accidents in China: A framework based on the N-K model and Bayesian networks. *Ocean Engineering*, *309*, 118619. https://doi.org/10.1016/j.oceaneng.2024.118619

Morçöl, G. (2005). A New Systems Thinking: Implications of the Sciences of Complexity for Public Policy and Administration. *Public Administration Quarterly*, *29*(3), 297–320. https://doi.org/10.1177/073491490502900303

Mueller, B. (2020). Why public policies fail: Policymaking under complexity. *EconomiA*, *21*(2), 311–323. https://doi.org/10.1016/j.econ.2019.11.002

Rivkin, J. W. (2000). Imitation of Complex Strategies. *Management Science*, *46*(6), 824–844. https://doi.org/10.1287/mnsc.46.6.824.11940

Rivkin, J. W., & Siggelkow, N. (2002). Organizational sticking points on NK Landscapes. *Complexity*, *7*(5), 31–43. https://doi.org/10.1002/cplx.10037

Scottish Index of Multiple Deprivation 2020 v2. (2021, October 4). Scottish Government.

Stechemesser, A., Koch, N., Mark, E., Dilger, E., Klösel, P., Menicacci, L., Nachtigall, D., Pretis, F., Ritter, N., Schwarz, M., Vossen, H., & Wenzel, A. (2024). Climate policies that achieved major emission reductions: Global evidence from two decades. *Science*, *385*(6711), 884–892. https://doi.org/10.1126/science.adl6547

Weinberger, E. (1996). *NP Completeness of Kauffman’s N-k Model, A Tuneable Rugged Fitness Landscape*. https://EconPapers.repec.org/RePEc:wop:safiwp:96-02-003

Wright, S. (1932). *The roles of mutation, inbreeding, crossbreeding, and selection in evolution.*

Gary Evans, The Bournemouth University Business School,
Talbot Campus
(gevans@bournemouth.ac.uk)

TO WHAT EXTENT CAN THE Z-SCORE MEASURE SYSTEM PERFORMANCE?

Abstract

The Z-score has a rich history of use for analysing companies' financial performance. The composite method was originally developed to predict corporate bankruptcy and remains a favoured statistical technique used by institutional and private investors. Their use of Z-scores is to forecast the likelihood of a company failing in the next year based on its capital structure [history], to predict the company's financial distress or success [future]. Thus, the Z-score serves as a predictor to inform investors' decisions and potentially helps companies make better-informed decisions regarding their governance and capital structure. Having applied Z-score on multiple occasions and supervised its use by countless undergraduates and postgraduates, there is something intuitively appealing about the technique. When reflecting on the many applications of the Z-score, it is argued that the Z-score also measures the macro and micro-operations of companies and their critical service delivery systems. In this paper, we will present the history of the Z-score, demonstrate how the statistical method works, and argue for its relevance in measuring system and operational performance.

Keywords: Capital Structure, operations, performance measurement, systems, and Z-score.

1. Introduction

In Jackson's latest work, *Critical Systems Thinking: A Practitioner's Guide* (2024), he cites the BSc and EFQM as methods for measuring system performance. Whilst the BSC and EFQM are proven methods, there may be an opportunity to focus more on the resources of an entity's capital structure, as possible with Altman's (1968; 1993) Z-score.

The importance of managing capital structure is as important as ever for companies (Attrill & McLaney, 2021). A company's capital structure is more dynamic than we may think, as it strives to finance the entity over the long and short term, as argued by Wild et al. (2007). Financing is used to procure non-current assets and current assets, enabling the company to deliver its products and services to customers. Some assets, such as non-current assets, signify security to lenders, particularly if the company needs loans to finance its capital structure due to insufficient profits or reserves (Bardia, 2012). If the company needs loans, this introduces risks associated with borrowing to buy assets, as interest charges increase the company's overall cost of capital. It can lead to what Nguyen et al. (2021) refer to as leverage traps: future borrowing is not possible due to the ongoing cost of capital, compounded by business strategy mistakes.

A company's capital structure is crucial to its financial sustainability and long-term market viability (Holmes et al., 2015). According to Szymanski et al. (1993), an optimal borrowing-to-equity capital structure maximises growth and development while minimising the risk of bankruptcy. Capital structure affects the company's ability to win market share: the higher its relative market share, the higher its profitability (Mitani, 2014; Mognetti, 2002). The emphasis on profitability and return aligns with the position of Achim et al. (2010), as the return on a company's investment demonstrates its inherent ability to generate revenue from its operations. Bardia (2012) points to higher returns as indicating the company's ability to generate cash from operations to repay debt and mitigate the risk of insolvency. According to Hussey (2014), high returns, as measured by earnings per share, are also attractive to institutional and private investors.

The imperative appears to be for companies to effectively manage their capital structure and assess their profitability and return on investment (Karadag, 2015). Boigues (2016) calls for profitability and return ratios to measure the efficiency of a company's management team in utilising resources to generate profits, such as return on sales. However, Attrill et al. (2021) highlight the limitations of such ratios, for example, the reliability of financial data and the issue of inflation, which can lead to misleading figures. To address the concerns raised by Attrill et al., there is an opportunity to use more advanced methods to assess company performance, such as Altman's (1968) Z-score.

This paper aims to make the case for using the Z-score to measure system performance by outlining its history, introducing the technique and the data used to compute the Z-score, and discussing its relationship to operational and service delivery systems. Additionally, it discusses the method's utility for measuring system performance.

2. Z-score

This section summarises the history of the Z-score and its independent critique by researchers, such as Bardia (2012).

2.1 The history of the Z-score

The Z-score was empirically developed by Altman in 1968 to predict corporate bankruptcy, thereby better informing institutional and private investors about their potential investments in corporate stock. Altman studied sixty-six manufacturing companies worth over $1 million, of which 50% went bankrupt. Based on his first statistical run of the Z-score, Altman predicted 72% of the bankruptcies before they occurred. Altman believed that predicting the financial success or distress of companies provided a better understanding of company performance and was an improvement on the more traditional methods of investor financial analysis, such as return on shareholder funds. Taffler (1984) confirmed the reliability of the Z-score in forecasting the likelihood of a company failing in the next trading year from its capital structure performance [history], thereby predicting a company's success or distress [future]. He concluded that the Z-score is a predictor that helps companies make informed decisions about their capital structure. Becket (2004) confirmed that the Z-score for failing companies continued to decline as they approached insolvency and eventually bankruptcy.

2.2 Independent critiques of the Z-score

There have been a few interesting critiques of the Z-score, focusing on the data it uses, the accuracy of the method, and its relevance to different industry sectors, such as those by Bardia (2012), Naiping and Li (2011), Hayes et al. (2010), and Gerantonis et al. (2009). Bardia questioned the Z-score because it relies on multiple discriminant analyses, which select specific financial data over other data. Other data may yield a linear function of the multiple explanatory variables, which is equally acceptable. Naiping and Li found that the Z-score for public companies is significantly higher than for private companies. They concluded that the financial risk for private companies is significantly higher than for public companies. In the retail industry, the critique by Hayes et al. concurs with Taffler (1984), as they confirm that the Z-score predicts bankruptcy with 94% accuracy. This finding aligns with Altman (1993), who stated that the Z-score is more reliable in manufacturing and retailing. However, Gerantonis et al.'s cross-sector critique revealed that the Z-score's reliability for predicting failure was 66% in the first year, decreasing to 20% by the fourth year. We can note that the Z-score is likely to be more reliable in certain industries, such as retailing, than in others when operationalising the Z-score methodology.

2.3 Whose decision is it to use the Z-score in a company

The use of the Z-score and other operational and improvement methods in companies is a decision of their governance and leadership. While leadership provides the general direction of a company (Frawley et al., 2019), governance is responsible for designing, implementing, and monitoring structures, processes, and systems, as outlined in Slack et al.'s (2022) Transformation Process Model. Here, they indicate input from transformed resources, input from transforming resources, and the transformation process for customer service. Although an imperfect model of operations, it illustrates total input costs and revenues. However, Ogland and Evans (2025) cite a lack of governance and leadership as a reason for the high failure rates of TQM projects using models such as the European Foundation for Quality Management (EFQM) Business Excellence Model (Hakes et al., 2007). There seemed to be a disconnect between governance and leadership in the TQM projects they analysed. They concluded that governance is better aligned with organisational commitments and that leadership is distributed and cultivated bottom-up to improve the success rates of TQM projects. A decision to use the Z-score would benefit from aligning governance with the commitment to implement the method and from distributed leadership to ensure the financial management system can track total costs and revenues.

3. Z-score's methodology

Altman (1968; 1993) designed the Z-score to predict bankruptcy and corporate performance using various financial data. It means the Z-score is a composite measure of performance, combining individual measures to provide a comprehensive view of companies' trading and their ability to generate cash flows to cover expenses. Essentially, the Z-score summarises a considerable amount of financial data into a single, easily understandable value. In doing so, the Z-score composite measure reduces the amount of financial data that needs to be processed, providing a clearer picture of a company's overall performance and being useful for benchmarking and monitoring changes over time.

Because of the data it uses, the Z-score is a quantitative methodology for performance analysis (Morris, 2010), albeit discriminatory in the data it uses to compute the final Z-score, as noted by Bardia (2012). The data feeds into the Z-score metric, which utilises five predetermined weights provided by Altman to compute individual classification scores and the final Z-score for a company. Below is the Z-score metric and each weight for the classifications x1 to x5. For example, 0.717 is the weight for x1 and 0.847 for x2, and so on. To emphasise, the weights provided by Altman enable users to multiply the financial data shown in x1 to x5 by the weights to calculate the individual classifications and the final Z. The weights are fixed; thus, users cannot alter them based on their preferences.

Z = 0.717 x [x1] + 0.847 x [x2] + 3.107 x [x3] + 0.420 x [x4] + 0.998 x [x5]

The weights Altman uses do give clues to his thinking on the importance of each classification, x1 to x5. He places the highest weight on x3, 3.107, suggesting he is examining how a company’s management team employs its current and non-current assets to generate cash flows, profits, and returns for investors. He probably views this classification as the one more likely to lead to insolvency and bankruptcy if total assets are not utilised effectively to generate sales to cover operating costs. His second priority is x5, 0.998, further highlighting the importance Altman places on generating sales to cover operating costs, thus providing a slightly different measure of a company’s asset utilisation rate. x1, 0.717, and x2, 0.847, are of medium priority to him, as they focus on the company's working capital cycle and the earnings generated by the cycle after deducting operating costs. The classification x4 has the lowest weight and appears to reflect the relationship between equity and debt, specifically between short-term and long-term liabilities. Altman likely considers equity, including profit, as a benefit of other classifications, such as x3, and any loans used to procure assets, rather than on how assets are utilised to generate sales.

The final and most important element of the methodology is the Z-score benchmarks to determine whether an entity is experiencing financial success or distress. Indicating improvement, it can also suggest insolvency or an investment opportunity, and we believe the benchmarks reflect system performance. Drawing on the ideas courtesy of Castle (1998; 1996), the extent of system integration and system maturity; thus, an entity scoring ≥2.90 is likely to have higher system integration and maturity than an entity scoring ≤1.20. Table 1 shows Altman’s benchmarks and their interpretation.

Of interest to this research is Altman’s focus on a company's total assets to generate sales, which is especially important in the retail industry, such as sports and physical activity. Other sectors have the business decision to outsource manufacturing or production, which is not possible for the delivery of sport and physical activity services. The delivery of sport and physical activity services is a simultaneous process, as argued by Buswell et al. (2022); thus, it is virtually impossible to outsource service delivery. We can now consider the financial data that feeds into the Z-score.

Table 1: Altman’s benchmarks and their interpretation (*Adapted from Altman (1968; 1993)*

Benchmark	*What does this mean?*	*System integration & maturity*
≤1.20	A high chance of bankruptcy	Low
≈1.20-2.90	The firm is in a grey area and an ambiguous area	Medium
≥2.90	A low or no chance of bankruptcy	High

4. Financial data used in the Z-score metric

The financial data that feeds into the Z-score metric is deliberately selected by Altman (1968, 1993) and is sourced from companies' accounts, specifically the income statement and the statement of financial position. Other elements in company accounts can help with our financial analysis, though, such as the chairperson and chief executive officer reports and the notes to the accounts that provide detail on how the figures were calculated by the company accountant, including necessary adjustments to comply with the Generally Accepted Accounting Principles (GAAP) (Hussey, 2014). All accounts are subject to internal and external audits to provide a true and fair view and to confirm that the company is a *going* *concern*. Compliance with GAAP and audits gives users of such financial information confidence in the data's reliability, despite the concerns raised by Attrill et al. (2021) about the data.

Each classification (x1 to x5) has its own financial data requirements for computing its ratio, which is then used to compute the Z-score metric. Table 2 presents the financial data for each classification, along with our interpretation of the focus of each classification (x1 to x5).

Table 2: Financial data for the classifications

Classification	*Financial data*	*Interpretation*
x1 =	Working capital/total assets	Liquidity
x2 =	Retained earnings/total assets	Age of the firm
x3 =	Earnings before interest and tax/total assets	Profitability
x4 =	Net worth/total liabilities	Financial structure
x5 =	Sales/total assets	Capital turnover

Source: Adapted from Altman (1968; 1993)

Our interpretations of the classifications are based on repeated measures over time (Morris, 2010). x1 appears to concentrate on the company's working capital cycle, given the financial relationship between current assets and liabilities. Additionally, the utilisation of both non-current and current assets is considered within the trading cycle. x2 the level of earnings generated by the company's total assets over the long term, and the condition of the company's non-current and current assets, such as facilities and equipment used to deliver products and services. x3, the level of gross profit generated from sales, less the cost of sales, less business expenses. Again, the use of non-current and current assets to earn the company's sales for the trading period of interest.

x4, the relationship between the equity invested by the owners and the amount of loan capital, i.e., debt finance, in the company's capital structure. A rule of thumb suggested by Hussey (2014) is 50:50, i.e., equity 50%, debt finance 50%. If debt finance exceeds 50%, it begins to cause problems for a company due to interest payments, thereby squeezing its cash flow. x5, the efficient and effective use of non-current and current assets by the company's management to generate sales. The higher the capital turnover (i.e., utilisation rates), the better. It is fair to say that calculating x1 to x5 is a challenging aspect of using the Z-score for users.

5. Calculating the Z-score for a company

An example of how to compute a company's Z-score is shown here. The Company operates in the sports and physical activity industry. For the sake of fairness, it will be referred to as Sports Co. As an established health and fitness provider, Sports Co. trades across the UK, and its recent accounts report that it is a going concern and optimistic about its future trading activities. Table 3 presents the financial data extracted from the Sports Co.'s Financial Statements.

Table 3: Financial data for the classification ratios

Financial statement	*Nature of the financial data*	*Description*	£
Statement of financial position	Working capital	Current assets – current liabilities	298,701
Statement of financial position	Total assets	Non-current + current assets	930,966

Income statement	Retained earnings	Profit saved by the Company	322,024
Income statement	EBIT	Profit from day-to-day operations	-£20,132
Statement of financial position	Net worth	Assets over liabilities	482,423
Statement of financial position	Total liabilities	Current + long-term liabilities	448,543
Income statement	Sales	Income & revenue from trading	224,591

Source: Adapted from Sports Co.

After collecting the financial data from the Statements, we can now calculate the ratio for each classification, x1 to x5. The ratio is what is shown in the brackets of the above Z-score metric, such as [x1], [x2], and so on. Each classification calculation involves a division to compute the ratio, which we then multiply by the weight for that classification, such as x1's 0.717. At no point are the computed ratios converted into percentages, as with other financial ratios, such as profitability and return (Hussey, 2014). Rather, the metric only uses the ratio computed for each classification, x1 to x5. What follows in Table 4 are the workings out for each classification ratio x1 to x5.

Table 4: Calculations for the classification ratios - *Source:* Author

Classification	*Workings out*	*Ratio*
x1 =	£298,701/£930,966	0.320851

x2 =	£322,024/£930,966	0.345903
x3 =	-£20,132/£930,966	-0.02162
x4 =	£482,423/£448,543	1.075533
x5 =	£224,591/£930,966	0.241245

The x1 to x5 ratios can now be multiplied using Altman's predetermined weights. To recap, the user cannot change Altman's weights; they are fixed. The weights are somewhat contentious and attracted criticism from commentators, such as Bhandari (2014). Nonetheless, the Z-score has been shown to be a reliable predictor of financial success or distress across the retail and manufacturing sectors, including sport and physical activity. Further, the repeated-measures (Morris, 2010) underscore the reliability of the Z-score metric and its implications for sports companies, such as insolvency and eventual bankruptcy. Table 5 reports the multiplication of each x1-x5 ratio using Altman's weights.

Table 5: The multiplication of the x1 to x5 ratios using Altman's weights (Source: Author)

Classification	*Workings out*	*Figures for the Z-score metric*
x1 =	0.320851 x 0.717	0.2301
x2 =	0.345903 x 0.847	0.293
x3 =	-0.02162 x 3.107	-0.0672
x4 =	1.075533 x 0.420	0.452

x5 =	0.241245 x 0.998	0.241

We can now input the figures into the metric to compute the Z-score for Sports Co. As you will recall, Sports Co. reported a true and fair view of trading, a going concern and optimistic about its future trading activities. Below is the Z-score for Sports Co. Please note that there are no weights or x1 to x5 ratios in the final model, as we have already accounted for these above.

$$0.2301 + 0.293 + -0.0672 + 0.452 + 0.241 = \mathbf{1.149}$$

The Z-score of 1.149 indicates insolvency and a high likelihood of bankruptcy, which challenges the position of the Sports Co. For us, it is also indicative of poor operations performance.

6. To what extent can the Z-score measure system performance

Here, the system concepts, service system performance, and the Z-score comparison with other operational methods are critiqued to assess the extent to which the Z-score can measure system performance.

6.1 System concepts

For sports and physical activity organisations, such as Sports Co., the relevance of *boundary*, as a system concept (Beer, 1979; Checkland, 1981), is crucial in defining their identity as a trading entity. Many commentators have contested the critical importance of boundary judgements, including Scott et al. (2007), Midgley (2000), and Ulrich (1994). However, the account by Stowell et al. (2012) is the most accessible for making sense of boundary decisions, and Midgley (2000) provides a complementary perspective. Sports Co. is a physical entity that we can recognise through its various elements and its position in the external environment where it delivers products and services. Because the boundary concept is relevant, we can define Sports Co. as,

> A sports and physical activity delivery system for individuals seeking to enhance their health and fitness, support their rehabilitation following an injury or illness, or make

lifestyle changes.

We could also illustrate the Sports Co. delivery system using a System Map, as called for by Stowell et al. (2012). A closely related system concept (Checkland, 1981) to boundary is *hierarchy*.

The relationship between hierarchy and boundary is established once the system of interest has been defined. For instance, Sports Co. is a delivery system within the sports and physical activity business environment, operating at the same level as other service providers. At this point, hierarchy becomes more relevant. Beer (1979) views the environment as a system, and systems are nested alongside other systems at the same level of recursion, which are also part of much larger systems. Regardless, the system concepts (Checkland, 1981) apply at all levels of recursion, and Beer's views are applicable to the sports and physical activity sector, as Carter (2005) found from his analysis of national sports resources. Carter concluded that sport is a delivery system, a finding endorsed by Veal (2010), who has long held that leisure, sport, and tourism are interconnected systems connected to other systems, such as public health.

Hierarchy is also relevant internally to organisations through the designed and implemented organisational structures. Sports entities use horizontal and vertical structures to allocate resources and coordinate all work for service delivery. The accounts of Hoye et al. (2022) and Paton et al. (2011) attest to the coordination of efforts across sports entities and service delivery operations, respectively. Hierarchy very much influences the design of entity control systems as well.

Upon further review of the Accounts of Sports Co., it is evident from the Chairman and CEO reports that the entity has control. In their summaries, they indicate performance against the Company Strategy and business objectives. Sports Co., Strategy sets out a clear intent, and the detail in its objectives is wide-ranging. The Board seems alert to trends in their business environment, such as changes in consumer preferences, competitor actions, and consequences of changes to national healthcare policy objectives. How their partnerships and collaborations help achieve their business objectives, too. Their control over the entity is also clear in the Notes to the Accounts, where they provide explanations of the calculations for sales, cost of sales, and business expenses. There is a level of financial transparency to help the reader understand how they arrive at a true and fair view of trading, and why they feel Sports Co. is a going concern, even though our computed Z-score of 1.149 suggests otherwise. However, based on the threshold for what constitutes financial control as determined by Attrill et al. (2014) and Hussey (2014), Sports Co. appears to meet the control benchmark. Further, the system concept of *control* arises from how it influences purposefulness, as theorised by Checkland (1981).

As much as control is evident in the financial information on Sports Co., so too is *communication*. The operationalisation of its Strategy and business objectives appears well-communicated across Sports Co.'s organisational structures. Checkland (1981) highlights the importance of communication in keeping system actors informed and leveraging their collective experiences to deliver the organisation's products and services effectively. The shared learning among system actors aids the organisation and enhances its knowledge-creation processes. Effective communication engages actors and motivates them to strive further toward achieving business objectives. A different side of organisational communication is its strategy. The strategy communicates intent, assures stakeholders and potential partners, and, to a lesser extent, customers. Thus, Sports Co. mostly satisfies the system concept of communication (Checkland, 1981) in how it reports its business affairs.

It is too difficult to give a view on the system concept of *emergence* (Checkland, 1981). To achieve this, access to Sports Co. is necessary to understand how the entity operates in delivering its products and services. What we can say is that it is responsive to the external environment and is monitoring its performance.

In summary, except for emergence, the system concepts theorised by Checkland (1981), namely boundary, hierarchy, control, and communication, seem to apply to sports entities. Thus, we can argue that sports entities are systems.

6.2 Service system performance

If the case is accepted that Z-score satisfies the system concepts (Checkland, 1981), then to what extent does Z-score measure service system performance, as discussed by Palmer (2018)? There can be little doubt that the Z-score measures the performance of the entire service delivery system, such as Sports Co. The delivery system encompasses not only operations management terms but also service quality terms. Contemporary sport and physical activity venues are designed to maximise the customer experience due to the symbiotic relationship among the venue's architect, builder, and operator. (Schwartz et al. 2017; 2015). Their triangular relationship is essential to balancing the technical and functional quality requirements (Gronroos, 1984) of design, build, and technical operation.

The delineation of front- and back-office functions, as called for by Shostak (1985) and Eiglier et al. (1987), is crucial for appreciating the interrelationships of space within the sport and physical activity service delivery system. Slack et al. (2022) delineate functions in their operation's Transformation Process Model, arguing that input from transformed resources, input from transforming resources, and the transformation processes for output products and services to customers. They stress this from the customer perspective, i.e., backwards, to maximise customer satisfaction. They also theorise the operation as a macro-operation, i.e., the whole entity, and as a mix of micro-operations, such as reception, food and beverage, health and fitness, rehabilitation, and changing facilities. Slack et al. indicate that each micro is responsible for implementing the agreed-upon operations strategy and is empowered to do so. It suggests a devolved budgeting approach, which is highly motivating for the managers responsible for each micro.

Much of the above would be formalised in an operation's approach to TQM, such as ISO 9000 (Beckford, 2017), to maximise the execution of the service quality imperatives, i.e., intangibility, inseparability, perishability, and ownership (Palmer, 2014). The service quality dimensions are also measured using SERVQUAL (Parasuraman et al., 1988), which assesses tangibles, reliability, responsiveness, assurance, and empathy. We argue that Z-scores' focus on total assets and sales effectively captures service system performance in financial terms, as well as the inter-relationships among the service quality factors.

6.3 Z-score comparison with other operations management methods

If viewing the entity as a Transformation Process Model (Slack et al., 2022) with embedded systems, then there are other methods available to measure system performance, such as Viable System Methodology (VSM) (Beer, 1979), European Foundation for Quality Management (EFQM) Business Excellence Model (Hakes et al., 2007), Balanced Scorecard (BSC) (Kaplan et al., 1996), Integrated Quality System (IQS) (Castle, 1998; 1996), Six Sigma (Clay, 2018), and the Value Chain (Porter, 1985). The popularity of these methods is evident in Slack et al. (2022), particularly those aligned with TQM, such as EFQM. Ogland and Evans (2025) empirically demonstrated that TQM is more alive than dead, albeit requiring a critical version for contemporary organisations to cope with their environmental complexities and called for a Critical Total Quality Management (CTQM) approach.

Beer's (1979) VSM measures the productivity and latency of a system using indices to improve the efficiency and effectiveness of organisational systems and processes. The improvement to systems and processes is then accomplished using the VSM five sub-systems: 1. Operations, 2. Coordination, 3. Delivery Management, 4. Strategy, and 5. Governance. By applying sub-systems to redesign systems and processes, organisations can significantly enhance their performance, as demonstrated by Sadd et al. (2022) in their application of VSM to create FAME for event planning and management.

EFQM (Hakes et al., 2007) measures business excellence by focusing on enabling and results, including customer results. A high-performing business excellence organisation would score 500+ points out of 1,000, and the difference between the two scores would be an area for leaders to focus on, resources permitting, of course. An appeal of the EFQM is its self-assessment and external validation, and the use of the EFQM Framework can lead to the design and redesign of organisational systems. The EFQM is relevant to private and public entities.

Kaplan et al. (1996) developed the BSC to shift organisations away from just financial measures of performance to a more balanced set of twenty-six indicators focused on learning and growth, customers, internal processes, and financials. Kaplan et al. believed these are critical measures of organisational performance and stimulate improvement when the twenty-six indicators are below the pre-set target. The BSC remains popular and can be used to operationalise strategic objectives, alongside performance measures. A scorecard is unique to each entity and compares its performance across trading periods. It is a self-assessment, but no external validation is provided.

IQS, pioneered by Castle (1998; 1996), measures systems integration and maturity. Although IQS can measure service integration and maturity, its design is inspired by operations management. IQS measures integration and maturity across eight systems: environment, control, strategy and policymaking, focus, production improvement, service, and competitors.

IQS uses predetermined statements to compute the overall percentages. Like the EFQM, an integrated and mature organisation system needs to score ≥50%. However, from Castle's empirical work with IQS, few organisations score ≥50%, even if scoring 500+ using the EFQM metric. Castle believes an integrated, mature system is close to excellent and unlikely to cause customer dissatisfaction. Evans et al. are developing an IQS version to measure organisational governance and leadership.

Six Sigma (Clay, 2018) stimulates improvement across all operations management functions by prioritising defect reduction, minimising variability, and enhancing overall quality and efficiency. All this is designed to reduce costs, increase customer satisfaction, and achieve this through greater employee engagement. Brook (2024) also argues that Six Sigma can sustain competitive advantage and overall profitability in the long run.

Porter's (1985) Value Chain also measures profit through primary and support activities. His Value Chain prompts organisations to seek new synergies and configurations of primary and support activities to generate higher profit margins. The margins materialise through higher sales because of changes to the organisation's Value Chain. Value Chain analysis is a self-assessment exercise with no external validation. For an organisation to realise the benefits of Value Chain analysis, its cost and management accounting processes must account for each primary and support element, such as purchasing, IT, and logistics, as well as the BCG, DPM, and product life cycle (Koch, 1995).

In short, VSM (Beer, 1979) focuses on improving organisational systems and processes, EFQM (Hakes et al., 2007) business processes excellence, the BSC (Kaplan et al., 1996) on balanced indicators for critical systems, IQS (Castle, 1998; 1996) system integration and maturity, Six Sigma (Clay, 2018) on efficiencies of the operations function, and the Value Chain (Porter, 1998) net profit margins via new synergies and configurations of the Value Chain. Each method measures a different thing, so the Z-score complements these methods.

7. Discussion

The z-score (Altman, 1968) is proposed as a statistical technique for measuring system performance. It differs from other methods in that it is a composite measure of system performance, serving as an economic framework for performance measurement. Because of this, when we use a Z-score, we perceive its purpose as producing a *systemic coefficiency of* *performance* for the system of interest, such as Sports Co.

Z-scores measure something different from other methods; thus, they complement them. We perceive its main strengths as a holistic measure of performance. It does not use averages, which was a criticism of SERVQUAL (Parasuraman et al., 1988), and its averaging of averages, which hides a multitude of sins until paired testing was introduced. All the Z-score calculations are based on audited financial data, and for us, the Z-score measures much more than either financial distress or success. For instance, x5 focuses on sales systems and processes, including customer satisfaction, service staff productivity, booking systems, programming, and sales and marketing systems, as called for by McDonald et al. (2016). x3, total assets, i.e., non-current and current assets necessary to deliver products and services to customers, including all asset management systems. Thus, the Z-score will produce an economic measure for each system Transformation Process Model (Slack et al., 2022).

Of course, Z-scores have weaknesses, such as reliance on historical financial data, the language of financial management, which can be daunting to some, and the perceived wizardry of the technique. Some might find interpreting the x1 to x5 ratios difficult, particularly when determining the final Z-score for a system. The fact that no qualitative data is used, some would argue, potentially limits the analysis of a system's performance, as highlighted by Attrill et al. (2022).

The decision to use Z-scores is ultimately one of governance and leadership, regardless of whether it is corporate or nonprofit governance. It is true for the theory of governance we may use to describe governance within entities, such as agency, institutional, or resource dependency, as suggested by Clark (2004). We see the purpose of governance and leadership is to implement the structures and processes necessary to achieve strategic goals, objectives, and direction, and to monitor performance against these imperatives, as endorsed by Hoye et al. (2022). Ogland et al. (2025) also called for governance and leadership to effectively implement TQM initiatives, such as ISO 9000 and Six Sigma, as often the missing activity that leads to TQM projects failing or, at the very least, delivering modest operational efficiencies or customer satisfaction indices. These observations undoubtedly point to an opportunity to apply the Z-score to TQM and project management, as these will present very different challenges for the model's utility.

Firkins et al. (2012) stress four strategic roles for entities and their second: to set a very clear vision and mission for the organisation, and to develop the skills to monitor progress towards the strategic goals. They view this as a critical capability of governance and leadership. Likewise, Henry et al. (2004) highlight efficiency and effectiveness as two of their eight good principles of organisational governance. However, Geeraert et al. (2022) remain highly sceptical of organisations and their monitoring and control processes. The Z-score would help address this as a whole-system measure, and one focused on the utilisation of resources by managers, even though work would be required to establish the x1 to x5 baseline measures using an organisation's historical financial data.

Nonetheless, having used Z-score on multiple occasions, the user can supplement its analysis with alternative ratios, such as long-term stability and solvency (Hussey, 2014). Many BSc and MSc students have done this, leading to more probing analyses, such as Ballam (2022). Z-score complements well the System Dynamics (Forrester, 1961), type methods, such as Warren’s (2008) strategic management dynamics and its focus on future performances through time, Morecroft (2007) strategic modelling and business dynamics to improve feedback systems, and Sterman (2000) and his systems thinking and modelling for a complex world through the use of causal diagrams. Because of these benefits, we feel the Z-score is a valuable inclusion in the methods for system analysis; however, as a *systemic coefficency of performance*.

8. Conclusion

This paper presents a case for the inclusion of the Z-score (Altman, 1968; 1993) in system performance analysis. We believe the Z-score is a useful measure, and we will continue to use the technique for the *systemic coefficiency of performance* measure of a system of interest.

As we move forward, we will continue to apply the Z-score in the sport and physical activity sector and further investigate the x1-x5 weights. We intend to create baseline ratio measures for the different types of sport and physical activity organisations and develop other measures to supplement the x1 to x5 ratios and the final Z-score for the system of interest. Lastly, to introduce systems thinking, systems practice (Checkland, 1983) to BSc and MSc students.

References

Achim, M. V. & Borlea, S. N. (2010). Business Performances: Between profitability, return and growth. Annals of the University of Craiova Economic Series, 2 (38), 1–12.
Altman, E. I. (2013). Predicting financial distress of companies: Revisiting the Z-score and ZETA models. In Bell, A. R., Brooks, C. & Prokopczuk, M. 2013. *Handbook of research methods and applications in empirical finance*, Cheltenham: Edward Elgar Publishing.
Altman, E. I. (1968). Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy. *Journal of Finance*, 23 (4), 589-609.
Attrill, P. & McLaney, E. (2021). *Accounting and Finance for Non-Specialists*, 12th Edn. Harlow: Pearson.
Ballam, L. (2022). An investigation into capital structure in the UK health and fitness industry using the Z-score method, *Bournemouth University Business School*, June 2022.
Bardia, S. C. (2012). Predicting Financial Distress and Evaluating Long-term Solvency: An Empirical Study, *IUP Journal of Accounting Research & Audit Practices*, 11 (1),47–61.
Beckford, J. (2017). *Quality: A Critical Introduction*, 4th Edn. London: Routledge.
Becket, M. (2004). *How the Stock Market Works: A Beginner's Guide to Investment*, 4th Edn. London: Kogan Page Publishers.
Beer, A. S. (1979). *The Heart of Enterprise*, London and New York: John Wiley & Sons.
Bhandari, S. B. (2014). Two Discriminant Analysis Models of Predicting Business Failure: A Contrast with the First Model, *American Journal of Management*, 14 (3), 11–19.
Boigues, S. R. (2016). *An empirical factor analysis of efficiency and profitability ratios in the US retail industry*, Michigan: ProQuest.
Buswell, J., Williams, C., & Sutton, C. (2022). *Service quality in leisure, events, tourism and sport*, 2nd Edn. Wallingford: CABI Publishing.
Carter, P. (2005). *Review of National Sport Effort and Resources*, London: Sport England.
Castle, J. A. (1998). New methodologies for integrating quality management, *The TQM Magazine*, 10 (2), 83–88.
Castle, J. A. (1996). An integrated model in quality management, TQM, BPR and ISO 900, *The TQM Magazine*, 8 (5), 7–13.
Checkland, P. B. (1981). *Systems Thinking, Systems Practice*, Chichester: John Wiley & Sons.
Clarke, T. (2004). *Theories of Corporate Governance*, Oxon, UK: Routledge.
Clay, K. (2018). *Why They Fail… and the Simple Keys to Success*, Dallas: Six Sigma Development Solutions, Inc.
Eiglier, P. & Langeard, P. (1987). *Servuction*, New York: McGraw-Hill.
Ferkins, L. & Shilbury, D. (2012). Good boards are strategic: What does that mean for sport governance of sport organisations, *Journal of Sport Management*, 26, 67–80.
Forrester, J. W. (1961). *Industrial Dynamics*, Cambridge, Mass: MIT Press.
Gerantonis, N., Vergos, K. & Christopoulos, A. G. (2009). Can Altman Z-score Models Predict Business Failures in Greece? *Research Journal of International Studies*, 12 (10), 21–28.
Geeraert, A. & van EeKeren, F. (2022). *Good Governance in Sport: Critical Reflections*, London: Routledge.
Gronroos, C. (1984). A service quality model and its marketing implications, *European Journal of Marketing*, 18 (4), 36-43.
Hakes, C. & Wilkinson, J. (2007). *The EFQM Excellence model for Assessing Organisational Performance: A Management Guide*, Van Haren Publishing, Zaltbommel, www.vanharen.net
Hayes, S. K., Hodge, K. A., & Hughes, L. W. (2010). A study of the efficacy of Altman's Z to predict bankruptcy of speciality retail firms doing business in contemporary times. *Economics and Business Journal: Inquiries and perspectives*, 3 (1), 122–134.
Henry, I. & Lee, P. C. (2004). Governance and ethics in sport, in J. Beech and S. Chadwick (eds). *The Business of Sport Management*, London: Prentice Hall.
Hussey, R. (2014). *MBA Accounting*, Basingstoke: Palgrave Macmillan.
Holmes, K., Hughes, M., Mair, J. & Carlson, J. (2015). Events and Sustainability, Abingdon: Routledge.
Hoye, R., Smith, H. C. T., Nicholson, M. & Stewart, B. (2022). *Sport Management: Principles and*

Applications, 6th Edn. London: Routledge.
Kaplan, R. S. & Norton, D. P. (1996). *The Balanced Scorecard: Translating Strategy into Action*, Boston, Massachusetts: Harvard Business School Press.
Karadag, H. (2015). Financial Management Challenges in Small and Medium-sized Enterprises: A Strategic Management Approach. *Emerging Markets Journal*, 5 (1), 26-40.
Koch, R. (1995). *Strategy: How to Create and Deliver a Useful Strategy*, London: FT & Pitman Publishing.
McDonald, M. (2016). *Marketing Planning: Understanding Marketing Plans and Strategy*, 2 Edn. London: Kogan Page.
Midgley, G. (2000). *Systemic Intervention: Philosophy, Methodology and Practice*. New York: Kluwer Academic & Plenum Publishers.
Mitani, H. (2014). Capital structure and competitive position in the product market. *International Review of Economics & Finance*, 29, 358–371.
Morecroft, J. (2007). *Strategic Modelling and Business Dynamics: A feedback systems approach*, Chichester: John Wiley & Sons, Ltd.
Morris, C. (2010). *Quantitative Approaches in Business Studies*, 7th Edn. Harlow: Pearson's Education Limited.
Mognetti, J. F. (2002). Organic Growth: *Cost-effective Expansion from Within*, Chichester: Wiley & Sons.
Nguyen, N. T. V., Nguyen, C. T. K., Ho, P. T. M., Nguyen, H. T., & Nguyen, D. V. (2021). How does capital structure affect a firm's market competitiveness? *Cogent Economics & Finance*, 9 (1), 2002501.
Naiping, Z. & Li, Z. (2011). The evaluation of financial risks of listed companies based on the empirical evidence from the Chinese Stock Market, *Tiangsu University*, China: Zhenjiang.
Ogland, P. & Evans, G. (2025). Total Quality Management: Dead or Alive? *Systemist*, Vol. 26, (1), pp.2-27
Ogland, P. & Evans, G. (2025). Fact of Fiction: TQM's Need for Governance and Leadership, *Systemist*, Vol. 46, (1), pp.1-14
Palmer, A. (2014). *Principles of Services Marketing*, 7th Edn. Maidenhead: McGraw-Hill.
Parasuraman, A., Zeithaml, V. A. & Berry, L. L. (1988). SERVQUAL: A multiple scale for measuring consumer perceptions of service quality, *Journal of Retailing*, 62 (Spring), 12–40.
Paton, S., Clegg, B., Hsuan, J. & Pilkington, A. (2011). *Operations Management*, London: McGraw-Hill.
Porter, M. E. (1985). *Competitive Advantage: Creating and Sustaining Superior Performance*, New York: Free Press.
Sadd, D., & Evans, G. (2022). The development of a new framework for assessing major events informed by systems thinking. *Systemist*, *43*(1), 25–48.
Schwarz, E. C., Westerbeek, H., Liu, D., Emery, P. & Turner, P. (2017). *Managing Sport Facilities and Major Events*, 2nd Edn. London: Routledge.
Schwarz, E. C., Hall, S. A. & Shibli, S. (2015). *Sports Facility Operations Management: A Global Perspective*, 2nd Edn. London: Routledge.
Scott, W. R. & Davis, G. F. (2007). *Organizations and Organizing: Rational, Natural, and Open System Perspectives*, New Jersey: Pearson International Edition.
Shostack, G. L. (1985). Planning the service encounter, in J. A. Czepiel, M. R. Solomon & C. F. Suprenant (eds), *The Service Encounter*, Lexington, MA: Lexington Books, 243–54.
Slack, N., Brandon-Jones, A. & Burgess, N. (2022). *Operations Management*, 10th Edn. Harlow: Pearson.
Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modelling for a Complex World*, New York: Irwin McGraw-Hill.
Szymanski, D. M., Bharadwaj, S. G. & Varadarajan, P. R. (1993). An analysis of the market share and profitability relationship. *Journal of Marketing*, 57(3), 1-18.
Stowell, F. & Welch, C. (2012). *The Manager's Guide to Systems Practice: Making Sense of Complex Problems*. Wiley.

Taffler, R. J. (1984). Empirical models for the monitoring of UK corporations. *Journal of Banking and Finance*, 8 (2), 199–227.

Ulrich, W. (1994). *Critical Heuristics of Social Planning: A new approach to practical philosophy*, 2nd Edn. New York and London: John Wiley & Sons.

Veal, A. J. (2010). *Leisure, Sports and Tourism: Politics, Policy and Planning*, Wallingford: CABI Publishing.

Warren, K. (2008). *Strategic Management Dynamics*, Chichester: John Wiley & Sons, Ltd.

Wild, J. J., Subramanyam, K. R., & Halsey, R. F. (2007). *Financial Statement Analysis* [online], New Delhi: Tata and McGraw-Hill Publishing Company Ltd.

UK Systems Society

UK Systems Society Gold Medallists

Professor Russell Ackoff
Professor Stafford Beer
Dr Frijov Capra
Professor Peter Checkland
Professor C.West Churchman
Professor Humberto Maturana
Sir Geofrey Vickers

***Systemist* is the publication of**

The United Kingdom Systems Society