

Systems Thinking in Public Health: A Bibliographic Meta-Narrative Review

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Background

Research across the formal, natural and social sciences has greatly expanded our knowledge about complex systems in recent decades, informing a broadly inclusive, cross-disciplinary conceptual framework referred to as Systems Thinking (ST). Its use in public health is rapidly increasing, though there remains a poor understanding of how these ideas have been imported, adapted and elaborated by public health research networks worldwide.

Method

This review employed a mixed methods approach to narrate the development of ST in public health. Tabulated results from a literature search of the Web of Science Core Collection database were used to perform a bibliometric analysis and meta-narrative content review. Annual publication counts and citation scores were used to analyse trends and identify popular and potential 'landmark' publications. Citation network and co-authorship network diagrams were analysed to identify groups of articles and researchers in various network roles.

Results

Our search string related to 763 publications. Filtering excluded 208 publications while citation tracing identified 2 texts. The final 557 publications were analysed, revealing a near-exponential growth in literature over recent years. Half of all articles were published after 2010 with almost a fifth (17.8%) published in 2014. Bibliographic analysis identified 5 distinct citation and co-authorship groups homophilous by common geography, research focus, inspiration or institutional affiliation.

As a loosely related set of sciences, many public health researchers have developed different aspects of ST based on their underlying perspective. Early studies were inspired by Management-related literature while later groups adopted a broadly inclusive understanding which incorporated related Systems sciences and approaches.

Conclusion

ST is an increasingly popular subject of discussion within public health though its understanding and approaches remain unclear. Briefly tracing the introduction and development of these ideas and author groups in public health literature may provide clarity and opportunities for further learning, research and development.

1.0 Introduction

The recognition and desire to understand patterns in systems all around us has stimulated a rapidly growing body of knowledge which is increasingly being applied to the field of public health. The study of complex phenomena and systems has evolved across multiple disciplines and research streams over time to form an overlapping set of sciences with a common philosophical basis.¹ At its root lies an alternative viewpoint that seeks to redress a commonly perceived traditional scientific bias towards Reductionism.² Instead, emphasis is placed on the relationships between the parts that form a physical system in addition to understanding the individual parts and their environment separately.³

The exploration of complex systems in modern Western scientific literature is often traced back to the field of Cybernetics, an interdisciplinary science related to the study and control of systems governed by regulatory feedback.⁴ In particular, the study of biological systems, open to their environment and regulated by homeostatic principles, led to a broadly proposed and widely applied mid-twentieth century 'General Systems Theory'.⁵

Over subsequent decades, research across the formal, natural and social sciences has greatly expanded our knowledge about systems to include a broad range of related concepts and theories. Abstract mathematical studies have contributed widely to adapted theories of Chaos⁶, Control⁷ and Complexity⁸, while applied mathematical modelling techniques have spawned entire new fields such as Operational Research (OR) and Systems Biology. Further empirical studies of physical and biological systems have revealed notions of 'self-organisation' and 'emergence', observed from the molecular to the social scale.⁹ An emphasis on relationships has also advanced our understanding of networks, initially investigated by sociologists and later aided by natural scientists to explore clustered 'small world' and fractal 'scale-free' patterns in complex systems such as the globalised society, the human body and the internet.¹⁰

The knowledge generated from studying complex systems in multiple disciplines has fed into the development of a cross-disciplinary "conceptual framework" referred to as Systems Thinking (ST). Systems Thinkers often contend that complex systems such as the immune system or the global economy cannot fully be understood by simply analysing their constituents. Rather, they argue the importance of incorporating the study of often non-linear and dynamic relationships between networks of 'agents' and the environment surrounding a conceptual Complex Adaptive System (CAS).² Through the collective self-organisation, adaptation and co-evolution of these networks of

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3 agents, Systems Thinkers propose that whole-system characteristics distinctly 'emerge' which differ
4 from the characteristics of the agents themselves.¹¹
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7 An increasing awareness of networks combined with better instrument sensitivity and growing
8 private sector demand has influenced the development of much scholarly as well as non-academic
9 literature around these concepts. The appeal of adopting a Systems view and adapting Systems ideas
10 to the applied field of *public* health seems natural given its traditional focus on complex social-scale
11 interventions. However, there remains a poor understanding of the use and development of these
12 abstract ideas in public health academic literature. This paper aims to contribute by bibliographically
13 tracing and analysing trends and clusters in the evolution of Systems Thinking as it has been
14 imported, adapted and elaborated by public health research networks worldwide.
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20 21 22 23 **2.0 Method**

24 25 2.1 Literature search

26 This review employed an inductive mixed methods approach to narrate the introduction and
27 development of ST in public health, guided by citation and co-authorship network diagrams based
28 on a literature search result from the Reuters Web of Science Core Collection database. A scoping
29 review was initially conducted to identify a number of terms popular and commonly used in ST in
30 order to populate a search string while generic terms such as 'complexity' were avoided to increase
31 specificity. Relating the ideas to public health, broadly inclusive terms were used in an attempt to
32 capture the full scope of research being conducted. The final search string was "systems thinking"
33 OR "complex adaptive system*" OR "complexity science*" OR "complexity theory" OR "non-linear
34 dynamic*" AND "health" OR "health system" OR "public health". The tabulated results were
35 downloaded and used to perform a bibliometric and bibliographic analysis to map the field and its
36 authors, followed by a meta-narrative review.
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49 2.2 Bibliometric and Bibliographic Analysis

50 Within the field of Library & Information Science, scholars have developed methods to tease out
51 relationships and clusters of literature by statistical analysis of citation links and co-authorship. The
52 time-based bibliographic mapping of a direct citation network is referred to as 'algorithmic
53 historiography', devised by Garfield and Sher in the 1960's.¹² A direct citation forms a directional and
54 un-weighted tie from a citing publication to an earlier cited one and the method is used to provide a
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3 'genealogical' graphical representation of a scientific history. This is based on the assumption that
4 "the bibliographic information contained in a collection of published scientific articles is sufficient for
5 the purpose of recapturing the historiographic structure of the field".¹² It was also used here to
6 identify potential 'landmark' publications and their bibliographic antecedents and descendants. For
7 the visualisation and analysis of these citation networks, the 'CitNetExplorer' programme was
8 used.¹³

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13 The annual publication counts and citation scores for matched and un-matched versions of the
14 dataset were used to identify popular texts. Annual counts were calculated using Microsoft Excel
15 based on a dataset filtered by the manual application of inclusion and exclusion criteria. Un-matched
16 citation scores include citation links with publications not within the search string results. This
17 helped to identify popular and grey literature indirectly related to the literature search. The matched
18 dataset was then used to generate citation network diagrams that visualised connections between
19 publications over time. Through an iterative process of exploration, a modified version of a
20 modularity-based clustering algorithm was used to identify several citation clusters to guide the
21 narrative review. Similarly, co-authorships network diagrams were developed based on the original
22 dataset using the 'VOSViewer' network visualisation software. Lead authors were clustered using the
23 'visualisation of similarities' (VOS) technique, a validated alternative to the commonly used
24 multidimensional-scaling and hierarchical clustering combination method.¹⁴

25 26 27 28 29 30 31 32 33 34 35 36 2.3 Meta-Narrative Review

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38 Alongside the development of citation and co-authorship network diagrams, a meta-narrative
39 literature review was carried out based on methodological guidance published by Wong et al.¹⁵ The
40 six guiding principles of Pragmatism, Pluralism, Historicity, Contestation, Reflexivity and Peer Review
41 were adhered to as best able, though limitations remained. The narrative is loosely ordered
42 chronologically to provide historical and relational context. Instead of attempting to catalogue the
43 entire breadth of systems ideas applied to public health, this review focused on highly-connected or
44 'central' nodes within groups and clusters of articles and authors in order to characterise several
45 research fronts that dominate the 'over-arching storyline'. Their influence was determined by a
46 combination of citation scores, VOS clustering and content review. In addition to network-based
47 identification of relevant literature, a manual search of the tabulated dataset was undertaken using
48 an inclusion and exclusion criteria. The dataset was reviewed iteratively in a sense-making process of
49 gradual knowledge development.

The final inclusion criteria for the content analysis were:

- Articles related to public health, utilising the WHO definition of “all organised measures (whether public or private) to prevent disease, promote health and prolong life among the population as a whole”.¹⁶
- All original and review articles related to ST within the public health domain based on title and abstract review. Those regarded as ‘unsure’ were marked and explored by full text review where possible.

Exclusion criteria were:

- any publications not related to public health;
- any publications not related to the study of complex systems or Systems Thinking
- any publication not in the English language;
- any book reviews;
- conference abstracts;
- publication duplicates.

3.0 Results

3.1 Results Tree

Our search string related to 763 publications searched in the Thomson Reuters WoS Core Collection Database. Filtering resulted in the exclusion of 208 publications: 177 were not related to public health, 18 were not related to ideas about complex systems or Systems Thinking, six were not accessible in the English language, three were book reviews, a further three were conference abstracts and one was duplicated. The remaining 555 publications were analysed alongside citation and co-authorship network diagrams, with a focus on eliciting research groups and citation clusters. Citation tracking was conducted using CitNetExplorer in an iterative process to add two grey publications.

3.2 Publication Count Analysis

Using Microsoft Excel, we created a bar chart displaying annual publication count with a line graph overlaid displaying percentage relative cumulative frequency. The general trend indicates that there has recently been a near-exponential growth ($R^2 = 0.9365$) in literature around this particular subject, though overall counts remain modest. The first article in the dataset was published in 1994, a management thought piece on the relevance of mathematical Chaos and Complexity theories in 'Total Quality Management'.¹⁷ Growth in literature between 1994-2006 was relatively slow, accounting for only 20% of the filtered dataset. Half of all articles were published after 2010 and almost a fifth (17.8% or 99 articles) published in 2014, the highest recorded annual publication count (Figure 2).

3.3 Top 20 Cited Publications

The dataset was analysed using CitNetExplorer for citation tracking, tracing references-of-references and identifying popular publications among authors in citation lists of the dataset, revealing a citation map comprised of 830 'node' articles. We focused on clusters and identified the 20 most cited publications by authors in the dataset,¹⁸⁻³⁷ which also revealed academic and grey literature not identified in the original search results (See Figure 1). 12 of the top 20 were peer-reviewed academic publications, two were institutional reports and six were non-academic

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3 scientific, management thinking and philosophy texts. A content review helped to identify groups of
4 authors and articles which included several of the top 20 most frequently cited.
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10 The earliest academic Top 20 text (#18)³⁵ was published in 1998 and followed up by others in 2001
11 (#10)²⁷ and 2005 (#17)³⁴ from authors representing a research group studying organisational
12 management and change in the US primary healthcare system inspired by “Complexity Theory”.³⁵
13 Similarly, the 4 most frequently cited academic articles in the top 20 were published in 2001 in the
14 BMJ (#1, 2, 4 and 5)^{18, 19, 21, 22} and constitute a highly cited series introducing leadership,
15 management and education-related “Complexity Science”¹⁸ to healthcare professionals. A third set
16 of publications (#11, 14 and 19)^{28, 31, 36} in the American Journal of Public Health in 2006 described
17 insights from a transdisciplinary ‘Initiative on the Study and Implementation of Systems’ (ISIS)
18 project, which sought to test a collection of Systems ideas to explore a complex international
19 tobacco-control public health network; this was followed up with another Top 20 article by the
20 authors in 2008 (#20)³¹.
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28 Of the two institutional reports, the first (#7)²⁴ was published by the US Institute of Medicine in 2001
29 and promoted innovative change in the healthcare system with a section on CAS written by Plsek,
30 one of the BMJ Series authors. The other report (#6)²³ is a 2009 introductory primer on ST published
31 by the WHO’s ‘Alliance for Health Policy and System Research’ (AHPSR), which also promoted ST
32 along the 4 ISIS project approaches.
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37 The remaining six non-academic texts (#3, 8, 9, 12, 13 and 16)^{20, 25, 26, 29, 30, 33} identified in the Top 20
38 were all written in the 1990’s by authors affiliated with the Santa Fe institute, a popular
39 interdisciplinary research organisation promoting systems research. They conveyed cross-
40 disciplinary ideas about complex systems observed in a number of disciplines through the use of
41 metaphors and analogies. The popularity of the books among our dataset’s authors warrants further
42 exploration but was outside the scope of our review.
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50 **4. Bibliographic Narrative Review**

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52 Our bibliographic analysis identified at least 5 distinct and prominent citation or co-authorship
53 groups, homophilous by common authorship, geography, research focus, inspiration or institutional
54 affiliation (Table 1).
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4.1 US Primary Care Group

The earliest research group identified was formed of US-based healthcare management academics. Among them were Miller, Crabtree, McDaniel and Stange, authors of the #18 publication “Understanding Change in Primary Care Practice Using Complexity Theory”.³⁵ The authors claimed inspiration from a popular bestselling Management Thinking book by Wheatley entitled ‘Leadership and the New Science’ (1992)³⁸ to develop a “complexity model of practice organisation”³⁵ and later worked with Anderson to develop an associated case-study methodology (#17). Their intention was to understand ‘resistance to change’, a well-documented but poorly understood phenomenon affecting many family practices in the “turbulent and difficult” era of US Managed Care.³⁵

Miller et al. applied Wheatley’s leadership framework, itself inspired by mathematical Chaos theory principles, to conceptualise a CAS as a combination of internal models which they visualised with Venn-like diagrams. They further employed analogies of ‘Attractors’, another abstract Systems concept, to signify competing visions or desired end states illustrated as dots in the Venn field. Like many Systems Thinkers, they described CAS characteristics such as non-linearity, nested systems, emergence, self-organisation and adaptive co-evolution using rich metaphors of lines and shapes to analyse individual and organisation-level behaviour. Subsequent articles incorporated terms such as ‘bifurcations’ from Chaos Theory and explored other abstract concepts such as surprise, creativity and learning.^{39, 40}

The authors’ work represents the earliest identifiable research group in our dataset focusing on CAS-inspired Healthcare Management, adapted during a wave of popular book releases by many Systems scholars at a time of large scale transformation in the US public health system. Citation tracing and content review revealed descendant publications by their colleagues who build on this highly metaphorical conceptualisation to trial new case study³⁴ and mathematical modelling methods such as Agent-Based Modelling.⁴¹ Our analysis of this co-authorship network also revealed a weak link between the US Primary Care Group and another more heterogeneous network of authors with some highly central actors (Figure 3).

4.2 Forum on Systems and Complexity in Medicine and Healthcare

Linked by co-authorship to two US Primary Care Group members, Martin & Sturmberg are identified as highly central actors in a diverse research group homophilous by affiliation with the Journal of Evaluation in Clinical Practice's multidisciplinary 'Forum on Systems and Complexity in Medicine and Healthcare', of which the late 'Complexity and Postmodernism' (1998) philosopher Paul Cilliers was series editor.²⁰ Cilliers was identified in the top 20 (#3)²⁰ while Sturmberg and Martin were found to be a prolific pair of authors metaphorically exploring complex systems in family practice.

The Forum is a loose, heterogeneous network of researchers, including scholars from the US Primary Care Group and the BMJ Series, with varying interests relating to primary care and public health. In a 2011 article, of the 56 publications cited by Sturmberg as the Forum's contribution the pair was found to have co-authored a combined 21 (37.5%).⁴² In keeping with its late editor's specialism, the Forum's work is characterised by an extensive use of metaphors and analogies adapting abstract Systems ideas and principles from other disciplines to public health, usually at the social scale. Such adaptation can often be prone to misrepresentation, resulting from 'export' and 'context' effects when transferring concepts from one discipline or context to another.¹¹ It is therefore important to empirically validate these ideas, though doing so remains a significant challenge.

Citation tracing also revealed the pair to have co-edited an introductory 'Handbook of Systems and Complexity in Health', a compendium of 51 articles published in 2013 with Forum members and several other experts.⁴³ The handbook aimed to address a pressing need for greater explanatory literature and promotes this highly metaphorical use of systems theories and methods as they relate to healthcare and public health.

4.3 BMJ Series

The BMJ Series was published in 2001 by American and British authors Plsek, Greenhalgh, Wilson, Holt and Fraser following the introduction of a large-scale regulatory change in English health system performance management known as the 'National Service Framework'. In further similarity with the

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3 US Primary Care Group, the articles echoed prevailing metaphorical conceptualisations of CAS at the
4 social scale inspired by Management Thinking: with internalised agent rules, fuzzy boundaries, non-
5 linearity, unpredictability and analogies of 'Emergence'. However the 'Attractor' concept was re-
6 interpreted by this group to signify an idea closer to 'underlying motivation' rather than a 'vision' as
7 proposed by the US Primary Care Group.¹⁸
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11 The BMJ Series preferred the term "Complexity Thinking"¹⁹ to Systems Thinking, unfortunately the
12 latter is also confusingly used as a shortened form for Critical Systems Thinking, a subset of
13 Operational Research. The authors adopted a broad, accessible approach to explore leadership,
14 healthcare management and learning from a complex systems perspective and used the articles to
15 introduce Systems concepts to healthcare professionals. The ideas resonated greatly with readers
16 and a large number of descendant publications such as those illustrated below (Figure 4) sought to
17 adapt the introductory concepts to their particular field of inquiry. Further variation in
18 understanding attributable to export and context effects from transferring Systems ideas has often
19 led to increased confusion and calls for caution by critics who point to a lack of empirical validity in a
20 nascent science.⁴⁴
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29 The authors have defended their highly popular contribution,⁴⁵ highlighting the subsequent
30 elaboration of their ideas in other publications while arguing the need for greater epistemological
31 development and advocating the use of novel social science methodologies such as the Meta-
32 narrative⁴⁶ and Realist Review⁴⁷ developed by Greenhalgh et al. The latter method's application to a
33 local Canadian health system in 2012 also relates this group by co-authorship to the next.
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4.4 The Initiative on the Study and Implementation of Systems (ISIS) Project

The ISIS tobacco control project was a US National Cancer Institute (NCI) funded, a four-year transdisciplinary supply-side tobacco-control initiative. Inspired by the adoption of Systems approaches in other economic sectors, its initial aim was to study the public health tobacco-control system and address common systemic challenges such as fragmented or duplicated efforts, limited integration of research and a lack of co-ordination among providers.³ The researchers adopted a broadly inclusive and unifying viewpoint championing Systems Thinking, described as a 'conceptual framework' or worldview that transcended Reductionist, Critical Realist and Constructivist perspectives and on which basis multiple related Systems approaches have been developed. The project's scope eventually increased to incorporate 4 major approaches: Systems Organising, System Dynamics, Network Analysis and Knowledge Management applied at the inter-organisational and international scale with the aid of participatory methods such as 'concept mapping', a statistical clustering method for semantic statements.⁴⁸ The project eventually broadened its focus from the application to tobacco-control towards understanding "approaches to integrated systems thinking" and "how to apply systems thinking to improve health outcomes".³

The ISIS tobacco-control project contributed several articles to the top 20 list of publications in 2006 (#11, 14 and 19) and followed up with an expansive monograph entitled 'Greater than the Sum'.^{28,31,36,3} In promoting Systems Thinking, the authors sought to unify the varying perspectives, vocabulary and understanding among the related Systems sciences. They also identified several cross-cutting methodological features with common processes, technologies and analytical techniques that could improve future mixed methods Systems research. This conceptual framework and its 4 key approaches were recently adopted at a global scale by the WHO in a bid to promote a better understanding of health systems and their interventions, particularly in Low and Middle Income Countries (LMICs).²³

4.5 WHO AHPSR Group

The WHO Alliance for Health Policy and Systems Research ('Alliance') is an institutional body promoting 'Systems Thinking for Health Systems Strengthening' interventions, most notably through its Top 20 flagship report published in 2009 (#6) and subsequent cluster articles exploring various Systems approaches. The report married together the six-building block WHO Health System framework⁴⁹ with the ISIS tobacco-control project's conceptualisation of Systems Thinking and its

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3 emphasis on the four prominent Systems approaches (Organising, Dynamics, Networks and
4 Knowledge) in an introductory primer co-edited by De Savigny & Adam.
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9 The primer was followed by special supplements published in 2012 and 2014. The first elaborated on
10 the application of Systems ideas to the health system and its existing frameworks, promoting use
11 through case study examples.^{50, 51} The latter series was a larger collection of studies conducted by a
12 network of scholars worldwide exploring the use of these approaches to better understand health
13 systems in LMICs. Entitled 'Advancing the Application of Systems Thinking in Health', it promoted
14 mixed-methods research combining qualitative aspects of System Dynamics and Network Analysis
15 with social science methods such as Realist Evaluation and its variants.⁵²⁻⁶⁵
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21 The adoption and promotion of Systems Thinking by the WHO has contributed a significant portion
22 of new empirical literature at a coarser meso-macro scale in comparison to earlier micro-meso
23 study. The use of the 2007 WHO health system framework has also emphasised geographical health
24 systems in the group's applied research which differs from earlier issue-focused systems such as the
25 tobacco-control system. Its authors acknowledged that Systems approaches are not limited to the 4
26 commonly mentioned and highlight a number of useful Systems ideas, methods and tools applicable
27 to complex problems in health systems worldwide.⁶⁵
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33 **5. Discussion**

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35 The study of complex systems no longer remains a novel pursuit but has been studied for decades
36 using various methods in a number of disciplines and applied fields. However the emergence of
37 complexity theories in public health is a more recent phenomenon which has focused the attention of
38 practitioners and researchers towards ideas such as connectedness, non-linearity, co-evolution,
39 uncertainty and unpredictability. These ideas influence how public health experts view their research
40 environment and understand what happens in populations.
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46 In this review, we bibliographically traced the evolution of Systems Thinking as some of its concepts
47 were adapted from Management-related academic and popular literature, and later expanded to
48 incorporate related Systems sciences and approaches. We demonstrated a wide resonance of systems
49 ideas among practitioners observing complex biopsychosocial and ecological patterns in public health
50 at multiple scales. The direction of change in scale and complexity of research has also gradually
51 expanded over time from micro-meso scale case studies to include meso-macro levels of mixed
52 methods multinational empirical study.
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3 Analysing the five multidisciplinary research groups identified in our results highlighted the varying
4 conceptualisation of these ideas. As a loosely related set of sciences, many public health researchers
5 have combined different aspects of Systems Thinking based on their underlying perspective. The
6 multiplicity of possible combinations of elements may be an obstacle for creating consensus among
7 researchers but is also seen at this early stage as a demonstration of the concept's elasticity across
8 different disciplines, visions and contexts. The adoption of a broadly inclusive and unifying
9 conceptualisation of Systems Thinking in public health can facilitate further transdisciplinary
10 epistemological research to develop validated and effective methods of studying Systems principles
11 and evaluating complex interventions which may not best be suited to Randomised Control Trials
12 and other reductive mechanisms of inquiry.
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20 However Systems Thinking will need to be developed further into concrete and practical approaches
21 and methods. It offers an opportunity to create alternatives to approaches that have shown their
22 limits: linear planning methods which assume predictable outcomes and do not provide enough
23 flexibility in the management of public health interventions. Further validation of mixed methods
24 approaches and the correlation of observed patterns with existing Systems principles may help to
25 close an as-yet unaccomplished feedback loop milestone whereby Systems Thinking informs our
26 knowledge-about-systems, rather than simply being informed by it.¹¹
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32 Following this, we can expect more primary studies to investigate how these novel approaches can
33 have an effect on the practice of professionals and ultimately on populations' health. The debates
34 around complexity will continue in public health and more frameworks will be developed. The search
35 for workable frameworks will create rich and novel ideas and influence public health practice in the
36 future.
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41 Systems Thinking has the power of changing the structure and dynamic of relationships between the
42 actors within health systems and their respective role. These approaches recognise the need to
43 incorporate the perspective of every actor and integrate these visions into future plans. This may
44 become an avenue to give more power to civil society and communities in the management of public
45 health programmes.
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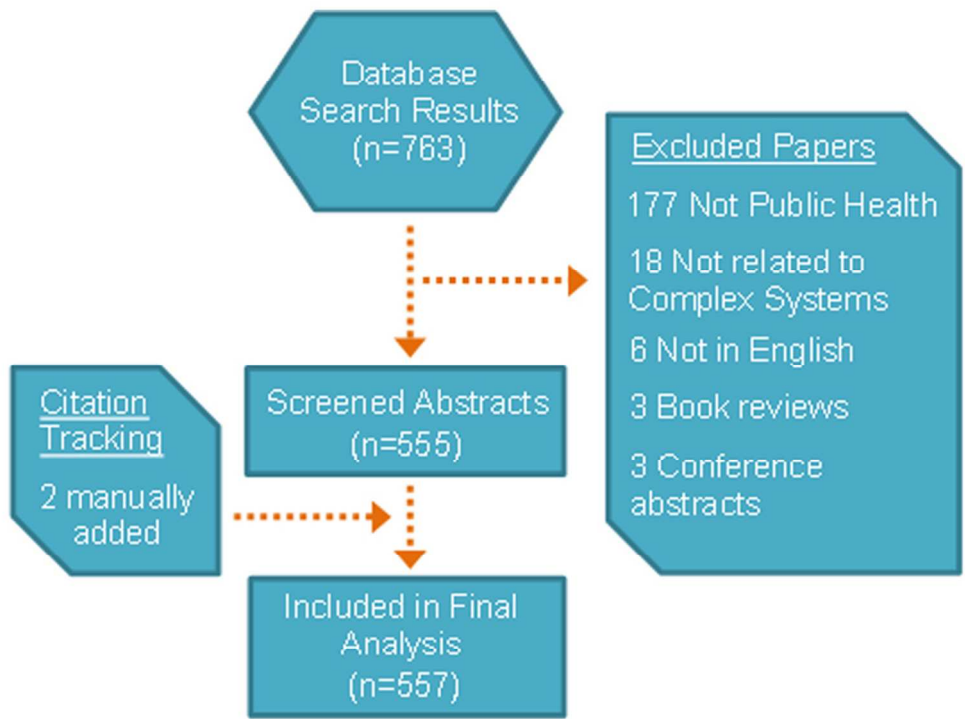
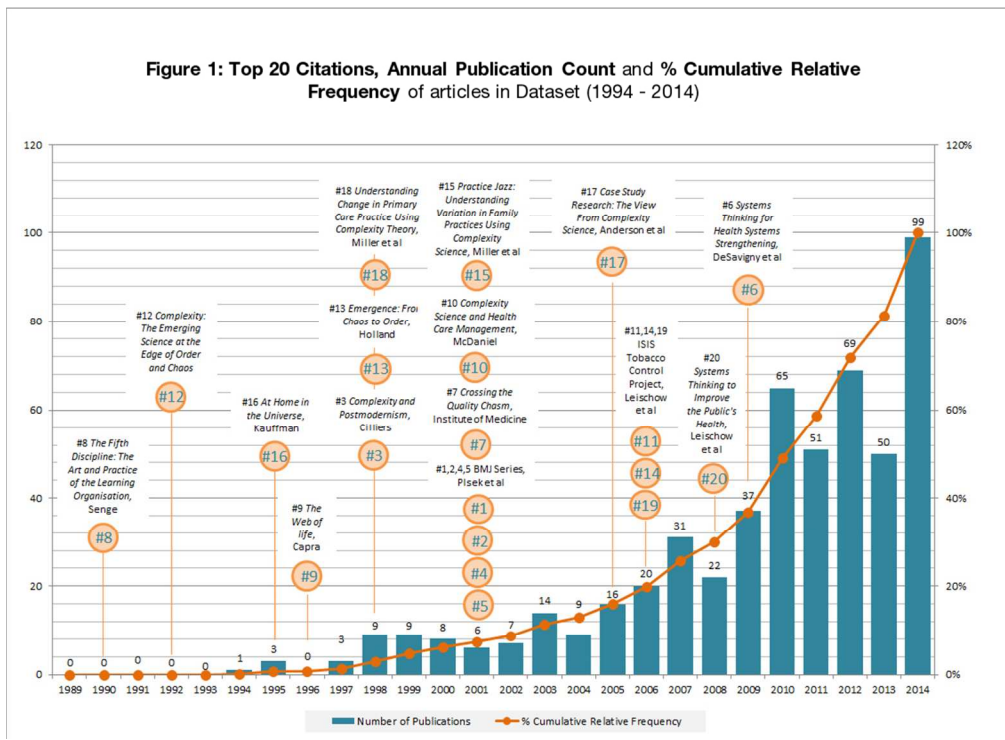


Figure 1: Search Results Tree
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Top 20 Citations, Annual Publication Count and % Cumulative Relative Frequency of Articles in Dataset (1994 - 2014)
396x289mm (72 x 72 DPI)

Group	Lead Authors	Geography	Institutional Affiliation	Research Focus	Basis of Understanding	Empirical Methods
US Primary Care Group	Miller, McDaniel and Anderson et al	United States	University of Texas at Austin, University of North Carolina at Chapel Hill	Organisational Change in Primary healthcare	Leadership and the New Science', Wheatley (1992)	Case Study
BMJ Series	Pisek and Greenhalgh et al	United Kingdom	University College London	Leadership, Healthcare Management, Learning	Management Thinking	--
Forum on Systems & Complexity in Medicine and Healthcare	Martin and Sturm beg et al	International	Journal of Evaluation in Clinical Practice	Varied including Primary Care	Philosophy & Management Thinking	Various
Initiative on the Study and Implementation of Systems	Leischow, Best and Sterman et al	International	National Cancer Institute	Tobacco Control	Inclusive of all Systems Ideas	Systems Organising; System Dynamics; System Networks; Systems Knowledge
WHO Alliance for Health Policy and Systems Research	DeSavigny and Adam et al	International	World Health Organisation	LMIC Health Systems	ISIS Tobacco Control Project	Systems Organising; System Dynamics; System Networks; Systems Knowledge

Table 1: Co-authorship groups identified within the research network on Complexity and Systems Thinking in public health

Table 1: Co-authorship groups identified within the research network on Complexity and Systems Thinking in public health
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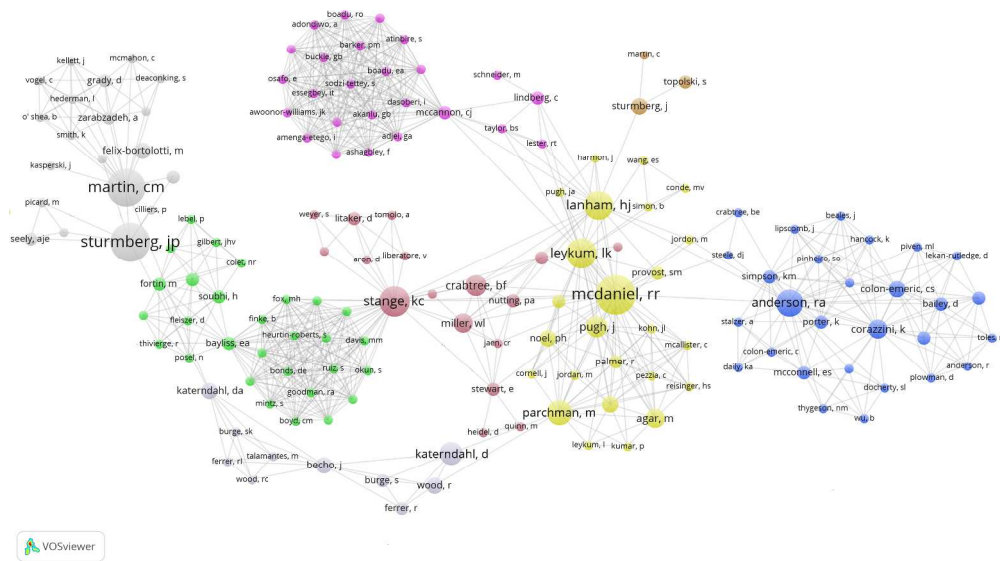


Figure 3: This network diagram illustrates co-authorship ties between groups of researchers within the dataset. Node size is related to the betweenness centrality measure of the author i.e. the number of times an author directly bridges the shortest path between two researchers. This diagram visualises ties between the 'US Primary Care Group' and several authors from the 'Forum on Systems & Complexity in Medicine and Healthcare' group.

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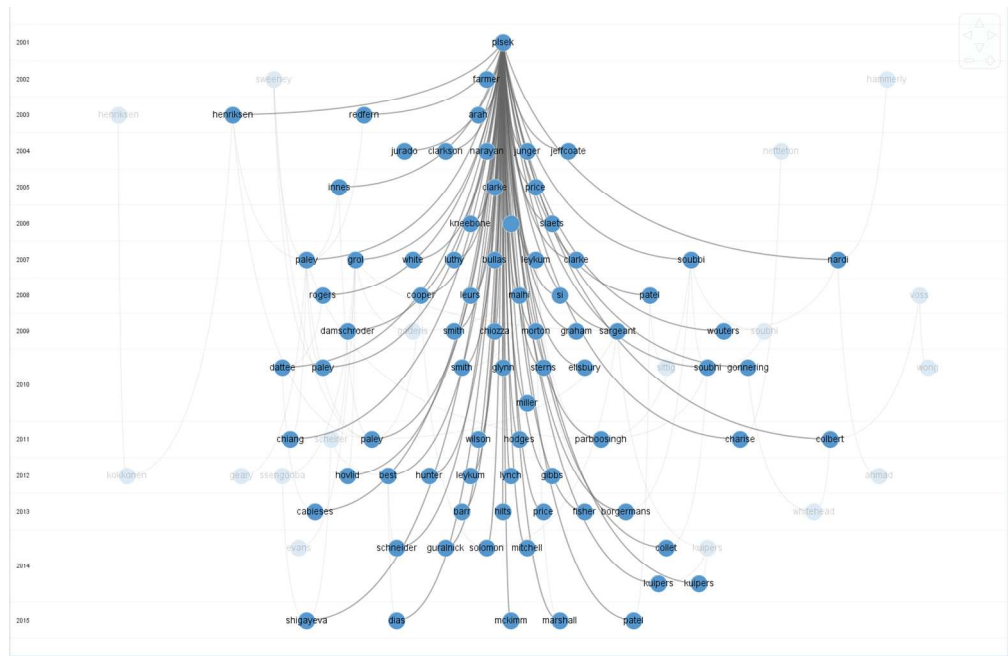


Figure 4: Citation Network Diagram visualising the BMJ series primary landmark paper and descendent articles

Review