A MULTI-METHODOLOGY STUDY OF THE HISTORIC IMPACT OF SOFT SYSTEMS METHODOLOGY AND ITS ASSOCIATED DATA VISUALIZATION APPROACH IN THE CONTEXT OF OPERATIONS AND BUSINESS STRATEGY

Scott J. Warren

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APPROVED:

Brian Sauser, Major Professor
David Nowicki, Committee Member
Charles Blankson, Committee Member
Robert Cloutier, Committee Member
Jeffrey Ogden, Chair of the Department of Marketing and Logistics
Marilyn Wiley, Dean of the College of Business
Victor Prybutok, Dean of the Toulouse Graduate School

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The purpose of this three-essay dissertation was to expand knowledge and theory regarding soft systems methodologies (SSMs) and data visualization approaches in business, engineering, and other social sciences. The first essay depicts a bibliometric analysis study of the historic impacts of SSM from 1980-2018 on business, engineering, and other social sciences fields. This study found 285 articles that described or employed SSM for research and included outcomes such as top SSM authors, author citation impacts, common dissemination outlets, time-bound distribution of publications, and other relevant findings. This study provided a picture of who, what, why, when, and where SSM has had the greatest impact on academic thought and practice. The second essay presents research on the academic impact of Systemigrams, an associated data visualization approach, finding examples of conceptual or research development that employed Systemigrams to depict complex problem situations. Recommendations for improvement of designing these data visualizations to increase their field use resulted from this study. The final essay leverages a selection of the articles as use cases to produce a grounded theory study to identify phenomena that arose from the use of SSM for operations and firm strategy research. This study identified two broad themes including (i) scope, structure, and process challenges and (ii) performance and evaluation limitations. These themes were explained by six patterns that emerged from the publications. Each produced change recommendations for SSM process, practice, and reporting to support its continued viability and adoption in business and operations research.

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INTRODUCTION

Systems are commonly defined as a group of interacting elements, or subsystems, with a unified goal and defined by its boundary as well as the nature of the internal structure linking its elements (e.g. physical, logical, etc.). Furthermore, systems can be defined as “hard” (e.g. mechanical engineering) or “soft” (e.g. management). Soft systems have more subjective qualities, because the human elements change dynamically in response to local needs. Peter Checkland defined soft systems methodology (SSM) as a bridge between hard and soft systems which has shown increasing use over the last three decades to address complex business and engineering problems that involve humans and subjective factors.

The complexity and difficulty of translating the outcomes of analysis related to “messy” or ill-structured problems into usable solutions has led to some mild criticism of the speed and viability of the SSM process for moving the analytic outcomes into strategic or product improvement recommendations (Mingers & White, 2010). There has also been limited research into the effectiveness of soft systems approaches over time, in part because some analysts have found the method’s requirement of stringent research with stakeholders to be onerous, leading them to apply only a portion of the SSM stems (Mingers, 2011). A gestation of SSM that has been used to depict the conceptual models of SSM and act as the medium to create and visualize a multi-perspective view of a system of interest is the Boardman Soft Systems Methodology (BSSM). The introduction of Systemigrams, also known as Systemic Diagrams, by Boardman & Cole (1993) expanded on SSM to help provide a better way to visually model complex systems. Since then, many authors have defined, described, and used Boardman’s conception to more fully realize their systems (Sewchurran & Petkov, 2007; Cloutier, Sauser, Bone, & Taylor, 2015; Simonette, Rodrigues, Seno, Plínio Franco Thomaz, Martinelli, & Hardman, 2008).

Systemigrams, have been used to model business processes as a means of bringing life to complex engineering root definitions, modeling ideologies of defense strategy, and even describing plagiarism.

The total impact of soft systems methodology and Systemigrams for research practice and outcomes is taught in many logistics, supply chain, and operations management courses. While commonly discussed as viable means of analyzing complex systems, it is unknown how significantly either has impacted business and engineering fields through published research and conceptual writing. The goal of this dissertation was to explore SSM, BSSM, and Systemigram's use frequency in the literature, to identify gaps in practice and additional needs discussed by authors, and what may be done to move the methodology forward in the future. Towards that end, two research study articles were produced, along with a third piece which synthesizes those findings into a proposed research framework that addresses challenges identified in the studies.

The first article, intended for *Systems Research and Behavioral Science*, began with bibliometric analysis of the historical impacts of both Checkland and Boardman's versions of soft systems methodology. Collected data covered a period from 1981, with the onset of Checkland's book, and contained multiple data sources including data mining tools such as Harzing's Publish or Perish (see Figure 1), scholarly databases, and other resources to collect academic works for review. Data used in this study included h-index scores, Scimago journal index scores, and citation counts as indicators of the impact of publications produced to publish research outcomes or conceptual discourse regarding SSM. This data was inducted into Microsoft Excel for analysis regarding the most published authors, author impact on academic thinking based on citation counts and strength of the journals in which pieces are published.

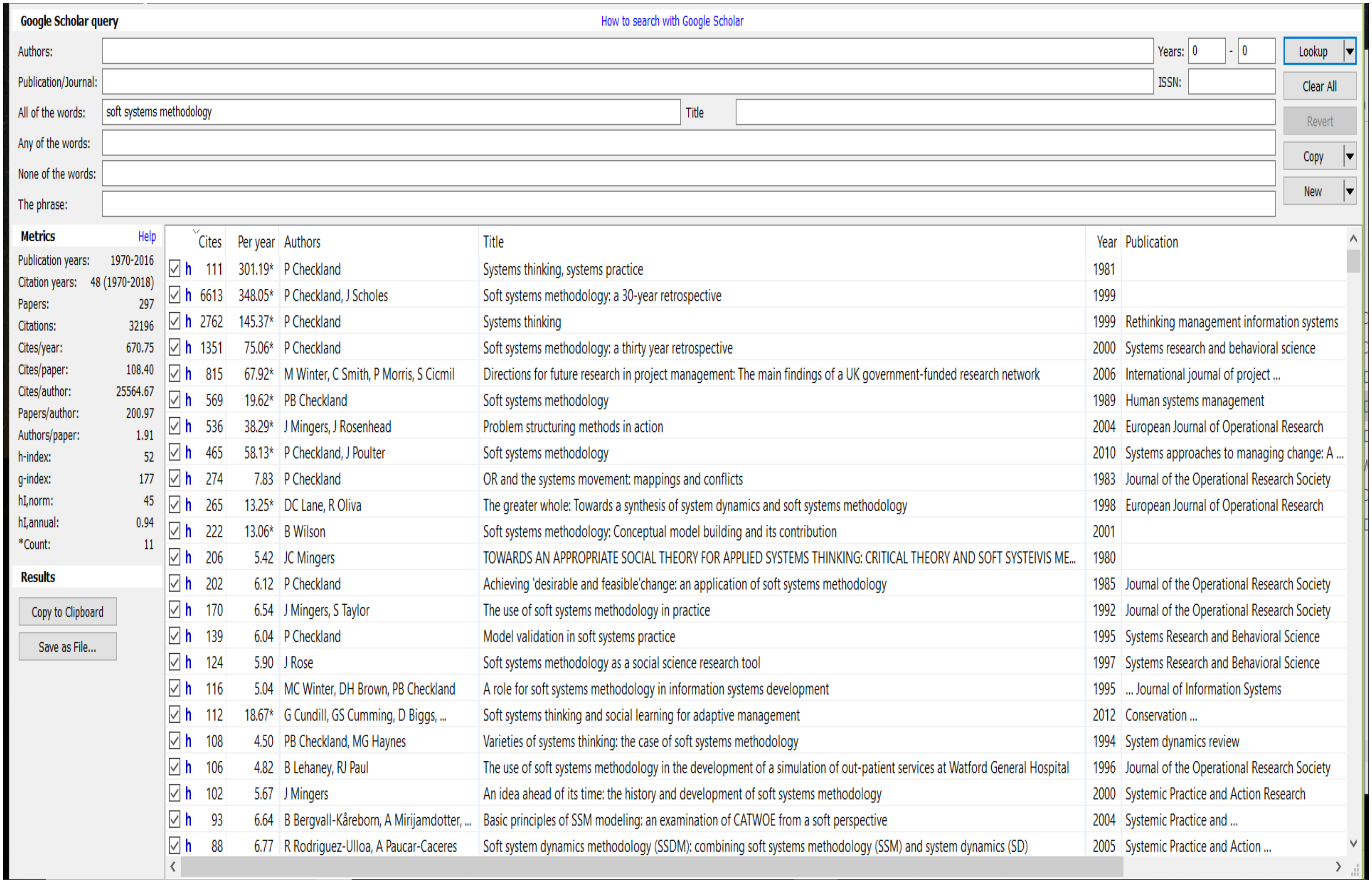

Figure 1. **Harzing's *Publish or Perish* data mining tool with data outcomes related to SSM.**

The second research piece employed what Mingers & Brockelsby (1997) called *multi-methodology* and Robson & McCartan (2016) refer to as *multi-strategy research* to capture different, but interfunctionally aligned data sources for synthesis that provides a clearer picture of the history and state of Systemigrams as a data visualization technique to depict complex systems and situations. This research engages in a.) bibliometric analysis of the same form as the first research article to determine the frequency with which Systemigrams have been used since 1994, b.) content analysis of the gathered articles from that analysis so that gaps and problematic uses by other authors regarding their past use can be identified, and c.) qualitative, open ended analysis of responses provided by researchers who currently or have in the past used Systemigrams for data visualization so that they can explain both positive aspects as well as needed improvements. Each of the research outcomes is presented using data visualizations.

From the outcomes of the first two studies analysis, a conceptual research framework for called *concurrent systems methodology* (CSM) is offered that seeks to address identified challenges with SSM and Systemigram data visualization. This is done by proposing a series of "frames" to narrow the scope of analysis and reduce cognitive load on researchers, while connecting research outcomes more cleanly to hard systems engineering or business outcomes, depending on the goal for a particularly complex study. These frames focus on areas such as business strategy, operationally efficient organizational resource allocation, and product system engineering and logistics. We begin with a focus on how systems thinking, SSM, and the use of Systemigrams for analysis are defined. From this examination, we identify how best to proceed with improvements to SSM using an integration of soft, hard, and strategic systems analyses for future conceptual framework development.

Outcomes and Contributions to the Body of Knowledge

Each of the articles is presented in the following chapters with literature reviews appropriate to each and complete descriptions of the research methodologies included. Data visualizations for each main finding are presented with discussion of the outcomes and recommendations. Each article is linked with the through line of the historic, measurable impacts of SSM and Systemigram visualization of complex problems or situations, along with identified needs for moving the methodology more prominently into widespread use to address interlinked problems of hard, soft, and strategic systems in business and engineering settings. In the interest of space saving, all references from the articles are presented at the end of the dissertation.

Operationalizations

- Abductive research approach: This approach to research vacillates between inductive and deductive reasoning to develop research findings that are rooted in logical inference, starting with observations to seek explanations engrained in empirical evidence, seeking to reconcile how the fit of data and observations.
- Bibliometric analysis: Statistical analysis focused on publications, commonly made up of books, articles, white papers, conference proceedings and other relevant sources and commonly employed by information scientists.
- Business or organizational strategy: This meso-level strategy construct focuses on the internal structure and actual of the firm such as human resource allocation to functional units (e.g. engineering, accounting, etc.) that best supports the achievement of firm market performance.
- Corporate strategy: A macro-level approach to planning how a firm should compete

in a market against rivals to achieve profits, market share, and other relevant performance outcomes. This requires the allocation of firm resources, creation of competitive strategy, understanding of competitor behavior, market demands, and other relevant information. Comparing firm competencies and resources, a leader then decides on the best strategic course of action for the whole organization to achieve sustainable competitive advantage.

- Grounded theory: A systematic methodology for social sciences research that develops theoretical constructs from data analysis by grounding these in evidence. This form of inquiry looks for patterns in a significant corpus of data to produce descriptions of emergent phenomena. The process commonly employs open, axial, and selective coding phases to build understanding or these phenomena using an orderly approach to produce descriptions and inferences.

- Operations management: The discipline of business management that focuses on designing, developing, and controlling production processes and business operations to efficiently and effectively produce goods and services.

- Operations strategy: At the micro or execution level, this strategy is driven by how best to efficiently and effectively produce goods and services in support of broad corporate strategy, with reference to business and corporate strategies. Operations strategy seeks to minimize costs of production, logistics, operations, and other relevant processes while maximizing the effectiveness and performance of units that fall under operations such as supply chain and transportation.

- Phenomenon: The concept of interest or pattern detected in a grounded theory study that emerges from the analysis of related data.

- Soft systems methodology: Commonly referred to as SSM, this research methodology was developed from older systems engineering process and used to analyze complex structures and situations. SSM follows a seven-step process leading to proposed actions to resolve ill-structured problems detected in business, logistics, operations, military, and other organizations.
- Systemigram: Systemigrams are visualizations of complex situations produced in conjunction with John Boardman's version of soft systems methodology. These are commonly shown through scenes or segments of a complex system to focus viewers attentions on particular system components, building up to the holistic view of the system of interest.

ESSAY 1

BIBLIOGRAPHIC AND VISUAL EXPLORATION OF THE HISTORIC IMPACT OF SOFT SYSTEMS METHODOLOGY ON THEORY AND RESEARCH

Abstract

Soft systems methodology (SSM), an analytic method commonly employed in engineering and business research, produces models focused on human activities in relation to complex, engineered systems. Peter Checkland's SSM involves seven stages; five address real-world aspects and observable data, while two leverage a systems thinking viewpoint for developing a depiction representative of the multi-perspective lenses on the systemic complexity of a problem to provide a clearer picture. This research piece explores the historic impacts of SSM on research and systems thinking through analysis of articles, books, chapters, white papers, and theses to distill its use for research and methodology development in engineering, business, and other social sciences fields from 1980-2018. Focused exploration resulted in 285 articles that described or employed SSM for research. This bibliometric meta-analysis produced outcomes and visualizations that include top SSM authors, author citation impacts, and h-index scores common dissemination outlets for SSM work and Scimago journal subject areas and impact scores, distribution of years published, and other relevant outcomes. We found that some authors, journals, books, and chapters have had the highest impact on the SSM discourses during the history of its use. The outcomes of this research allowed us to build a picture of who, what, why, when, and where SSM has had the greatest impact on research, systems thinking, and methodology as we look towards its future after nearly 40 years of use.

Index terms: Soft systems methodology (SSM), systems thinking, bibliometrics, historical impact

Introduction

Systems are commonly defined as a group of interacting elements (or subsystems) with a unified goal and defined by its boundary as well as the nature of the internal structure linking its elements (physical, logical, etc.). Furthermore, systems can be defined as “hard” (e.g. mechanical engineering) or “soft” (e.g. management). Soft systems have more subjective qualities, because the human elements change dynamically in response to local needs. Peter Checkland (1981) defined soft systems methodology (SSM) as a bridge between hard and soft systems which has shown increasing use over the last three decades to address complex business and engineering problems that involve humans and subjective factors.

The complexity and difficulty of translating the outcomes of analysis related to “messy” or ill-structured problems into usable solutions has led to some mild criticism of the speed and viability of the SSM process for moving the analytic outcomes into strategic or product improvement recommendations (Mingers & White, 2010). There has also been limited research into the effectiveness of soft systems approaches over time, in part because some analysts have found the method’s requirement of stringent research with stakeholders to be onerous, leading them to apply only a portion of the SSM stems (Mingers, 2011).

Since early work on SSM by Mingers (1980) and Checkland’s groundbreaking 1981 *Systems Thinking, Systems Practice* book that formalized SSM as a research approach, it has become a common means of understanding to analyze problems with no single answer research in engineering and business fields. SSM has been deemed valuable in complex situations that involve multiple stakeholders and systems. While many students and professors will recognize the term soft systems methodology, SSM’s impact on in engineering, business, and other social sciences is less understood. What has been the reach of SSM in these areas? Who are the authors using the method? How extensively is the tool used for research? It is also important to understand where the outcomes of SSM research published and, using commonly accepted impact scores for associated journals, and the degree to which they are perceived to be impactful. The goal of this piece is to answer these questions through a bibliometric meta-analysis of pieces that discuss as an approach or employ SSM for research.

We begin with an examination of how systems thinking and the related SSM approach are defined. An exploration of the use of SSM in the fields of business, engineering, and other social sciences then grounds this research. This is followed by bibliometric analysis of articles found to discuss or employ SSM to depict the impact of the approach over the last 35 or more years. Finally, we identify some improvements to SSM identified by authors that could come through an integration of soft, hard, and strategic systems analyses for future conceptual framework development.

State of Knowledge and Practice

The current knowledge regarding SSM originated in theory and practice work around General Systems Theory dating back to the 1950s and 1960s in a period following World War II, as organizations sought to build complex physical and human systems. Since that time, some authors have built new analytic tools for producing more rapid depictions of complex problems from SSM like the conceptagon and Systemigrams (Boardman & Sauser, 2008). The goal of these improvements has been to use the better visualizations of the complexity to develop improved physical "hard systems" like manufacturing and software products, "soft" human organizational systems, and business strategy. The following sections some of the relevant history of soft systems methodology and Systemigram development.

General Systems Theory

Systems thinking, as a term and set of processes, was first introduced and formalized in the 1950s. Originally labeled General Systems Theory (GST), it was developed as both conceptual framework and mathematically expressed theory, most notably by Ludwig Von Bertalanffy (1950). His original conception was that problems identified symptomatically in complex systems across different disciplines affected one another, but they had to be first described independently and then in terms of their interrelations to clearly understand how they affected one another. While this was only a starting point, GST allowed systems thinking to flourish across disciplines such as ecology, engineering, business, and education (Caws, 2015; Bronfenbrenner, 1976; Francois, 1999; Checkland, 2000; Mingers & White, 2010, Banathy & Jenlink, 2003). Furthermore, original research was done over the last thirty years in multiple areas to meaningfully grow the value and use of systems thinking.

Systems thinking describes the act of examining and seeking to understand a system, an interlinked set of things, people, actions, and subsystems in a cooperating mechanism or set of activities, as a complex, Gestalt whole. Rather than requiring a person to try to perceive a multifaceted system one small piece at a time without its relationships; systems thinking seeks to present the entire picture as a means of identifying where different components meet and either perform well or require change. This approach still requires that an analyst shift their gaze from the whole system to the parts in a back-and-forth effort. It is this process that allows them to comprehend how components fit together, interact, and depend on one another for the entire system to operate and achieve its overall function. Such holistic thinking permits the mind to discover patterns among each element that may not be immediately evident or emerge over time as situations surrounding the whole change and interact with other, interrelated wholes to create the system.

Systems thinking is synonymous with holistic judgement regarding a coherent phenomenon. At its core, this approach examines the interconnectedness of each part of the system, uncovering patterns regarding how different components work together to produce certain systemic outcomes, as well as what may hinder desired results. Although it may also be traced to General Systems Theory (GST) produced by Von Bertalanffy in 1950, Checkland (2000) traced it to 1954 when the development of a mathematically expressed general theory of systems first emerged. The Society for General Systems Research founders stated that systems theory "provide(d) a meta-level language and theory in which the problems of many different disciplines could be expressed and solved" (Checkland, 2000). Unfortunately, GST has not resulted in the substantive investment by scholars to produce a generalized holistic view across disciplines. Instead, systems thinking has expanded slowly over the last 65 or more years in fields such as education, biology, engineering, and increasingly focusing on components of supply, demand, and logistics in the field of business.

Soft Systems Methodology

To help foster systems thinking with complex organizations and processes, Peter Checkland (1985) formalized separate definitions of hard and soft systems, calling his own conception "Soft Systems Methodology" (SSM). This means of analyzing non-technical, less predictable, human-focused systems emerged from General Systems Theory. He offered a seven-stage process for applying SSM that requires the systems analyst to think both about the real world and the conceptual model of the system under study, allowing them to bridge the complexity of the two. The seven stages include: 1. Enter the unstructured problem situation; 2. Express the problem situation; 3. Formulate root definitions of relevant human activity systems;

4. Build conceptual models from the root definitions; 5. Compare models with real world; 6. Define desirable and feasible changes; 7. Take action in the problem situation. This is a linear process that should result in systemic improvement to the system under study.

From his analysis of the literature, Checkland (2000) defined "hard" systems as those focused on analyzing defined systems towards a goal of solving well-defined technical problems. Such systems interact with one another and through examination of the points at which they touch can be depicted to identify how they may be engineered to perform better. Thus, the purpose of a hard system or analysis of one is to solve a problem. By comparison, a "soft" system is one that involves poorly ill-defined situations with human stakeholders and cultural mores. These soft systems are complex and when viewed from outside may be deemed mysterious. This stems from their often poorly defined boundaries and conceptual definitions related to its component parts, subsystems, or relations between similarly sized systems. This is often because the system has emerged and evolved organically in response to its environment and needs, so its form may appear chaotic at the outset of analysis. Because these changes may have been done quickly, without consideration of the consequence of a decision, there may be many ways for the system to be improved to perform more effectively.

Engineers are meant to inquire into whether the soft system can be organized into what Checkland called a learning system. Figure 1 presents Checkland's "attempt to make clear the difference between hard systems thinking and soft systems thinking." Using a "hard systems" view, the Observer sees the world as full of systems that they can engineer, they see the world as systemic. In soft systems, the Observer sees the world as full of complexity and confusion, but this can b e organized for exploration it as a learning system, using a system inquiry process.

Methodology

This study sought to depict the impact of soft systems methodology in the engineering, business, and other social research fields. To do so, a multi-strategy bibliometric analysis (Robson & McCartan, 2016) was performed on the term "soft systems methodology" to gather evidence related to the impact of SSM as evidenced in published research and theory disseminated publicly. As part of objective, Positivist research (Rosenberg, 2015), this required capturing pieces where we could directly evaluate evidence that the pieces included direct discussion of SSM as a methodology or employed it as a research approach with observable outcomes. Bibliometrics, as a data analytics research methodology, comes from the library and information sciences. It is used to capture quantitative outputs regarding descriptive and network statistics based on citations, authors, keywords, texts, and dissemination outlets to identify trends, impacts by use, subjects, and fields that have adopted SSM. The data outcomes are valuable for visualization to depict the impacts of published research over time. To hold the rigor of the publication outlets steady for this study, we examined only published pieces we could fully read through to determine whether SSM was discussed or employed for research. This meant we did not include conference proceedings, unless they were available for review beyond an abstract. This left peer-reviewed articles, books, book chapters, white papers, and dissertations/theses as our data sources. To gather these sources, our data collection methods, which sought to be exhaustive, employed data mining and Boolean searches from multiple sources using the following approach.

Data Collection

Data was gathered from multiple sources to capture the largest possible data set and build a comprehensive profile of the use of SSM since 1981. The following are the digital tools employed, though not necessarily in order, because finding primary source materials often required using more than one source.

- Harzing's Publish or Perish – This was the initial search tool used to collate the starting data set (see Figure 1). This data mining tool from Google Scholar collects publications based on keywords and produces a listing all articles, books, book chapters, dissertations/theses, white papers, conference proceedings, and reference citations. In addition to authors, titles, and publication names, it also provides citation counts and links to the pieces.
- University library databases – JSTOR, ERIC, Web of Science, and others were used to gather PDFs of each article for review to determine if SSM was, in fact, present in the publication.
- Research Gate – Many PDFs of SSM pieces were available by their authors for download on this site. Some were freely available, while others were provided upon request.
- Google and Bing searches – Boolean searches were used to find online posted PDFs when they were unavailable elsewhere, as well as to determine whether some mislabeled publications were conference proceedings, books, or chapters, rather than peer-reviewed articles.
- Publisher web sites – Some articles were only available through publishers and were purchased or sometimes available for no cost.
- Amazon and Google Books – These were used to purchase Kindle or original books as necessary for review.
- Organization web sites – For those pieces not correctly labeled as conference papers, we gathered abstracts as confirmation that the full paper was available. If not, the piece was not included in the analysis.

- Scimago Institution Rankings – This site includes journal and country scientific indicators drawn from the Scopus database using Google PageRank algorithm to create rankings (called SJR ranks) for each dissemination outlet. When available, it also includes h-index rankings. Both were included in the corpus of data to gauge the impact of the journals in which SSM pieces were published. These do not include books, chapters, or most conference proceedings.

The Publish or Perish tool produced 1,000 results, limited in the tool to those that included the full keyword terms "soft systems methodology," "SSM," or "BSSM." These pieces were located from the university library databases and other Boolean searches to produce the original corpus of data for review. All other source outputs were integrated into the database. Using these data sources to build the database, we employed the following approach to analyzing the data to answer our questions as follows.

Data Analysis

To organize, clean, and, analyze or display the collected data, we followed Onwuegbuzie & Teddlie's (2003, p. 75) suggested approach for multi-strategy data analysis, though modified to fit our process that was dictated by our questions and sources, as described below. This included the following steps, though not always in this order because the process was recursive as new data was discovered and refined:

1. *Data transformation and reduction:* These two stages were combined in a departure from Onwuegbuzie & Teddlie's approach because the transformation process was part of the reduction stage. PDFs of publications or hard copies of other texts were reviewed to determine if SSM or BSSM was discussed or used for research. In the transformation, the qualitative data

captured from reviews of the publications was quantized with a binary score of 1 representing the presence of SSM in a piece or 0 if not. Those that did not were eliminated from the database. Further transformation took place in classification of the pieces from the *Publish or Perish* mining process when determining if they fit one of the following criteria: a. peer-reviewed articles, b. books, c. book chapters, d. white papers e. dissertations/theses. The publications also had to be available for review, so most conference proceedings were eliminated. Columns with incorrect or irrelevant data (e.g. repeated search dates, publishers, etc.) were also deleted.

2. *Data integration* - Research Gate, publisher sites, Scimago ranks, etc. data was assimilated into the database.

3. *Data comparison and correlation* – Data from the different sources was compared and correlated to confirm that each produced the same results and corrections were made, adhering to the source with highest credibility (e.g. primary source). These two stages were combined also differed from Onwuegbuzie & Teddlie's approach because they were concurrently performed. Data that could not be confirmed such as pieces that were identified as including SSM but without observable evidence, was eliminated.

4. *Data consolidation* – All data was consolidated into the database and primary source texts were organized in a digital folder, organized by subject area.

5. *Data display* – The outcomes of the organized database set were analyzed in Excel using Quick Analysis to produce visualizations in the form of tables, charts, and graphs. The outcomes of the data display step are the core of our findings, presented in the next section.

This research and analytic process answered the following questions:

1. What has been SSM impact on academic discourses in business, engineering, and other fields since its inception as evidenced by yearly publication trends and journal impact factors?

2. Where has thinking about SSM been disseminated most often?

3. What disciplines have been most impacted by SSM?
4. Who have been the major contributors to the development of SSM?

The cleaned, reduced data produced 286 publications referencing or employing SSM as a research approach and illustrate the impact of SSM since its early days.

Findings

The findings from our analysis show differing impacts of SSM, depending on fields of study. The distribution of articles related to SSM has varied considerably since 1980, with certain periods most highly representing its impact. Some authors have had a more outsized impact on thinking and use of SSM than others. The following sections explore these outcomes with accompanying data visualizations.

Impact of SSM on Academic Discourses Represented by Publication Trends and Impact Factors

The first major outcome is the publication trend tied to soft systems methodology from 1980 to 2018 as we approach 40 years of SSM discussion and use. Figure 2 shows how many publications with some reference to SSM were found during that period.

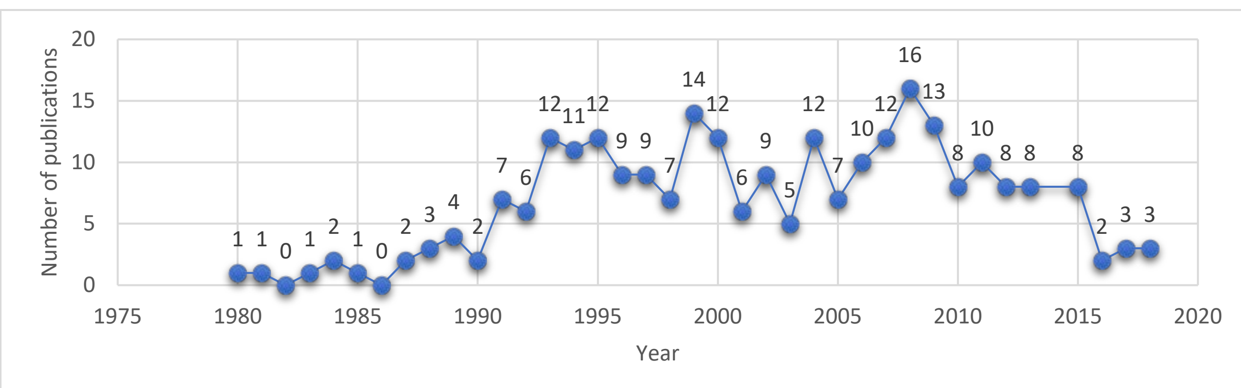

Figure 2. Number of publications by year (1980-2018).

In Figure2 we see small growth in the 1980s, with a big spike in the 1990s around the time of Checkland's (1989) highly cited (569) "Soft systems methodology" piece in the Health Systems Management journal and Mingers & Taylor's (1992) "The use of soft systems methodology in practice." Each simplified the process and provided examples that practitioners and theorists could apply. During that time more than 90 pieces discussed or applied SSM in practice, showing high interest in the methods that continued through the 2000-2009 period, with the 1990 to early 2000s being the strongest showing of SSM-related publications.

SSM Most Common and Most Impactful Publication Outlets

While seeing the impact of SSM through the number of publication outlets is valuable, it is also important to understand both where these pieces have been published to get a better sense of how accessible they are. Further, it is important to know the perceived impact of those journals that have been evaluated using objective measures such as SJR and h-index scores to get a better sense of academic impact in the social sciences more broadly. The publication outlets that are most highly represented are included in Figure 3.

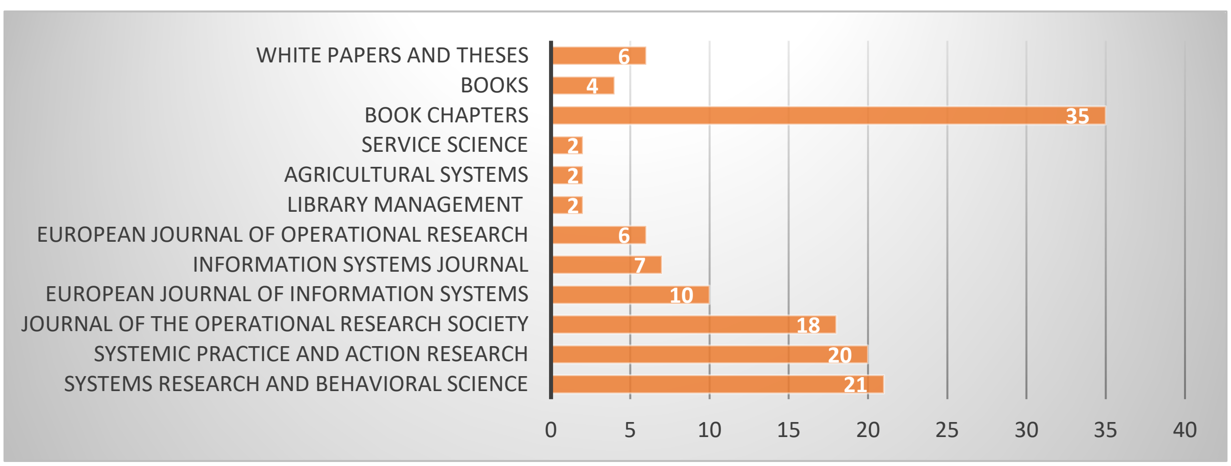

Figure 3. Highest frequency SSM publication outlets.

While the figure does not incorporate citation counts, the largest number of publications related to SSM has come in the form of book chapters. The top nine most represented journals each had published at least two SSM pieces, though only eight had citations because two of the pieces in Service Science were recently published. The following figure shows the citations for the top eight journals.

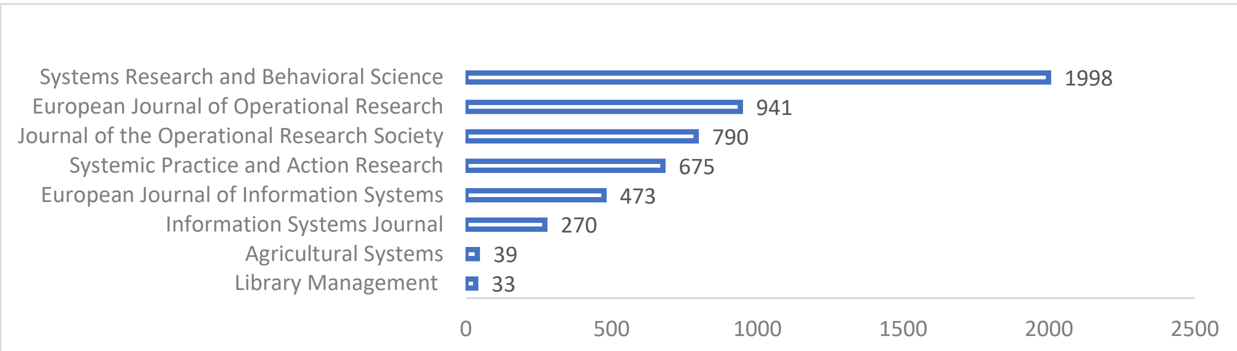

Figure 4. Top eight SSM journal outlets and citations of SSM-related articles.

Systems Research and Behavioral Science has been both a top destination for SSM pieces and the strongest impact on the field, based on citation counts. Most pieces were not research-based according to our analysis; rather, they discussed the development of SSM as an approach and often offered significant adaptations and additions to the methodology to make it easier to use or more applicable in different fields. While Systemic Practice and Action Research had significant publications, their impact was less evident on the field, though the number of research studies using SSM was greater than most other journals. However, the most significant publication outlets were not journals as shown in the Table 1.

Table 1: Citation counts for SSM-related publication outlets.

Dissemination outlet	Citations
Books (66.91%)	18052
Book chapters (13.44%)	3625
Systems Research and Behavioral Science (7.41%)	1998
European Journal of Operational Research (3.49%)	941
Journal of the Operational Research Society (2.93%)	790

Dissemination outlet	Citations
Systemic Practice and Action Research (2.50%)	675
European Journal of Information Systems (1.75%)	473
Information Systems Journal (1.00%)	270

For SSM, as a topic of discourse and research methods, Figure 4 visualizes the high impact of four books and thirty-five book chapters had versus journals. 11,144 book citations came from Checkland's 1991 book, which gave that publication the largest impact on other authors. Removing that text as an outlier, SSM-related books had almost twice the citation impact of book chapters and nearly a treble impact over the top journal's pieces as shown in Figure 4.

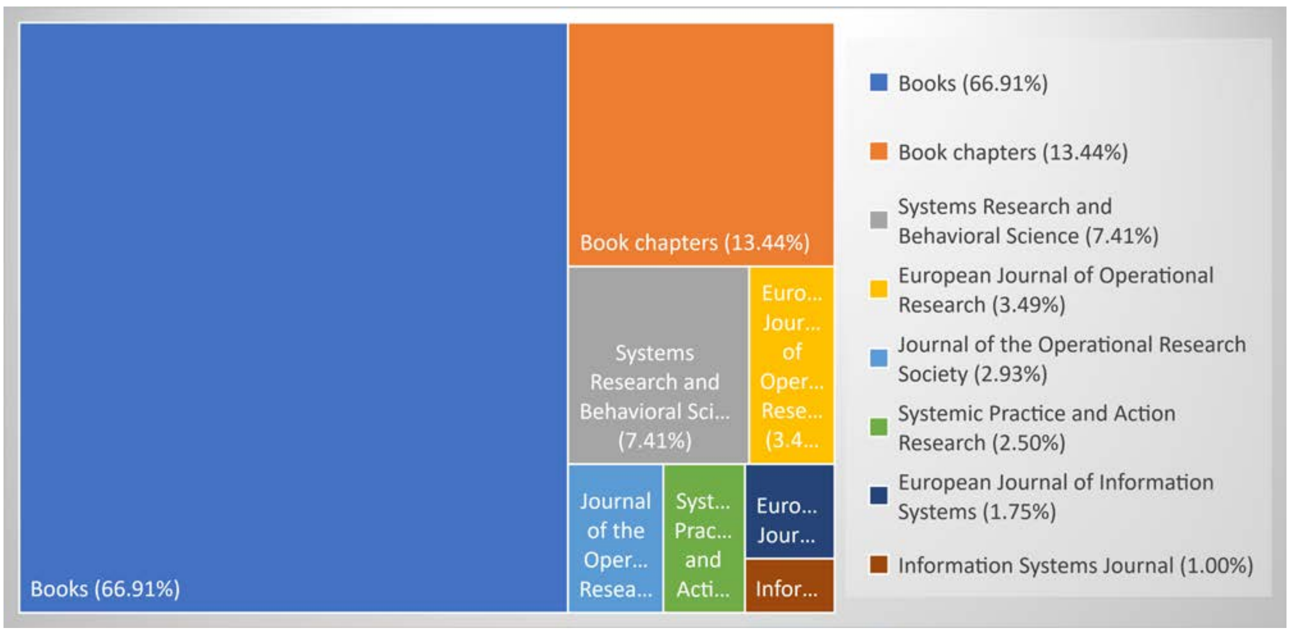

Figure 5. Citation impact of SSM dissemination outlets as a percentage of all citation.

Books had the largest percentage impact based on citation counts by a significant margin, with book chapters following substantially lower. Chapters and books combined accounted for 80.35% of all measured SSM citation impact, the top journals accounting for 19.08%. This means all other journals accounted for only .57% of all citation impact. Findings regarding the disciplines impacted by publications containing information about or research using SSM are included in the next section.

Disciplines Most Impacted by SSM

To capture which disciplines are most impacted by SSM, each publication was reviewed and coded according to the Scimago journal subject area that was most closely aligned with the content. While white papers, dissertations, books, and chapters do not have subject areas, those were coded in accordance with similarity to journal articles containing the same subject matter. Figure 6 presents the distribution of articles according to coding for Scimago subject area.

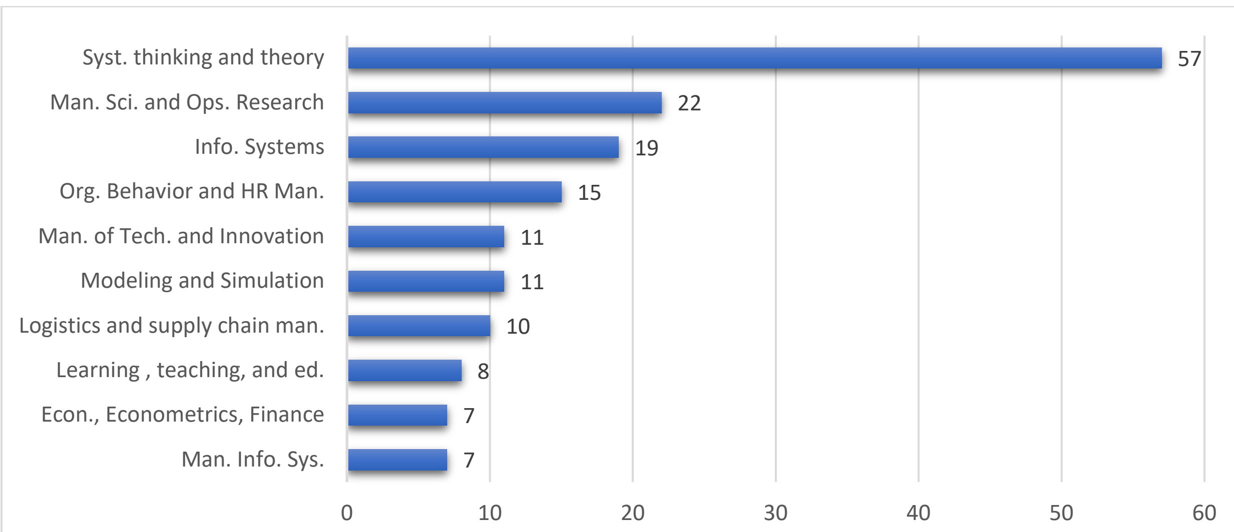

Figure 6. Top 10 SJR coded subjects of publications using SSM.

"Systems thinking and systems theory" constituted the largest subject, with management science and operations management trailing considerably. This was in part because our content analysis revealed that the majority of pieces coded as Systems thinking and systems theory discussed the development of SSM from the perspective of these topics, but often contained no research application and only described proposed alterations of the methodology for a particular purpose (e.g. software development by adding UML) or a description of SSM to a new audience (e.g. librarians, educators, etc.). The Scimago codes above were classified into broad subject categories based on the topics of the articles in the database and are presented in Figure 7.

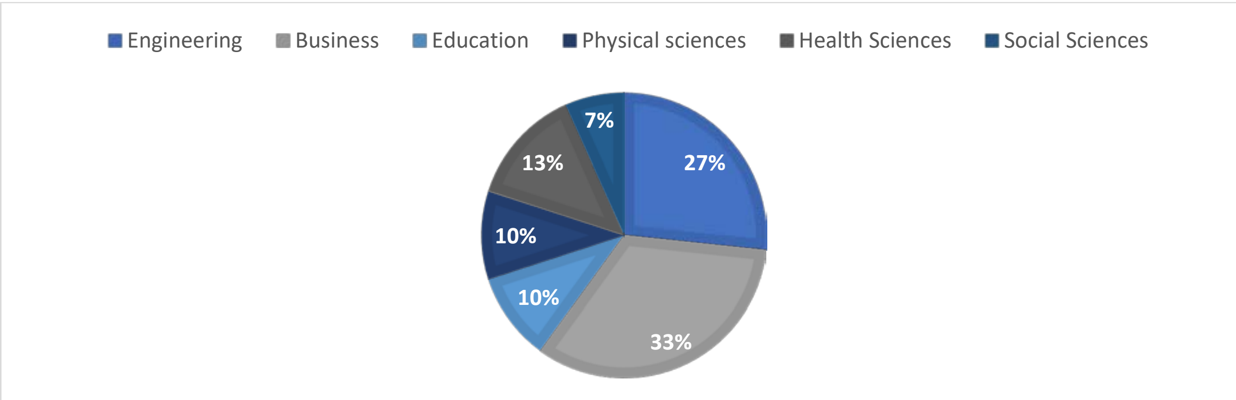

Figure 7. Disciplinary category representation of SSM-related articles.

Business was the largest discipline impacted by SSM research and discourse in publications from 1980-2018 with 10 subjects represented. Engineering was close behind with eight highly coded Scimago subjects. Physical science category pieces tended to focus on large scale, messy problems like water allocation in countries with poor access to clean drinking water, making SSM an appropriate tool for research. Education and health sciences also had ill-defined problems that made SSM useful for studying complex systems and while SSM was less impactful than with business or engineering, it showed some impact. The authors that contributed to these pieces had differential impacts on SSM research and practice as shown in the following section.

Major Contributors to SSM Theory and Research

As measured by the number of publications tied to SSM, twelve had the highest impact. These are presented in Figure8, showing the percentage of the 286 SSM-related publications analyzed here that they are responsible for as an author since 1980. Each had three or more publications related to SSM.

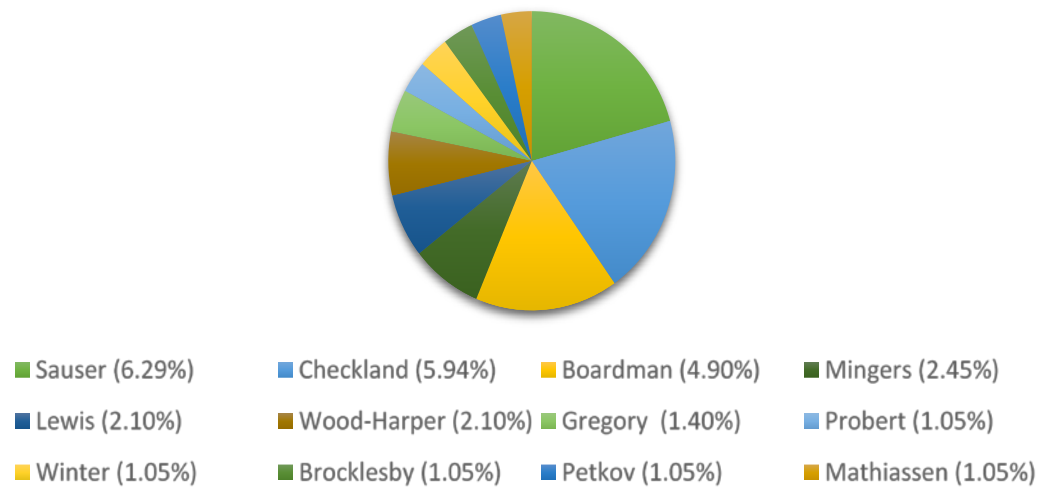

Figure 8. Top author representation among all SSM-related publications.

The top six authors combine to represent 23.78%, or nearly a quarter of all SSM-related publications since 1981. The remaining 75% by other authors indicates a broad distribution of the ideas and application of SSM, with the eight above serving as what Lave and Wenger (1991) might call "Core participants" in a Community of Practice centered on the development and use of soft systems methodology for research and theory development. While the distribution of the work is broad, the following figure shows that the citation impact is substantially different.

Figure 9. Author impact on field by citation representation percentage.

Checkland's impact is clearly massive, regardless of the field of influence. His work on SSM has garnered 23,780 citations, with 11,114 alone for his 1981 book. Mingers has contributed substantial work as well. Boardman, with his variant of SSM applied in engineering and business settings, and his work with Sauser show strong impacts among the remaining authors.

Conclusion and Implications

Since Checkland synthesized a coherent set of steps for soft systems methodology and Boardman developed his revised approach in the 1980s, they have continued to evolve to address perceived challenges and new means of applying the principles in diverse disciplines. While the search for SSM resulted in more than 32,000 citations, other "soft" methods such as failure modes and effects analysis (228,524) and system dynamics (2,380,988) show more impact by that measure since their inceptions. To grow the thinking about and use of SSM, more authors with great impact should publish in high quality journals to improve its visibility and value across disciplines. The creation of improved digital tools, adopting modified and more rapid approaches where appropriate, and linking soft, hard, and strategic analysis approaches to speed the development of outcomes that can be used to frame the ill-structured problem situations that SSM lends itself to. This should lead to improved systems development, better strategy, and enriched managerial decisions could increase adoption by a broader array of researchers and disciplines.

ESSAY 2

THE USE OF SYSTEMIGRAMS AND SOFT RESEARCH APPROACHES: IMPACTS ON DISCIPLINARY RESEARCH OR CONCEPTUALIZATION AND RECOMMENDATIONS FOR FUTURE DATA VISUALIZATION TOOLS

Abstract

As a major outcome of Boardman's soft systems methodology (SSM) research approach with complex problem situations is the systemic diagram, usually called a Systemigram. These visualization tools are an increasingly common tool for presenting complex data collected from multiple quantitative and qualitative sources. Since its introduction, authors have prepared Systemigrams in disciplines ranging from business and engineering to disaster preparedness and educational settings when challenges arise that do not lend themselves to being understood with other forms of data capture and analysis. Soft Systems Methodology (SSM), an analytic method commonly employed in engineering and business research, produces models focused on human activities in relation to complex, engineered systems. Checkland's SSM involves seven stages; five address real-world aspects and observable data, while two leverage a systems thinking viewpoint for developing a data visualization representative of the multi-perspective lenses on the systemic complexity of a problem to provide a clearer picture. John Boardman's creation and articulation of Systemigrams, or Systemic Diagrams, were a gestation of SSM that has been used to depict the conceptual models of SSM and act as the medium to create and visualize a multi-perspective view of a system of interest. This method is referred to as the Boardman Soft Systems Methodology (BSSM). A Systemigram is used to decompose and envisage a system of interest originally concentrated into the system's root definition and related subsystems. The Systemigram provides explanations of individual and related system threads such as the flow of

information or resources and actions taken by stakeholders. We take broad view of the evolution of Systemigrams as research outcomes to identify its strengths and weaknesses as a tool applied to hard and soft systems development and managerial strategy formation. Further, we conducted a survey with open-ended questions regarding participant experiences with Systemigrams to understand how they can be better used in the future. We then use whole set of findings to identify improvements for use of Systemigrams in future business, organizational, and engineering settings that should evolve the value of Systemigram data visualizations resulting from BSSM and SSM to improve their impact on research and practice.

Index terms: Systemigrams, systems thinking, bibliometrics, historical impact, data visualization, soft systems methodology, data analysis

Introduction

Systems are commonly defined as a group of interacting elements (or subsystems) with a unified goal and defined by its boundary as well as the nature of the internal structure linking its elements (physical, logical, etc.). Furthermore, systems can be defined as “hard” (e.g. mechanical engineering) or “soft” (e.g. management). Soft systems have more subjective qualities, because the human elements change dynamically in response to local needs. As part of understanding complex systems with research, Peter Checkland (1981; 2010) defined soft systems methodology (SSM) as a bridge between hard and soft systems. This seven-step approach has been used over the last three decades to understand complex business and engineering situations and settings that involve humans, multiple systems, and subjective factors that impact performance. The complexity and difficulty of translating the outcomes of analysis related to ill-structured problems into usable solutions has led to some mild criticism of the speed and viability of the SSM process for moving the analytic outcomes into strategic or product improvement recommendations (Mingers & White, 2010). There has also been limited research into the effectiveness of soft systems approaches over time, in part because some analysts have found the method's requirement of stringent research with stakeholders to be onerous, leading them to apply only a portion of the SSM stemming from the complexity of the research process (Mingers, 2011).

A major development with soft systems methodology was Boardman's (1994) re-conceptualization of Checkland's approach to improve its efficacy with engineered system. Beyond changing the steps, Boardman's work over the following years supported the creation of imagery that depicted the problem situations in a formal manner with rules and a sense of narratively describing the systems parts, functions, and actions. This Boardman's Soft Systems Methodology (BSSM) led to the notion of the systemic diagram, or Systemigram, which has been in regular use to depict complex system analysis findings since the late 1990s. By the early 2000s, a data visualization software for personal computers called *SystemiTool* was developed to support the rapid creation of Systemigrams, which had often been hand drawn to that point. While many in the field are aware of SSM and BSSM, fewer may be aware of Systemigrams and their value for visualizing data from complex soft systems analysis. Limited research has reviewed the academic impact of Systemigrams since their inception and additional studies are needed to understand the major authors, publications, and uses of these visualizations for understanding soft systems. Further, it is important to understand how these depictions and related tools may be improved to increase their acceptance and dissemination in business, engineering, and other fields to support research where ill-structured systems and problems exist that resist Positivist approaches like direct observation, surveys, and experimental methods. The goal of this piece is to answer these questions through a bibliometric meta-analysis of pieces that discuss as an approach or employ SSM for research. We begin with an examination of systems theory and systems thinking that led to the development of soft systems and multi-methodologies that are commonly used in the development of Systemigrams as a means of grounding this study.

State of Knowledge and Practice

The current knowledge on the use of Systemigrams originated in General Systems Theory (Von Bertalanffy, 1950), dating back to the 1950s and 1960s period. This development occurred following World War II as organizations sought to build complex physical and human systems. Systems thinking, as a term and set of processes, was first introduced and formalized in the 1950s. Originally labeled General Systems Theory (GST), it was developed as both conceptual framework and mathematically expressed theory, most notably by Ludwig Von Bertalanffy (1950). His original conception was that problems identified symptomatically in complex systems across different disciplines affected one another, but they had to be first described independently and then in terms of their interrelations to clearly understand how they affected one another. Systems thinking describes the act of examining and seeking to understand a system, an interlinked set of things, people, actions, and subsystems in a cooperating mechanism or set of activities, as a complex, Gestalt whole.

Rather than requiring a person to try to perceive a multifaceted system one small piece at a time without its relationships, systems thinking seeks to present the entire picture as a means of identifying where different components meet and either perform well or require change. This approach requires that an analyst shift their gaze from the whole system to the parts in a back-and-forth effort. It is this process that allows them to comprehend how components fit together, interact, and depend on one another for the entire system to operate and achieve its overall function. Such holistic thinking permits a research analyst's mind to discover patterns among each element that may not be immediately evident or emerge over time as situations surrounding the whole change and interact with other, interrelated wholes to create the system. Since that time, new analytic tools were developed to produce more rapid depictions of complex problems from SSM. The goal of these improvements has been to use the better visualizations of the complexity to develop improved physical "hard systems" like manufacturing and software products, "soft" human organizational systems, and business strategy. The following sections provide some of the relevant history of soft systems methodology and Systemigram development.

Soft Systems Methodology Historically

To foster systems thinking with complex organizations and processes, Peter Checkland (1985) formalized separate definitions of hard and soft systems, calling his own conception "Soft Systems Methodology" (SSM). A "soft" system is one that involves ill-defined situations that include human actions and cultural aspects that govern their outcomes. Soft systems are complex with poor boundaries; when viewed from outside, they may be deemed mysterious. This stems from their often poorly defined boundaries and conceptual definitions related to its component parts, subsystems, or relations between similarly sized systems. This is often because the system has emerged and evolved organically in response to its environment and needs, so its form may appear chaotic at the outset of analysis. Because these changes may have been done quickly, without consideration of the consequence of a decision, there may be myriad ways for the system to be improved to perform more effectively. Checkland offered a seven-stage process for applying SSM that requires the systems analyst to think both about the real world and the conceptual model of the system under study, allowing them to bridge the complexity of the two.

The seven stages include: 1. Enter the unstructured problem situation; 2. Express the problem situation; 3. Formulate root definitions of relevant human activity systems; 4. Build conceptual models from the root definitions; 5. Compare models with real world; 6. Define desirable and feasible changes; 7. Take action in the problem situation. This is a linear process that should result in systemic improvement to a human-related system under study. Engineers inquire as to whether a soft system of interest (SOI) can be organized into what Checkland called a *learning system*. Using a "hard systems" view, the Observer sees the world as full of systems that they can engineer, they see the world as systemic. In soft systems, the Observer sees the world as full of complexity and confusion, but this can be organized for exploration as a learning system, using a system inquiry process. The outcome of this process often requires a visualization of the collected data to more simply communicate research findings with complex systems to managers and stakeholders so that action can be taken.

Systemigrams Used to Depict and Comprehend Complex Systems

As a means of data visualization for the results of SSM research, John Boardman enhanced conceptual modeling with the introduction of Systemic Diagrams, commonly called Systemigrams. This soft system data visualization tool gives systems engineers and project managers the means to better understand and depict their identified problem situation (Boardman, 1994). A Systemigram acts to capture the concept of a system. It is a way of making a visualization from a complex set of data about that system, focused on a topic of inquiry regarding what one wants to understand about it; and, whether it functions harmoniously as intended, resulting in desired outcomes (Boardman & Sauser, 2008). That visualization results from a set of sentences describing how the system is constructed, its component elements as descriptive nouns (nodes); connective verbs describing the linear actions between those parts, represented on arrows. These interconnections show the flow of the system interactions from beginning to end as a way of describing the whole system, the sentence encapsulating its relevant elements to visualize the data the system analysis reveals. A sample Systemigram from a past research project is shown in the following figure, entitled, "What is Resilience?"

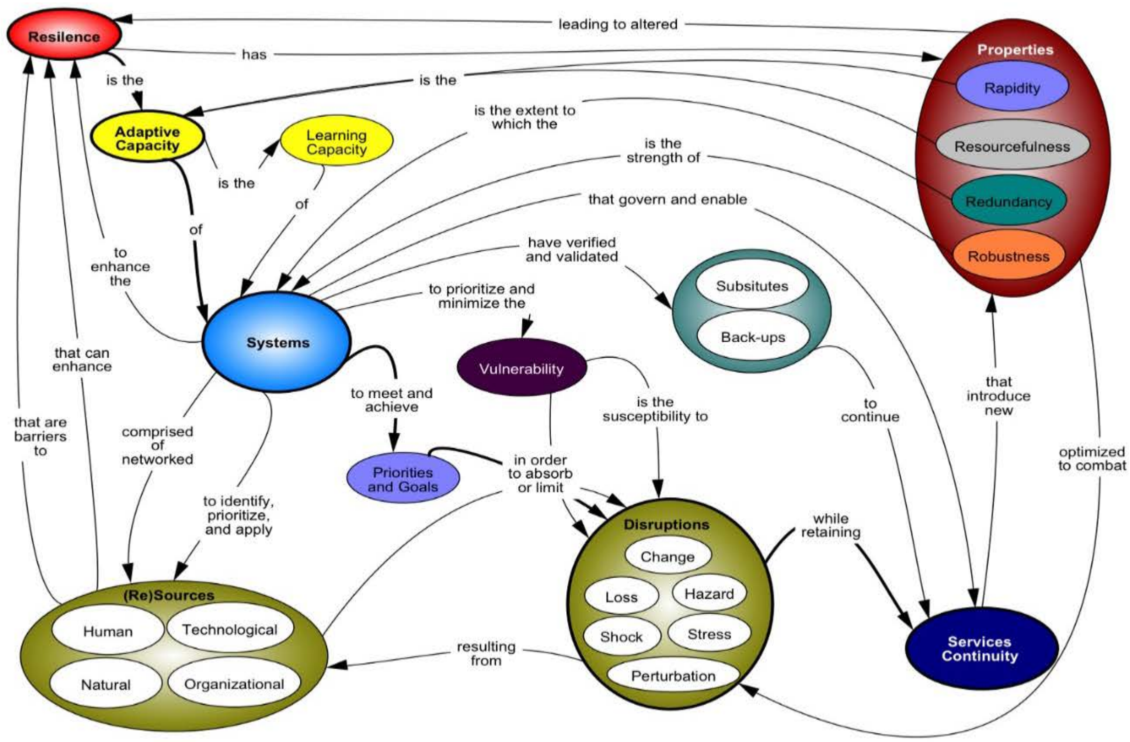

Figure 10."What is resilience?" Systemigram?

Systemigrams require that the examiner of a system consider different stakeholder perspectives and allow them to formulate not only a description of the system, but also explain how each element is connected and interacts. To that end, Boardman (1994) provided a cyclical set of four stages that incorporate Checkland's SSM: 1. Interaction and collaboration of human activity systems leading to *data capture*, 2.) Captured information used for *model creation* and 3.) Systemigram development leading to *model evaluation* for 4.) Systemigram revision used for *systems improvement*, before returning to the analysis of human activity systems again. Data is collected from the stakeholders and relevant artifacts of work processes that can help the analysts understand the current state of the system. In the process, the engineer or analyst first defines the area of interest and then gathers as much information about the system or process that is to be modeled, from as many sources (stakeholders) as is possible or relevant. This data capture phase requires documentation review surveys/questionnaires of stakeholders and interviews with stakeholders.

Rule 1. The primary sentence (mainstay) that supports the purpose of the system is read from top left to bottom right

Rule 2. Ideally, there should be 15-25

Rule 3. Nodes must contain noun phrases (people, organizations, groups, artifacts, and conditions), and link should contain a verb or verb phrase

Rule 4. No repetition of nodes. Redundant nodes lose the essence of relationships

Rule 5. No link crossover

Rule 6. Beautification should help the reader read the sentences in the diagram

Rule 7. Exploit topology to depict the why, how, and what of the system

Using these rules, Systemigrams tell a story of the inputs, outputs, functions, structure, and actions that exist in a complex system. They act as a diagrammatical representation of structured text and software like SystemiTool provides the user the ability to storyboard and display each piece of a Systemigram, which is key to their use. Visualization of a whole system picture is often necessary to show stakeholders how the entire system works together. However, in some cases, it is easier to understand the system by first viewing only pieces of the Systemigram at a time. Once the highest-level system abstraction is modeled, each individual node may be created as its own Systemigram to provide illustration of subsystems using a "system of systems" perspective (Gorod, Sauser, & Boardman, 2008), as illustrated in Figure 11.

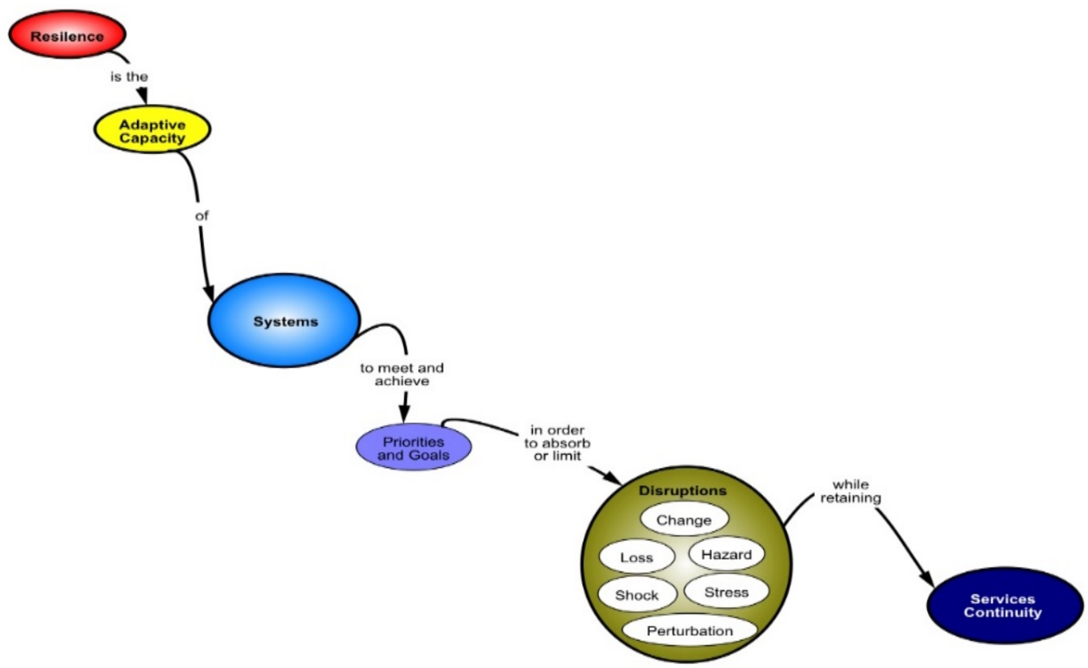

Figure 11. **Sub-system from the "What is resilience?" Systemigram.**

Once a family of Systemigrams has been created, they form an easily navigable story of the system. Story boarding also refers of the Systemigrams piece parts being individually shown prior to (or explained after) the whole system model is shown.

Systemigrams have been used since around 1994 when Boardman first described them to visually depict the outcomes of soft systems methodology with complex systems. However, it is unclear what their impact has been on academic and business practices that require research on complex systems involving humans, technologies, and poorly structured problem situations. Further, since that time, several authors have proposed improvements to soft systems methodology in different disciplines, that lead to different perspectives about the use of Systemigrams to conceptualize research findings. The following section describes our methodology for understanding the impact of Systemigrams on data visualizations of soft systems, the gaps in use identified in related publications, and suggested improvements identified by researchers who have used Systemigrams and related digital tools to depict complex problem situations during that time.

Methodology

This study explored the impact of Systemigrams as a means of data visualization outcomes resulting from the study of complex systems using “soft” research methodologies in engineering, business, and other disciplines. A multi-strategy research approach was employed (Robson & McCartan, 2016) involving bibliometric analysis of articles that include Systemigrams, content analysis of those articles to determine whether they identified improvements to their application for research, and surveys of Systemigram developers using semi-structured questions. Since bibliometrics is a data analytics approach that fosters visualization, we began by using a data mining tool with the term “Systemigram” to gather a corpus of articles from 1994-2018 which were added to an existing set the authors already collected during other studies. Multi-strategy or multi-methodology approaches (Mingers & Brocklesby, 1997; Pollack, 2009) are common in the library and information sciences. They are used to gather information about the impact of research publications by examining citations, authors, keywords, texts, and dissemination outlets to identify trends, impacts by use, subjects, and fields that have adopted SSM. Databases explored included JSTOR, ERIC, ABI/INFORM, ASSIA, IEEE Xplor, Health Source, IGI Global, PsycArticles, ProQuest, and others included in a meta-search provided by both a free to use data miner and university Boolean record search. Perceptions of Systemigrams and how they can be improved in practice were gathered a survey was sent to active and past users of SystemiTool, a product employed to produce Systemigrams, that has existed since around 2002.

Data Collection

Data was gathered from multiple sources to capture the most comprehensive profile of the use of Systemigram available. The first set of data was collected by gathering available publications with Systemigram(s) as a key word to locate publications that used systemic diagrams for research data visualization. We also included a survey of active and former Systemigram developers to assess their perceptions of the process of Systemigram development and the available tools to identify potential improvements.

Bibliometric Data Gathering Approach

The following digital tools were employed to locate primary source materials, which facilitated a process that often required using more than one data source.

- Harzing's Publish or Perish – This was the initial search tool used to collate the starting data set (see Figure 1). This data mining tool from Google Scholar collects publications based on keywords and produces a listing all articles, books, book chapters, dissertations/theses, white papers, conference proceedings, and reference citations. In addition to authors, titles, and publication names, it also provides citation counts and links to the pieces.
- University library databases – JSTOR, ERIC, IEEE Xplor, and others provided by the university were used to gather PDFs of each article for review to determine if SSM was, in fact, present in the publication.

- Research Gate – Many PDFs of SSM pieces were available by their authors for download on this site. Some were freely available, while others were provided upon request.
- Google and Bing searches – Boolean searches were used to find online posted PDFs when they were unavailable elsewhere, as well as to determine whether some mislabeled publications were conference proceedings, books, or chapters, rather than peer-reviewed articles.
- Publisher web sites – Some articles were only available through publishers and were purchased or sometimes available for no cost.
- Amazon and Google Books – These were used to purchase Kindle or original books as necessary for review.
- Organization web sites – For those pieces not correctly labeled as conference papers, we gathered abstracts as confirmation that the full paper was available. If not, the piece was not included in the analysis.
- Scimago Institution Rankings – This site includes journal and country scientific indicators drawn from the Scopus database using Google PageRank algorithm to create rankings (called SJR ranks) for each dissemination outlet. When available, it also includes h-index rankings. Both were included in the corpus of data to gauge the impact of the journals in which SSM pieces were published. These do not include books, chapters, or most conference proceedings.

The Harzing's Publish or Perish tool produced 1,000 results, limited in the tool to those that included the full keyword terms "Systemigram." These pieces were in our university library databases and through other Boolean searches (e.g. Google, Bing, Metacrawler, Google Scholar) to produce the original data set used for citation and content analysis. All other source outputs were integrated into the database.

Using these data sources to build the database, we employed the following approach to analyzing the data to answer our questions as follows. To hold the rigor of the publication outlets steady for this study, we examined only publications we could access full-texts for to determine whether Systemigrams were discussed or employed as a data visualization technique. Therefore, we included only conference proceedings that included full research papers. Books, peer-reviewed articles, chapters, research-based white papers, and dissertations were the bulk of our data sources used for analysis. To gather these sources, our data collection methods, which sought to be exhaustive, employed data mining and Boolean searches from multiple sources using the following approach. To gather perceptions of past and current users of Systemigrams as data visualization outputs, we also conducted a brief survey.

Survey Approach with Systemigram and SystemiTool Users

The survey included 33 questions, with eight demographics questions and another 18 focused on SSM/BSSM usage that commonly leads to Systemigram outcomes. The remainder specifically asking about experience with developing Systemigrams with digital tools, including SystemiTool. Three of the survey questions related to Systemigrams were open ended and asked:

- If a new version was created, what could be done to improve the use of SystemiTool?
- What other recommendations would you have to improve the usability and your likelihood to use SystemiTool for Systemigram development in the future?
- What recommendations do you have to increase the likelihood that you would use Soft Systems Methodology fully in the future?

The outcomes of the bibliometric data analysis, content analysis, and qualitative survey responses were analyzed together for commonalties in the following manner.

Data Analysis

To prepare the data, we implemented Onwuegbuzie & Teddlie's (2003, p. 75) suggestions, modified to fit our data, as described below. This included the following steps, though not always in this order because the process was recursive as new data was discovered and refined:

1. *Data transformation and reduction:* These two stages were combined in a departure from Onwuegbuzie & Teddlie's approach because the transformation process was part of the reduction stage. PDFs of publications or hard copies of other texts were reviewed to determine if SSM or BSSM was discussed or used for research. In the transformation, the qualitative data captured from reviews of the publications was quantized with a binary score of 1 representing the presence of SSM in a piece or 0 if not. Those that did not were eliminated from the database. Further transformation took place in classification of the pieces from the *Publish or Perish* mining process when determining if they fit one of the following criteria: a. peer-reviewed articles, b. books, c. book chapters, d. white papers e. dissertations/theses. The publications also had to be available for review, so most conference proceedings were eliminated. Columns with incorrect or irrelevant data (e.g. repeated search dates, publishers, etc.) were also deleted.

2. *Data integration* - Research Gate, publisher sites, Scimago ranks, etc. data was assimilated.

3. *Data comparison and correlation* – Data from the different sources was compared and correlated to confirm that each produced the same results and corrections were made, adhering to the source with highest credibility (e.g. primary source). These two stages were combined and differed from Onwuegbuzie & Teddlie's approach because they were concurrently performed. Documents that could not be confirmed to include Systemigrams were eliminated.

4. *Data consolidation* – All data was consolidated into the database and primary source texts were organized in a digital folder, organized by subject area. The source texts were analyzed for their suggestions regarding how to improve soft systems methodology and/or the use of Systemigrams. The suggestions were quantified by type: a. modification of steps, b.) addition of steps, c.) reduction of steps, d.) addition of secondary methodology (e.g. System Dynamics), e.) use of other tool set (e.g. SysML), or f.) improvement to available visualization technology.

5. *Data display* – The outcomes of the organized database set were analyzed in Excel using Quick Analysis to produce visualizations in the form of tables, charts, and graphs. The outcomes of the data display step are the core of our findings, presented in the next section. These are linked to narrative statements from authors that help direct our recommendations for future improvements that may lead to the increased adoption of soft systems methodology and/or Systemigrams for research in engineering, and business.

This research and analytic process allowed us to answer the following questions:

- How often have Systemigrams been discussed in academic literature and in which disciplines?
- How often have Systemigrams been used as research outcomes in the academic literature and to what purpose?
- What challenges with the use of Systemigrams have been identified for improvement?

The original search in Harzing's Publish or Perish data mining tool produced 219 references to Systemigrams in Scopus and Google Scholar-related citations. The cleaned, reduced data produced 85 publications referencing or employing Systemigrams. The qualitative findings from the survey were analyzed using a systematic-qualitative approach (Aslani & Naaranoja, 2015) to examine participants utterances to identify commonalities among sentiments, which were compared with the results of the document content analysis and bibliometric data to identify thematic recommendations for improvement to the use of Systemigram development and associated tools.

Findings and Discussion

Our analysis presents the frequency of use with Systemigrams either to describe the process of creating them or as research outcomes from different methodologies. The following sections explore these outcomes with accompanying data visualizations.

Impact of Systemigrams on Academic and Practice Research Visualizations

The first major outcome is the publication trend tied to Systemigrams from 1994 to 2018. Figure 12 shows how many publications with some reference to Systemigrams during that period.

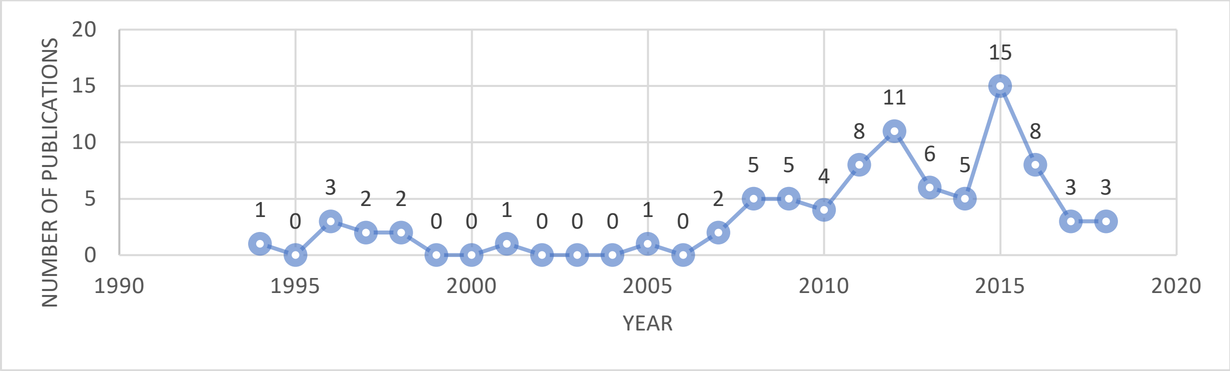

Figure 12. Publication trends for pieces including Systemigrams by year (1994-2018).

In Figure 12, we see small growth in the discussion around using Systemigrams from 1994 to around 2007, when the number of publications increases dramatically. The period from 2007 to 2017 was the strongest period of Systemigram presentation for illustration of the approach or research outcomes. This was also the period during which Systemigrams were most often used as a "soft," complex qualitative data visualization technique to present research outcomes rather than to simply discuss proposed frameworks for improving methods. The publication outlets that are most highly represented are included in Figure 13.

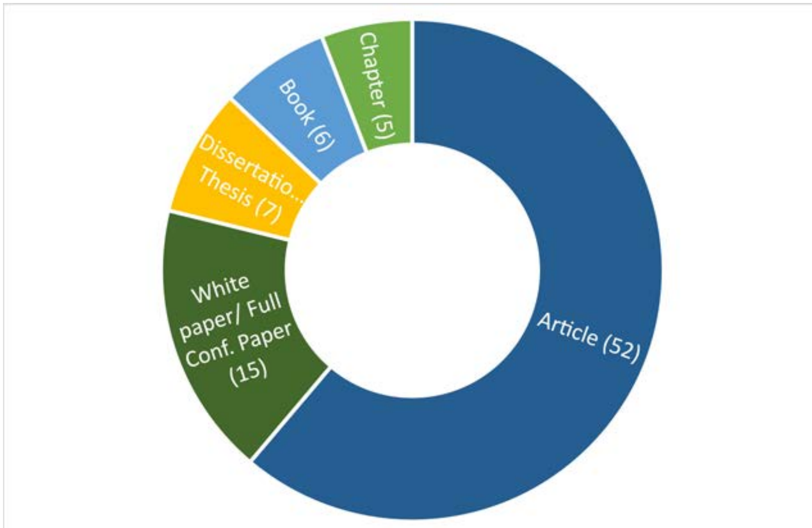

Figure 13. Highest frequency publication outlets with Systemigrams (n= 85).

While the figure does not incorporate citation counts, the largest number of publications related to SSM has come in the form of book chapters. The top nine most represented journals each had published at least two SSM pieces, though only eight had citations because two of the pieces in Service Science were recently published. The following table includes descriptive information on the top Systemigram related publications.

Table 2: Top ten Systemigram-related publications

Year	Citations	Authors	Title	Publication
2008	250	Boardman & Sauser	Systems thinking: Coping with 21st century problems	Book
2015	82	Arnold & Wade	A definition of systems thinking: A systems approach	Procedia Computer Science
2001	77	Cooke-Davies	Towards improved project management practice: Uncovering the evidence for effective practices through empirical research	Dissertation/Thesis
2011	68	Randall, Nowicki, & Hawkins	Explaining the effectiveness of performance-based logistics: A quantitative examination	International Journal of Logistics Management
1998	50	Conroy & Soltan	ConSERV, a project specific risk management concept	International Journal of Project Management
2014	43	Khansari, Mostashari,	Impacting sustainable behavior and planning in smart city	International Journal of Sustainable Built

Year	Citations	Authors	Title	Publication
		& Mansouri		Environment
2015	41	Rainey & Tolk	Modeling and simulation support for system of systems engineering applications	Book
2007	40	Blair, Boardman, & Sauser	Communicating strategic intent with systemigrams: Application to the network-enabled challenge	Systems Engineering
2010	38	Sauser, Boardman, & Verma	Systomics: Toward a biology of system of systems	IEEE Transactions on Systems, Man, and Cybernetics
2012	37	Bayuk, Healey, et al	Cyber security policy guidebook	Book

The top ten articles account for around 60% of all cited works that discuss the use of Systemigrams. The most cited authors (Boardman & Sauser, 2008) had around three times the citation count as the second highest authors (Arnold & Wade, 2015), as presented in Figure 14.

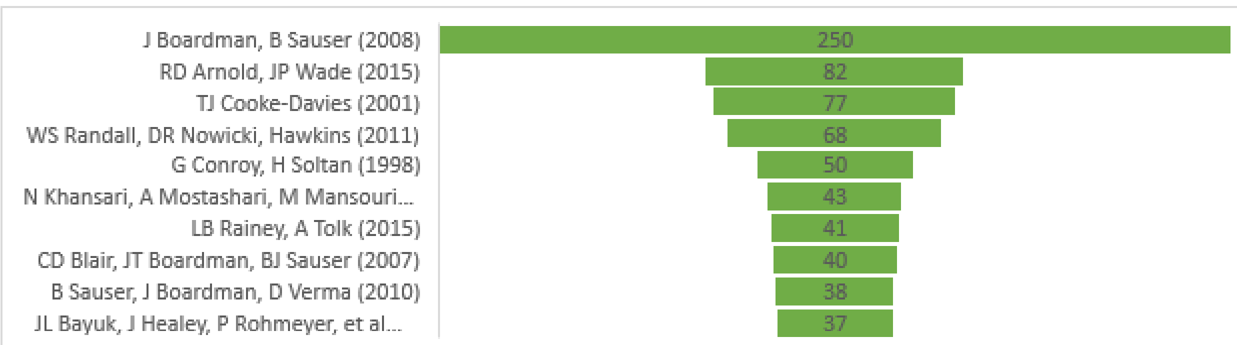

Figure 14. Visual depiction of the highest cited Systemigram-related authors.

While the authors presented in Figure 3 had the highest cited pieces, individual author analysis with the largest percentage of all published Systemigram-related pieces shows a similar, but slightly different picture in Figure 15.

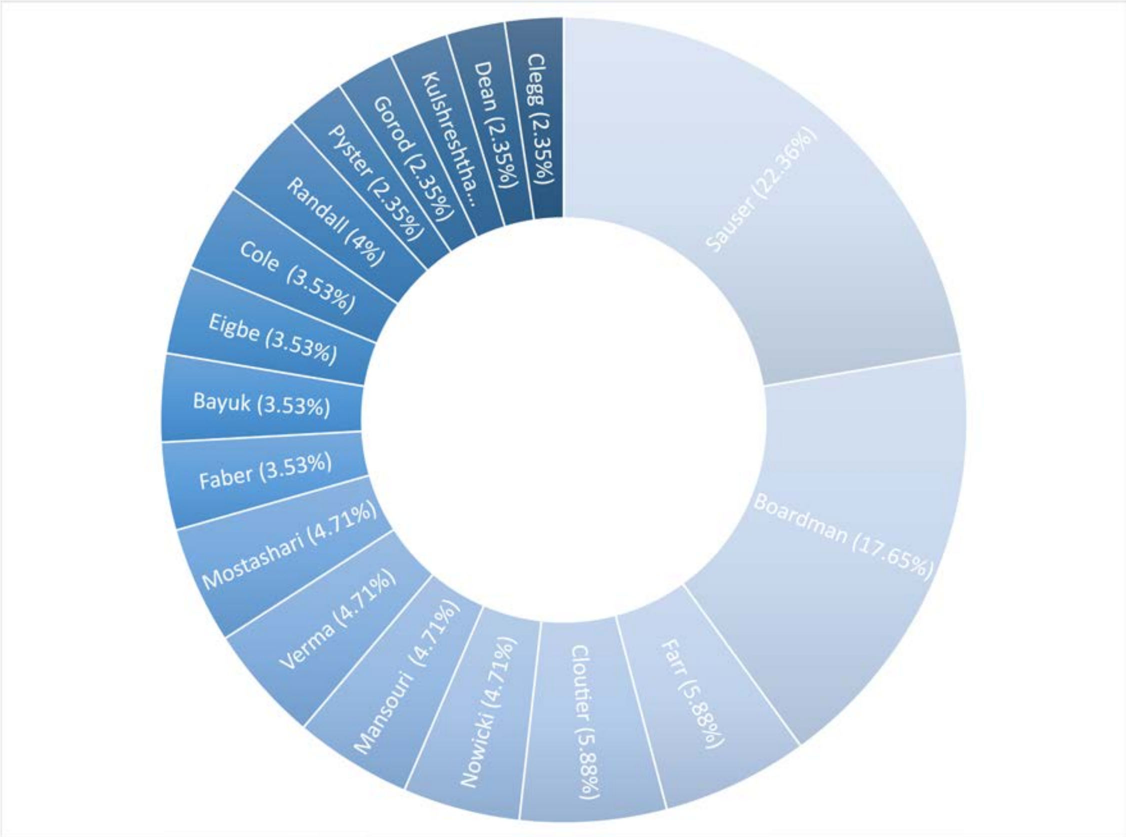

Figure 15. Authors by percentage representation of all Systemigram pieces.

Sauser and Boardman, both strong proponents of the both Boardman's version of soft systems methodology (SSM) and the use of Systemigrams, provided the largest number of peer-reviewed articles with research outcomes. For Systemigrams illustrating process or research outcomes, Table 3 shows the dramatic impact of books by Boardman, Sauser, and others have had over the last nearly 25 years.

Table 3: Top publication outlets for Systemigrams by citation concentration

Dissemination outlet	Citation percentage
Books	30%
International Journal of Project Management	12%
Procedia Computer Science	10%
Dissertations/ Theses	8%
International Journal of Logistics Management	6%
IEEE Transactions on Systems, Man, and Cybernetics	6%
Systems Engineering	6%

Dissemination outlet	Citation percentage
White papers	5%
International Journal of Sustainable Built Environment	4%
Book chapters	2%

Two hundred fifty citations came from Boardman and Sauser's 2008 book that illustrated the conceptagon, soft systems methodology in practice, and the use of Systemigrams as data visualization outcomes. This text is sometimes used as a course text to teach related concepts. Figure 16 presents the impact that books and the International Journal of Project Management have had versus other dissemination outlets.

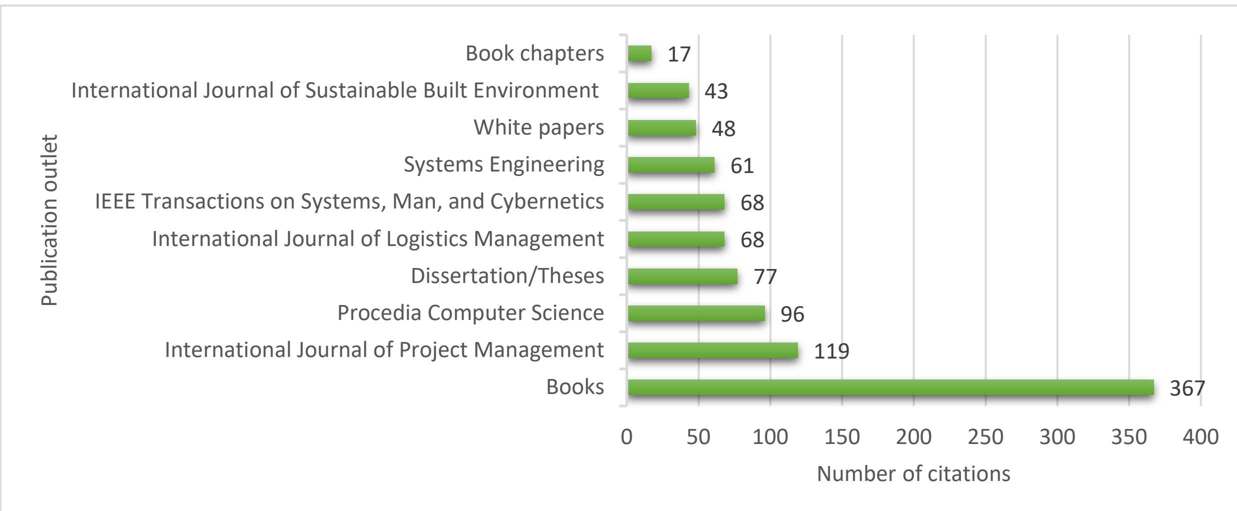

Figure 16. Systemigram citation counts by publication outlet.

Books had the largest impact, based on citation counts, largely weighted by the popularity of the Boardman and Sauser (2008) text. Five of the next six publications were peer-reviewed journals or conference proceedings with relatively high Scimago (SJR) and h-index (h) scores. For example, the International Journal of Project Management has a 1.46 SJR and 110 h value, indicating high readership and reach of these pieces. IEEE Transactions on Systems, Man, and Cybernetics has a 1.3 SJR and 103 h-index, comparing favorably with many top journals in the field and providing significant impact to Systemigram-related research and theory development. Peer reviewed journals and books account for around 68% of all citations. Disciplines working with Systemigrams and impacted by related systems thinking are discussed in the following section.

Systemigrams for Systems Thinking and Research in the Disciplines

To examine which disciplines are most impacted by Systemigrams as visual research outcomes from systems thinking-related methodologies, each publication was read, analyzed, and coded according to the Scimago journal subject area aligned with the content. While white papers, dissertations, books, and chapters do not have subject areas, they were coded in accordance with similarity to journal articles containing the same subject matter. Figure 17 presents the distribution of articles according to coding for Scimago subject area, which is a respected publication ranking system derived from h-index and other metric scores.

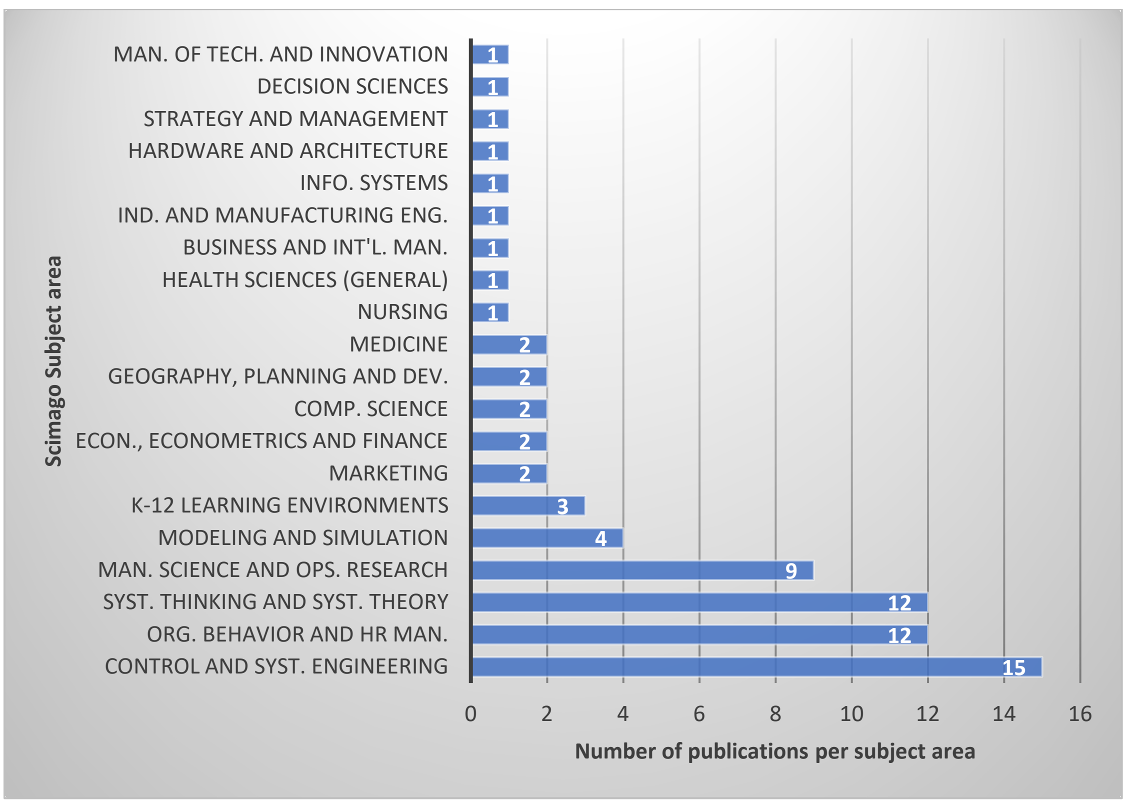

Figure 17. Top 10 SJR coded subjects of publications using Systemigrams.

Control and systems engineering was the largest subject area studied using Systemigrams. Organizational Behavior and Human Resources Management and its complex human problems and systems had slightly fewer publications, often focused on employee allocation and physical resource problems. Systems thinking and systems theory pieces, the category that tied for second largest number of pieces, tended to include pieces focused on expanding or solving perceived problems of either soft systems methodology or the use of Systemigrams. Management Science and Operations Research pieces largely examined problems of flow and process in organizations with a goal of depicting complex problem situations. The last two major subject areas were *modeling and simulation of complex systems upon the creation of a Systemigram* and *complex K-12 learning environments where the problem situation was difficult to observe*, with multiple systems touching upon one another concurrently. Overall, business has employed Systemigrams as data visualizations from most often from research on complex systems, with engineering slightly behind, followed by medical sciences and education.

Gap Analysis Outcomes

A content analysis (Robson & McCartan, 2016) was performed by reviewing the 85 publications that included Systemigrams, to determine whether they included either research outcomes from SSM/BSSM or other multi-methodology studies or examples tied to proposed conceptual frameworks. This led to the identification of several issues with publications that employed Systemigrams as system visualizations shown in Figure 18.

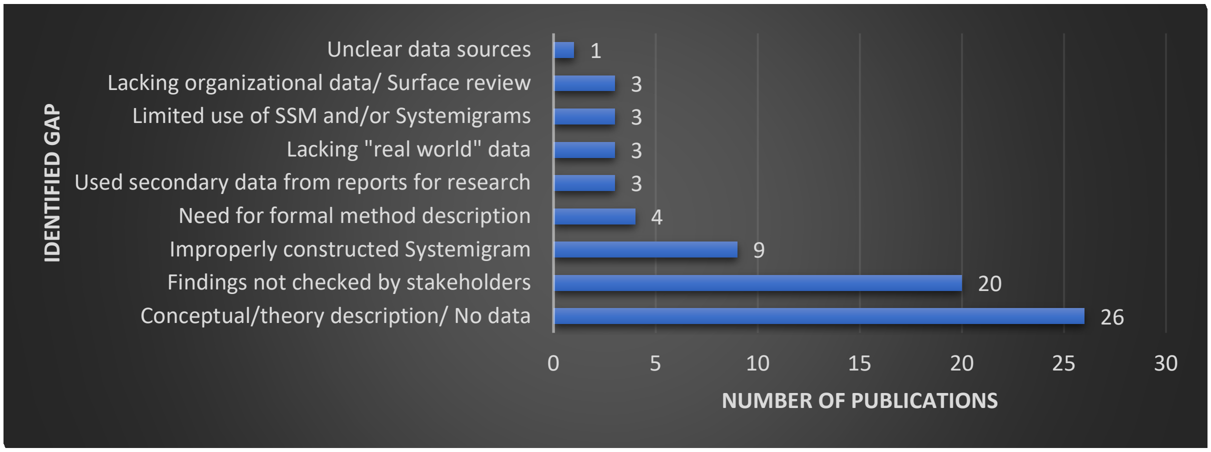

Figure 18. Common identified gaps in the reviewed Systemigram articles.

The largest issue regarding the use of Systemigram visualizations in the publications was that most authors were concerned with developing conceptual frameworks or new ideas for research and theory creation, but did not test these against data, real world or otherwise. Of the 26 pieces provided illustrative figures of Systemigrams used with permission from other authors, only around 31% contained original data from research studies. The second largest problem was that, while the Systemigrams were often created, they were made with “dummy” data from external examinations of business systems. Therefore, the fidelity of the research outcomes could not be checked by stakeholders to determine their credibility or value for making systemic change decisions. A third issue was that some authors did not follow the rules of Systemigram development, so while visualizations of data were present, the outcomes often lacked coherence and, therefore, value for decision-making regarding the systems or left major gaps. In other instances, it was unclear how the Systemigram was created, because no formal research methods were described. Overall, compared with other forms (e.g. flowcharts, Vee diagrams, etc.) there were limited uses of Systemigrams as visualizations of complex systems from research projects in the corpus of publications gathered for this study. This led us to the question as to what limited the use of Systemigrams. Open-ended survey questions were given to researcher who have used Systemigrams, coupled with either Checkland or Boardman's soft systems methodology indicated major challenges to expanding the use of Systemigrams as a data visualization technique, mainly stemming from dated or inappropriate supporting technologies.

Improving the Systemigram tools: The Views of Active and Past Users

In their open-ended responses, the participants gave more specific recommendations from their experience. For example, one participant supported several findings noted in the gap analysis, stating:

> I used SystemiTool to help our proposal teams decompose Requests for Proposal into clearly defined requirements for response. These were very effective for performance-based contracts where services needed to be defined along with their associated quality of service metrics. I also used it with proposal people to help determine the interfaces among organizational and service elements to produce effective solutions. I think a better interface and more training would have been helpful. Same for the graphical presentations.

In this instance, the participant noted that there are specific situations in organizations that could be better depicted from a service-dominant logic perspective (Vargo & Lusch, 2004). Providing better options to frame visualizations of complex organizations and the individual services provided, leading to improved Systemigram outcomes were important components, but internal "help" or training features in SystemiTool were a recurring need. Another respondent noted:

> The book accompanying the software should be a very simple "how-to." The examples should be Dick-and-Jane easy. I would be happy to contribute some of my examples if need be. I think the book's content is too colloquial and distracts from the method. The method absolutely works, and I have gotten nothing but positive feedback from colleagues as I use it.

Another participant asked for it to be easier to create and edit the visualization that can be presented in stages, with only certain descriptor "nodes" and verb connectors fully visible at a time. "Make it easier to distribute the show...without giving away the ability for someone to alter it after the fact.” This is an issue, because once a “Show” is created, it cannot be modified, and a new output must be done, limiting its efficiency. Another respondent explained that the “presentation of problems/solutions - the Systemigram is great but it is hard to distribute just the show for people.” Another respondent noted that, “For personal/private use to mull over problems I'd be more likely to use it if I didn't have to relearn the interface and if there was better help. For regular work problems? It's a hard sell to management as a solution in itself. Include a Systemigram on a PowerPoint and it had better be a simple one.” This was echoed by a respondent who had worked in business for decades when he said, “The biggest issue I face is how to communicate the results of this work to leadership without using any of the terminology. The same issue all systems engineers have - translating into leadership/management speak.” This issue of mismatch between the product’s and mangers’ linguistic sets is one that limits the value of the data visualizations that emerge, as another participant explained, “Trying to communicate either to a management in a way they will accept is a wicked problem in itself.” The challenge could be addressed by narrowing the scope of analysis in the tool according to type of system being depicted. This could be done through automation and introduction of other data sources that feed into the analysis.

For example, other participants also asked for support for rapid development of Systemigrams with specific frames for conducting research using existing textual narratives of problem situations with one saying, “Add a variety of auto-generators of systemigrams. Easiest would be to work from structured text. For example, one that works from patent claims, reading the claims and automatically producing a preliminary Systemigram. Should be a great aid in claim construction effort.” Another participant supported this idea with a desire to automatically generate Systemigrams with other data sources, saying “it would be great if the tool could generate Systemigrams based on the A-tables. So, you can start with rules in the A-table." In keeping with the idea of linking SystemiTool to narratives to other data sources, a third respondent noted suggested that "If you put a database behind the graphics, we would then need a way (scripting capability or perhaps an interface to R to interrogate the data to learn things that are not obvious from the diagrams." Better management of analytic data was another issue identified to better support research methodologies and Systemigram visualizations, "SSM could use more tooling to manage the information. I often am torn between SSM/BSSM and causal loop diagramming (systems thinking)." This was explained as a challenge by another respondent who said, "I had always felt that the ability to embed even more data behind each of the objects in a tool like SystemiTool would be valuable, but I came from a company where we built and used software that created data-driven models." Linking hard and soft systems language through artifacts that feed into the Systemigram analysis was made explicit when another respondent noted that, "1) make SystemiTool more dynamically linked to information in its artifacts and investigate how Boardman's Soft Systems Methodology can be expressed in SysML or other modeling tool." This is in keeping with initial conceptual work already undertaken by Cloutier, Sauser, Bone, & Taylor (2015) to integrate Systemigrams and SysML to produce improved visualizations.

Each respondent suggestions could provide more credible research outcomes by providing data sources from multiple data streams, each linked together through a particular analytic frame to limit the scope of inquiry (e.g. performance contracts with suppliers, management strategy employee productivity outcomes, organizational performance by unit, etc.) Limiting the scope of analysis should help focus researchers' attention to individual system aspects and speed the creation of visualizations. Further, reducing the subjectivity of the research methodologies commonly used with Systemigrams and SystemiTool (e.g. SSM, BSSM) by incorporating other data sources that are easily visualized and can offer additional support for the identification of problems in a situation can improve the acceptance of the findings by academics and managers that may prefer their data visualizations come from multiple data sources. From the survey of active users Systemigrams and SystemiTool, the top recommendations from the study participants regarding SystemiTool are presented in Table 4.

Table 4: Recommendations for improvement to SystemiTool for Systemigram development

Recommended improvement	***Top 5 ranked respondent choices***
Better define choice framing to focus problem situation analysis	75%
Make it simpler to visualize complex scenes	75%
Simplify the interface	66%
Need Mac version	55%
Better graphical outcomes easier to explain to supervisors	55%
Increase the training to use the tool	44%
Provide more fully worked out examples in multiple problem situations	44%
Link the Systemigram outcomes to engineering language that makes it easier to develop strategy, organization, strategy, system change	33%
Cloud-based software that saves to Google Drive, etc., w/o download to local machine	22%

Overall, while participants had mixed feelings about the efficacy of the current version of SystemiTool, which is now around 15 years old, they all valued it. A typical response was “It is a great tool and has a special place in my engineering toolbox!” and another “I will use the software for as long as it still works through Microsoft operating system changes. If I am concerned about anything, it is that the software may stop working.” A third noted the importance of using Systemigrams as a means data visualization in other research disciplines, “Get it into the training programs of every school you can find. Don't limit to engineering--the underlying thought process is just as useful for business people and social scientists as it is for engineers.” There was one limitation noted by several participants, illustrated by a respondent comment, “create a Mac version!”

Conclusions and Implications

When seeking to depict complex systems or problem situations, data visualization is a difficult task for any researcher. The number of systems involved, their touching points, relations, functions, and actions are challenging to include in a graphical representation and available approaches have been historically limited to SWOT, PESTLE, flow charts, and similar depictions. Systemigrams have shown some significant use in the last fifteen years to address this issue, though there remain areas for improvement identified in this study. A major gap noted in the publications that included Systemigrams was that a significant number did not produce research outcomes and merely discussed their value for that purpose. Further, users noted that, for increased adoption, improving the data visualization products currently available is necessary. This can be done by improving the interface and functionality, like SystemiTool, to make it easier to produce intelligible system depictions so that decision makers can better understand the information and what it means for firm strategy.

The development of improved digital tools including or beyond SystemiTool was suggested to speed analysis and improve visualizations. This will allow the research outcomes to better communicate relevant information to business stakeholders in corporate and other settings. Further, linking soft, hard, and strategic analysis frames in future digital tools to focus analysis to systems of interest should speed the development of germane analytic outcomes that clearly communicate the findings from the study of ill-structured problem situations that “soft” research methods such as SSM, BSSM, and dynamic systems approaches lend themselves to depicting.

Better integrating data sources from other, more quantitative research methods was also suggested to bolster the credibility of the research outcomes and data visualizations when presented to managers and academic audiences. Taking these steps should improve complex systems analysis and visualization in the future, leading to better product development, processes strategy, and managerial decisions for those that adopt the use of Systemigrams and soft research methods.

ESSAY 3

A GROUNDED THEORY STUDY OF SOFT SYSTEMS METHODOLOGY RESEARCH REGARDING OPERATIONS MANAGEMENT WITH LINKS TO FIRM STRATEGY AND PERFORMANCE

Abstract

Soft systems methodology (SSM), an analytic method commonly employed in operations research with complex systems ranging from individual problems rooted in complex causes to whole organizational problems stemming from strategy and performance issues. This method is used to produces model focused on human activities in such systems to identify likely areas for improvement by showing interrelations of systems, functions, and interactions. The initial conception of SSM involves seven stages that leverage a systems thinking viewpoint for developing a depiction representative of the multi-perspective lenses on the systemic complexity of a problem to provide a clearer picture. Later implementations of the method include the creation and articulation of Systemigrams, or systemic diagrams, used to depict the conceptual models of SSM to create and visualize a multi-perspective view of a system of interest. While proposed as valuable for operations research, the method has been employed less often than system dynamics, failure modes and effects, or other approaches to analyzing complex systems for operations research in the context of organizational and whole firm strategy. We take a grounded theory approach to analyzing the SSM for operations research to identify what may have limited its perceived value in business and other organizational settings, as well as offer recommendations for how to overcome each.

Introduction

Soft systems methodology is a valuable technique for understanding complex problem situations like those faced by operations management professionals that has been employed for nearly 40 years in different disciplines (Checkland, 1981; 1994; Boardman, 1994; Arnette & Brewer, 2017). The complexity and difficulty of translating the SSM research outcomes of analysis related to "messy" or ill-structured problems into usable solutions has led to some mild criticism of the speed and viability of the process for moving the analytic outcomes into strategic or product improvement recommendations (Mingers & White, 2010). There has also been limited research into the effectiveness of soft systems approaches over time, in part because some analysts have found the method's requirement of stringent research with stakeholders to be onerous, leading them to apply only a portion of the SSM stems (Mingers, 2011). SSM has been used to depict the conceptual models of SSM and acts as the medium to create and visualize a multi-perspective view of a system of interest is Boardman's soft systems methodology (BSSM). Systemic diagrams, also known as Systemigrams, were developed by Sherman, Boardman & Cole (1993). These tools expanded on SSM to help provide a better way to visually model complex systems. Since then, authors have defined, described, and used Boardman's conception to more fully realize their systems (Sewchurran & Petkov, 2007; Cloutier, Sauser, Bone, & Taylor, 2015). Systemigrams are used to model business processes and bring to life complex engineering root definitions, model ideologies of defense strategy, and improve project management operations.

This paper begins with definitions of management and firm strategy, explaining how they connect to operations management constructs. This foray is followed by how these concepts connect with General Systems Theory, the framework that acts as a conceptual grounding for

SSM, explaining how understanding complex systems should be undertaken. In addition, a brief review of SSM's history is provided, presenting an overview of which authors have used it, how it has been used and its development as a systemic thinking tool. This piece examines past use cases with the implementation of SSM and Systemigram outcomes as a means of identifying strengths and weaknesses of the approach. A major scope of the piece is where the methods were applied to later managerial strategy formation or hard systems development. Using these outcomes, we explore potential expansions of SSM related to speeding the methods by connecting them better to hard systems engineering and business outcomes, what Mingers & Brockelsby (1997) called multi-methodology. A primary outcome of this study is the identification of improvements to the use of SSM in practice for operations execution improvement and business strategy creation. Further, we sought to learn how to improve SSM-related research reporting with data visualization to improve the value of this method to support firm-level strategic performance outcomes.

Literature Review

We begin our exploration of SSM in the context of operations and firm strategy exploring how organizational (i.e. within-firm) and business strategy (i.e. firm performance in the market) is commonly defined. We further explore how operations and firm-level strategy and execution are understood to intersect. This is continued with an examination of how systems thinking and SSM as a method for analyzing complex system has been understood and generally applied. This is followed by an exploration of the use of these approaches in the fields of operations management and logistics over the last few decades. From this examination, we recommend how

SSM may be improved to broaden future adoption and academic acceptance in different research fields, but with a focus on operations and business strategy.

Business and Firm Strategy

Barney & Hesterly (2012) explained strategy as "theory about how to gain competitive advantages" that are framed by a strategic management process that includes a sequential set of analyses and choices that can increase the likelihood that a firm will choose a good strategy […] that generates competitive advantages" (p.4). By comparison, Rothaermel's (2013) more activity-oriented definition comes in the context of a company's competition in an industry as "the planned and realized set of actions a firm takes to achieve its goals" (p. 4). A firm, as an economic organization, is predicated on strategically utilizing available resources better than other competitors in the market (Smith & Reece, 1999). This approach allows firms to contend with rivals using their advantage from product quality, price, promotion, or placement, usually executed through integration and coordination that provides consumer value to generate profit. The integration of business activities and resources, whether physical, human, or other that are viewed to contribute to improved competitive advantage, and requires authority designated to managers and they, in turn, require significant and relevant information to make good decisions about how best to allocate firm resources (Hunt & Morgan, 1995). Managerial authority provides direction to and coordination of firm activities, centralized decision-making, co-location, common knowledge that allows effective communication among stakeholders needed to be operationally efficient (Fiorentino, 2016). As a major component of product and service value creation in companies, business and operations strategy have moderating and mediating effects on one another (Oltra & Flor, 2010), These, in turn, impact how the firm is designed as a system made up of subsystems and other necessary components (Kristal, Huang, & Roth, 2010). The relationships of firm and operations strategy is central to fulfilling the promise of firm strategy and achievement, requiring a logical and operational fit between the two (Anand & Gray, 2017; Wagner, Grosse-Ruyken, & Erhun, 2012).

Operations Management and Firm Strategy

Coase (1937/1953) noted that resources and products are applied by firms for specific competitive advantages in response to changing market prices and consumer demand, requiring that firms be operationally efficient to meet these demand uncertainties. Managerial strategic decisions require understanding that, when similar commodities are needed, the decision should be to produce within firm, necessitating a when non-similar commodities are needed, the firm strategy should be to use market suppliers rather than manufacture them within the company (Williamson, 1981; Khanchanapong, Prajogo, Sohal, Cooper, et al, 2014). This situation requires a different set of operations strategies for coordinating with third parties, including a consideration of transaction cost economics and contracting to protect the firm against actors that seek unfair advantage by failing to meet requirements (Williamson, 1979). When complementary firm and supplier activities are needed that require coordination for production or marketing, managerial decision-making strategy should consider that when coordination is simple, use basic market transactions. As system complexity increases, firms should employ complex contracts to ensure resources are available and to ward against bad actors (Williamson, 2010; Jacobides & Billinger, 2006; Randall, Nowicki, & Hawkins, 2011).

A common conceptual framework for connecting firm and operations strategy and related research is the knowledge-based view of the firm (Grant, 1996; Nonaka, Cvon Krogh, Voelpel, 2006), originating in the resource-based view (Wernerfelt, 1984; Bromiley & Rau, 2016). In this context, complex system analysis focuses on mechanisms by which knowledge and other dynamic resource integration occurs (Teece, Pisano, & Shuen, 1997), which accords a broader view for organizations that seek to understand their productive activities, operational strategy, and how each fit to the larger competitive approach (Teck Hui, 2004; Adamides, 2015). This requires measuring how that firm strategy is designed to be more effective at the borders of the boundaries of the company and market (Fiorentino, 2016), to achieve competitive advantage against rivals (Kim & Lee, 1993; Santos & Eisenhardt, 2005), considering transaction costs against what is gained in resources, efficiencies, and other desirable firm outcomes (Rindfleisch & Heide, 1997; Gamal Aboelmaged, 2012). The complexity of large organizations requires a mindset that can accommodate and simplify the interactions of different systems and strategies, which has led to the use of a theoretical framework that dates to just after the end of World War II.

Systems and Systems Thinking

Systems thinking, as a term and set of processes, was first introduced and formalized in the 1950s. Originally labeled General Systems Theory (GST), it was developed as both conceptual framework and mathematically expressed theory, most notably by Ludwig Von Bertalanffy (1950). His original conception was that problems identified in complex systems across different disciplines affected one another. However, these situations had to be first described independently and then in terms of their interrelations to understand how they impact one another (Von Bertalanffy, 1968). GST allowed systems thinking to flourish across disciplines such as ecology (Bronfenbrenner, 1974), engineering (Checkland, 2000; Mingers &

White, 2010), business (Caws, 2015), and education (Banathy & Jenlink, 2003). Systems are commonly defined as a group of interacting elements (or subsystems) with a unified goal and defined by its boundary as well as the nature of the internal structure linking its elements (physical, logical, etc.). Furthermore, systems can be defined as “hard” (e.g. mechanical engineering, software products) or “soft” (e.g. management, human resources, complex organizations). “Soft” systems have more subjective qualities, because the human elements change dynamically in response to local needs. Organizations and business firms are increasingly understood from a “part-whole” perspective in which interrelated systems work together to produce desired outcomes (Zott, Amit, & Massa, 2011). Strategy is also commonly a central variable, governing interactions in these systems, and are deemed to impact firm performance.

Operations and Firm Strategy in Complex Organizational Systems

Operations and business strategy definitions and concepts were initially explored by Stobaugh & Telsio (1983), Hayes & Wheelright (1984), Schroeder (1984), Buffa (1984) and others. In these works, authors defined relationships between how decisions made throughout an organization impact its performance. However, the central components of strategy as we understand them for this piece were defined by Mintzberg (1990):

- **Content,** or the strategy as a construct
- **Process,** or the formation of the strategy construct
- **Context**, or the dimensions of strategy formation that influence performance and organizational structure

Tuna’lv (1992) described firm-level strategy process as one in which organizations formally define the alignment of competitive, firm level strategy, with to comport with organizational and operations strategy. This approach is expected to help the firm achieve better performance outcomes such as increased efficacies that improve profit (Fiorentino, 2016). However, when analyzed along content dimensions, Swamidass and Newell (1987) found no significant improvements to performance. Studies commonly examined the relationship between operations strategy and performance to support the firm's achievement of competitive priorities in an industry (Oltra & Flor, 2010). Such priorities were included in Skinner's (1969) operations strategy capabilities framework and are defined as the proficiencies that different operations areas must learn or acquire to support the firm's competitive performance outcomes, explained in the context of its macro-level strategic outcomes (Miller and Roth, 1994; Hunt & Morgan, 1995). Wheelwright (1978) explained operations priorities as:

- Efficiency (i.e. Cost)
- Quality
- Delivery time
- Flexibility

Studies linking operations strategy to firm performance have most commonly examined their effects on firm competition or organizational structure in relation to achieving competitive priorities and desired results (Vickery, Droge, & Markland, 1994; Ward & Duray, 2000). Research questions have often focused on how operations strategy primarily impacts firm performance by identifying the differences between operations strategies employed by high-performing firms as opposed to that of low-performing firms (Ward, Duray, Leong, & Sum, 1995). Operations strategy research also examined the contextual conditions that impact operations strategy and performance focusing on industry type or underlying industry factors deemed to impact strategy choice (Badri, Davis, et al., 2000; Abbey, et al 2013) and business the actual strategy selection (Buffa, 1984; Rhee and Mehra, 2006; Rosenzweig & Easton, 2010). With business strategy as a contextual variable, relative to operations strategy and business performance outcomes, researchers commonly explored liminal firm constructs. These commonly included different levels in each type of strategy, both functional and business, because these echelons are assumed improve performance as fit between them increases (Rhee & Mehra, 2006). When used in an internally supportive role, business strategy is expected to drive the selection of functional operations strategies that result in firm performance gains (Wheelwright and Hayes, 1985). Operations strategies are therefore expected to support and align with a defined business strategy. Therefore, when supporting external firm strategy goals, operations strategy is expected to locate and provide resources that help create and sustain competitive advantage for the firm (St. John, Cannon, & Pouder, 2001; Schroeder, Bates, et al., 2002).

Firm-level leaders must therefore decide whether operations strategy drives business strategy or business should drive operations (Stonebraker and Leong, 1994). However, operations strategy process, when aligned with firm and organizational strategy, supports the development of business capabilities (Hayes, 1985). This, in turn, positively impacts performance; thus, business strategy plays a role as a contextual variable in that relationship (Kristal, Huang, & Roth, 2010; Wagner, Grosse-Ruyken, & Erhun, 2012). Given the complex relationship between operations and firm-level strategy and outcomes, determining whether operations or firm-strategy should be dominant in managerial decision-making requires significant information about the complex system and subsystems that make up an organization (Smith & Reece, 1999). However, numeric, rearward-looking performance results tend to provide information about outcomes rather than process, structure, or context that can inform how to improve an identified level of performance. Research methods like system dynamics (Capelo & Diaz, 2009) are increasingly employed for describing the qualities and structure of such systems to connect operations and business strategy perspectives to performance outcomes. However, one long-standing approach found to have efficacy for understanding complex organizational systems and strategies is soft systems methodology.

Soft Systems Methodology to Comprehend Organizational Complexity

Checkland (1981) defined soft systems methodology (SSM) as a bridge between hard and soft systems which has shown increasing use over the last three decades to address complex business and engineering problems that involve humans and subjective factors (Boardman & Sauser, 2008). The hierarchy of firm and industry structures is often used to strategize connections between operations and firm-level strategy to overcome coordination and cooperation challenges, leading to operational and profitability improvements (Fiorentino, 2016). To conduct effective analysis requires separation of coordination and cooperation based on the goals of each firm activity, whether market planning, supply chain construction, or other desired business activity (Adamides, 2015). Understanding this hierarchical structure is important for systems-based analysis with complex organizations (Boardman & Sauser, 2008). Complex systems can be decomposed into subsystems. This allows each component system to be understood separately in terms of how well each function and performs independently, as well as how well interfunctionally aligns to perform the purpose of the whole firm (Boardman & Sauser, 2008). Analysis of hierarchy in complex firm systems is expected to support firm adaptation to the competitive environment, leading to improved performance over time (Gamal Aboelmaged, 2012; Smith & Reece, 1999). Examining how these changes take place within and across systems is an efficient way to integrate knowledge that aids in firm performance (Crichton-Sumners & Mansouri, 2013). A view of the firm as a learning organization that requires absorption of environmental and strategic information (Cohen & Levinthal, 1990) help managers understand the role and importance of facilitating the integration of necessary knowledge bases, which in turn reduces learning transfer costs, supports organizational innovation, adaptation, and performance by better leveraging the dynamic capabilities of the firm (Almeida Costa, Workiewicz, & Szulanski, 2016; Nonaka, 1994).

For operations research, understanding the complexity of activity coordination is central to developing strategy in areas like manufacturing (Milgrom & Roberts, 1995) and supply chain (Wagner, Grosse-Ruyken, 2012). Thompson (1967) explained that firm interactions are commonly structured from loosest or least intense (pooled interdependence), to intermediate (sequential), to most intense (reciprocal). This perspective can be a lens for examining how efficiently and effectively firms, internal units, and suppliers perform as subsystems, though bounded by managerial decision making. Williamson (1981) asserted that economic agents are rational; however, they lack perfect information and cognitive capacity to make full use of available information and identify all possible outcomes. This problem requires that management strategists be aware of their limits and act accordingly, seeking all available information about relevant firm systems through whatever research means are available (Eisenhardt & Zbaracki, 1992). Data visualization can improve complex findings communication with decisions makers. Using these tools may reduce organization leaders cognitive load that supports decision making when facing uncertainty situations (Janvrin, Raschke, & Dilla, 2014; Lurie & Mason, 2007).

System Visualizations to Communicate System State and Recommended Change

The complexity and difficulty of translating the outcomes of analysis related to “messy” or ills-structured problems into usable solutions has led to criticism of the speed and viability of using any SSM process to address using their analytic outcomes for developing strategic or product improvement recommendations due to the demands of the market for rapid managerial decisions (Mingers & White, 2010). There has also been limited research into the effectiveness of soft systems approaches over time within single systems, in part because some analysts have found the method's requirement of stringent research with stakeholders to be onerous, leading them to apply only a portion of the SSM stems (Mingers, 2011). Since Checkland's introduction of SSM, a common variant used to depict the conceptual models of SSM and act as the medium to create and visualize a multi-perspective view of a system of interest is Boardman's (1994) Soft Systems Methodology (BSSM). Boardman's version replaces three steps (3-5) from Checkland's version. Rather than "creating root definitions of relevant systems," analysts produce "structured text." In place of "making and testing conceptual models based on worldviews," Boardman introduces in the fourth step the concept of Systemigrams, also known as systemic diagrams, by Sherman, Boardman & Cole (1996). This substitution expanded SSM to improve the visual modeling complex systems. In the fifth step, analysts are expected to engage in dramatization and dialogue as a means of explaining how the system and its components work together.

Since Boardman's modification, many authors have defined, described, and used the newer conception to more fully realize their systems including adding SysML, UML, and other software engineering language and processes to better depict the relationships of hard and soft systems (Sewchurran & Petkov, 2007; Cloutier, Sauser, Bone, & Taylor, 2015; Simonette, Rodrigues, Seno, Plínio Franco Thomaz, Martinelli, & Hardman, 2008). Systemigrams have been used to model business processes to explore complex engineering root definitions

(Meentmeyer, 2009), modeling ideologies of defense strategy (Piaszczyk, 2011), and whole industries (Proches & Bohanya, 2015).

Challenges from the SSM Research due to a Focus on Operations Strategy through Project Management and Engineering

Early research work with SSM in operations settings was performed by Checkland (1985), Mingers (1980) Stowell & West (1994), Boardman (1994; Meng, Coleman, & Boardman, 1997), while Mingers and other operations researchers tended to focus on project-level studies of high complexity. This micro level focus produced illustrations of how to employ SSM in complex situations, often providing detailed explanations of each step of the process. However, it was rare for authors to extend the research process beyond the fifth step of conceptual development of the system as it currently existed using with Checkland or Boardman's SSM version. While valuable, these publications tended more towards "how-to" papers that explained the process and provided recommendations for improving smaller scale processes at the operations level for managing complex projects but lacked connections to how these improvements were expected to positively impact broader internal business resource allocation (meso) or firm competitive (macro) strategies and performance.

This issue is the main point of inquiry for this study reported as we explore the adoption of SSM for operations research since Boardman's version spurred increased interest and use of SSM in the mid-1990s. While project-level research is necessary, part of the explained value of soft systems research approaches is the ability to help organizations understand the interconnections not only at an operations and execution level, but what impact recommended changes are expected to have across different levels of strategy in an organization. Determining whether authors have taken advantage of this affordance of the methodology is necessary to understanding whether the promise of the SSM approach meets the reality of application and what might be done to improve its adoption. The seventh step of SSM is “Take Action,” yet studies reviewed in the literature review reported rarely reached past the fifth or sixth step.

Therefore, it is important to determine whether those authors choosing SSM as their research method have taken advantage of its benefits to produce strong strategy recommendations for systemic improvements that have impact on the system(s) of interest. Further, without empirically testing those recommendations against reality and then evaluating their impact on performance at any level, we cannot know the value of SSM. With these challenges in mind, the focus of this piece is on coming to understanding what forms of strategy (i.e. operations, firm, business, etc.) were studied and the degree to which connections across strategy are made. We also explore whether and how SSM studies of complex systems have been implemented and tested. Our overall goal is to employ a grounded theory examination of SSM research artifacts contained in publications to determine whether the current state of SSM methodology is sufficient to ensure its value for operations and firm-level strategy evaluation going forward. We also sought to develop a set of reasonable recommendations for how to improve SSM and BSSM’s acceptance by managers, analyst adoption, and use, while growing its impact on the performance of organizational systems in the future.

Methods

The goal of this study was to build a broader understanding of influence of soft system methodology on operations management research and strategy thinking using research-based publications. Each study acts as an individual use case to build a corpus of data that can be examined for patterns regarding the connections of operations-level research and strategy across other levels of firm performance. The articles, chapters, and conference papers act as evidence of the performative outcomes of authors' systemic development of linkages between strategy and action in the literature to build improvement recommendations that should have impacts across different levels of the system including profit, returns on investment, efficiency, and other relevant outcomes. Because the performance relationships across the research cases were unclear, predictions could not be made and undesirable. Therefore, a method that would allow explanations to emerge was necessary and a grounded theory approach was selected (Corbin & Strauss, 1990) to meet the needs of the exploratory nature of this study.

From the research-based applications of SSM to operations topics, we sought identify descriptive aspects of those research activities in terms of whether, how, and the degree to which the research-based strategic improvements to process, product, or system were also explained in terms of how they would improve the organization's broader levels of strategy (e.g. industry competition, vertical integration, etc.). Since a major outcome of academic and practice research is to test the value of research recommendations using empirical research evidence, a secondary goal was to determine whether the research outcomes of SSM were empirically tested once the "Take Action to improve the problem situation" step was reached in past studies, intended to improve process, system, or other component of interest. Last, we sought to identify, visualize, and define any central phenomena that emerged out of the content analysis and coding of the corpus of articles. This will include a description of empirically grounded relationships among these emergent phenomena related to operations research and strategy. Figure 1 presents the data collection and analysis approach employed to explore these topics, which were derived from grounded theory (Strauss & Corbin, 1994/2008).

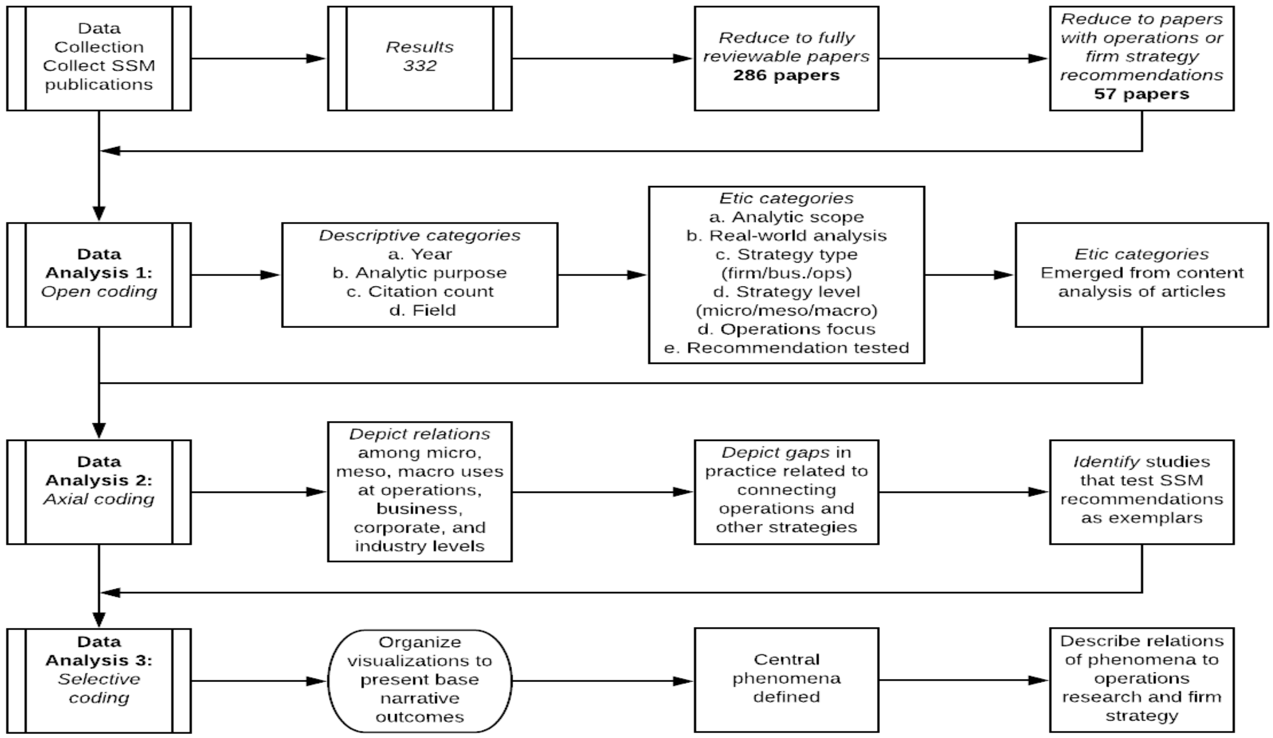

Figure 19. Data collection and analysis procedure visualization.

This approach was expected to help the authors identify patterns in the data linked to emergent phenomena located in the SSM operations research relationships with broader measures of firm strategic performance, grounded in past use cases to identify areas for improvement. The core categories that emerged are intended to help future SSM researchers better explain the relations of operations performance across interfunctional strategies at different levels of the firm and provide better intelligence to decision-makers in organizations.

Data Collection

The research publications used to build the data corpus came initially from the article mining and organization tool *Harzing's Publish or Perish.* The university library databases were also searched with the same terms to determine the availability of the publications. A third

Boolean search for the publications was done using a common internet search engine. The mining process resulted in 332 articles, chapters, books, conference papers, white papers, reports, and citations that included the search terms. For the purposes of grounded theory development, each publication acted as a separate case or instantiation of SSM use for operations explained in terms organizational strategy impact and outcomes.

Time Horizon for Publication Sampling

The initial time horizon for this study was 37 years, beginning with Checkland's 1981 book describing soft systems methodology. However, because research studies applying SSM and reporting the results in academic outcomes primarily began in 1994 with Boardman's version of SSM and his visualization model, the range was restricted to 24 years.

Publication Selection Criteria

The publications were required to meet the following criteria:

- Authors employed a form of soft systems methodology to conduct research on a topic related to operations management practice or strategy
- Publications had to be fully available for review
- Peer-reviewed
- Not a book
- If a conference proceeding, then the full paper had to be available
- Completed at least five of seven SSM steps and included recommended system change(s)
- Authors completed at least five of seven SSM or BSSM steps in their study

While there may be other publications unavailable that have relevance to the study, given the limitations of technology and researcher access, this sample provides a valuable overview of the use of SSM and allows us to have a useful set of cases for analysis from which valid claims can be made, grounded in a significant corpus of data (Corbin & Strauss, 1990; Ng & Hase, 2008).

Data Preparation

Those pieces where evidence indicated that the data mining outcome was simply a citation were eliminated from the data corpus. When a PDF or other document could not be located for review, those publications were removed from the data set, leaving 286 papers. Further culling took place, so that only publications that included research recommendations for process, structure, or strategy recommendations were retained leaving 128 publications. After those publications were eliminated that did not complete at least four steps were removed, 57 publications remained.

Data Analysis

The technique employed for this study is grounded theory, used to develop evidence of conceptual and application issues arising from the historical uses of SSM in operations and logistics strategy focused research (Ng & Hase, 2008). This analytic process is “abductive,” meaning that it cycles between inductive (evidence to theory) and deductive reasoning (theory to evidence) across each case (Robson & McCartan, 2016, p. 37; Reichertz, 2009). Each publication served as a SSM use case that contributed to constructing knowledge manifested as specific phenomena or conceptual frameworks, each stemming from analysis of how the approach has been used historically in for operations research.

Coding Approach for Credibility and Trustworthiness

Grounded theory is commonly a three-step, iterative process that includes 1. open, 2. axial, 3. and selective coding (Ng & Hase, 2008). The first stage, called open coding, generates categories from the data sources. While there is commonly a topic of inquiry used to provide scope to grounded theory research, such as we provided with our scope covering relationships of SSM and strategy development and testing, the researcher is expected to approach the analysis without a clear sense of what they will find in the data. Using the recommended constant-comparative approach to identify emergent (emic) themes and patterns from the corpus of data, we explored the similarities and differences across the SSM use cases to develop categories (Ravitch & Mittenfelner Carl, 2016; Corbin & Strauss, 1990). Additional analysts reviewed the emic categories to determine whether the evidence supported the identified pattern. Those without intersubjective agreement support across analysts were eliminated whereas those that had support were further examined to determine relationships across categories in a second phase.

Because an abductive approach was employed, categories emerged from analysis that resulted from a process of identification (emic) and contextualization (etic) using the predefined codes from business, organizational, and operations strategy. Doing so was intended to make the whole corpus intelligible to readers with interest in operations, business, and organizational system strategy to help ensure the findings are adequately grounded in relevant fields and with appropriate linguistic sets to establish their credibility with intended audiences. Once open coding was complete that allowed building conceptual categories with the data, axial coding was used to depict relations among the etic and emic categories that resulted from the abductive process (Reichertz, 2009). Employing a recursive process with multiple analysts to review identified categories was expected to reduce possible subjectivity in the findings, helping to establish trustworthy outcomes (Creswell, 2014).

Open Coding Categories

For grounded theory, open coding is the beginning of the process and commonly generates categories from the data sources. In this instance, there were a series of emic categories that emerged from content analysis of the articles tied to the research purpose of each piece. The categories generated in the open coding are included in Table 5.

Table 5: Open coding categories

Category	***Description***	***Example***
Publication title	Journal, conference proceeding, or other publication title	Journal of the Operational Research Society
Publication year	Year publication was in print or digital form	1994-2018
Citation count	How many times has the publication been cited as a measure of impact on the field?	N/A
Primary discipline	What is the field where the study takes place?	Business, engineering, etc.
Purpose of analysis	Operations improvement, problem depiction, etc.	Network node placement efficiency improvement
Primary system under study	What type of system was examined	Business, Military, Education, Political, etc.
Mode of research	Formal research methodology employed	SSM/BSSM/Holonic/Other
B/SSM steps completed	Which steps did the authors complete?	Ended at "Take action" step
Emic categories	Categories and supporting codes that emerged during the analytic process	Strategy and operations process connections

Citation counts, disciplines, and analytic purpose were etic categories, meaning defined prior to coding to help support the development of a description of the broader corpus of data and have lower subjectivity as categories because they are defined clearly in the literature. However, while searching the publications for these categories, additional, related codes arose that were of interest to depicting the state of SSM for operations research. These emergent constructs are called emic categories or codes. Each was reviewed by multiple researchers to strengthen the credibility and trustworthiness of the findings presented in this article, in accordance with best research practices for qualitative data analysis (Ravitch & Mittenfelner Carl, 2016; Lincoln & Guba, 1985).

Axial Coding Categories

A second set of etic categories was also employed to analyze the strategy and operations constructs that were the research focus of each publication to determine how commonly soft system methodology was used to conduct studies on different aspects. Noted connections across each case were used to identify instances where researchers sought to conceptually link micro-level operations process or strategy, meso-level business strategy or related actions, and macro-level firm strategy to improve performance, each of which served as a common outcome of operations research that employs SSM. When compared with business and organizational constructs from textbooks and handbooks that are commonly used to define how strategy and operations interface, a set of etic categories was defined to help explain the relations of findings from the open coding phase. The axial coding categories that emerged are presented in Table 6.

Table 6: Axial categories used for case relationship analysis

Strategy type
Firm-level
Structure-conduct-performance**
Five forces*
Industry structure/environmental opportunities*
Cost-leadership**
Resource allocation for completive advantage**
Product differentiation**
Business or organization level
Corporate drivers*
Vertical integration**
Mergers and acquisitions**
Firm or organizational learning**
Marketing*
International, global strategy, networks**
Innovation and Research & Development**
Strategic alliances*
Organizational structure or design**

* Barney & Hesterly (2012)
** Rothaermel (2013)
***Nonaka (1994)

Each category was used to identify instances where authors sought to identify one or more relationships between operations performance or strategy and business (i.e. organizational) or firm (i.e. corporate) level strategies that would be supported by recommended system change.

Selective Coding Categories

Results of the open and axial coding process were then used selectively to identify core phenomena that were presented in the patterns that emerged from the data corpus. The categories employed for this step in the analysis are in Table 7.

Table 7: Selective categories and descriptions

Category	Description
Firm-level strategy mention	Relationship of operations system and firm-level strategy is explained
Business strategy mention	Relationship of operations system and business-level strategy is explained
Corporate strategy mention	Relationship of operations system and organization-level strategy is explained
Operations strategy mention	Relationship of operations system strategy constructs is explained
Relationships between two (2) systems and strategies depicted	Operations and either firm (corporate) or business (organization) strategy linkages are visualized
Relationships between three (3) or more) systems and strategies depicted	Operations, firm, and business (organization) strategy linkages are depicted
Operations research recommendations explained in terms of impact on relevant business metrics outside of operational gains	Explanation of how changes to operations impact business outcomes such as competitive advantage, profitability, sustainability, etc.
Real-world recommendation testing/ evaluation	Were recommended change(s) to system or operations empirically tested based on performance?
Business topic focus	OM research specifically conducted on a recognized business subject (e.g. logistics, marketing, etc.)
"How-to" method description	Presented a "how-to" apply SSM framework for a particular field or purpose
Project management focus	SSM used to study Project management operations process, outcomes, organizational design, or similar

These categories were used to identify common uses of SSM in operations management research, challenges to the value of research outcomes from the SSM model as structured for use in strategy analysis and development, and operations process or strategy improvement. This approach allowed the development of recommendations for conceptual and methodological changes that should improve the value of SSM for research on operations for a wider variety of stakeholders, defining a clearer relationship between SSM recommendations and empirical testing of those findings, and improving the explanatory power of SSM. These may be used to support improvements not to the underlying systems theory that supports why SSM is useful, but how it may be used to better analyze specific business systems and communicate findings and relationships to decision-makers that can better understand how these impact different parts of the company in a way that benefits profitability, sustainability, and other metrics of interest to business leaders. Thus, the value of the grounded theory approach is that it allows the emergence of both conceptual and practical outcomes that moderate operations theory and application that can help improve the future adoption and use of SSM to study across levels of firm strategy.

Findings

This section presents the descriptive and trends, followed by the grounded theory outcomes. The six grounded theory patterns are explained in terms of the two major phenomena that were identified from the open, axial, and selective coding process. While the descriptive results were generally informative and influenced the recommendations presented in conjunction with those phenomena or thematic outcomes, they served mainly to frame the emergent findings.

Descriptive Results

The following sections present descriptive outcomes regarding the data corpus used to contextualize the grounded theory findings that follow. These include yearly distribution of the publications, journal distribution, and author distribution within the data corpus. This descriptive data helps provide a context for the chronology and major sources of publications included in the historical data set.

Publication Trend Regarding SSM Articles with Strategy and Operations Findings

In the lexicon of grounded theory, each publication analyzed for this study served as its own case. While the data set of these cases began with pieces published as early as 1994, the distribution is not regular. Some years had significantly more publications that others, while some years had none. This was likely due to the choices of authors regarding which methodology was most appropriate to their research topic. Figure 20 provides a visualization of these studies.

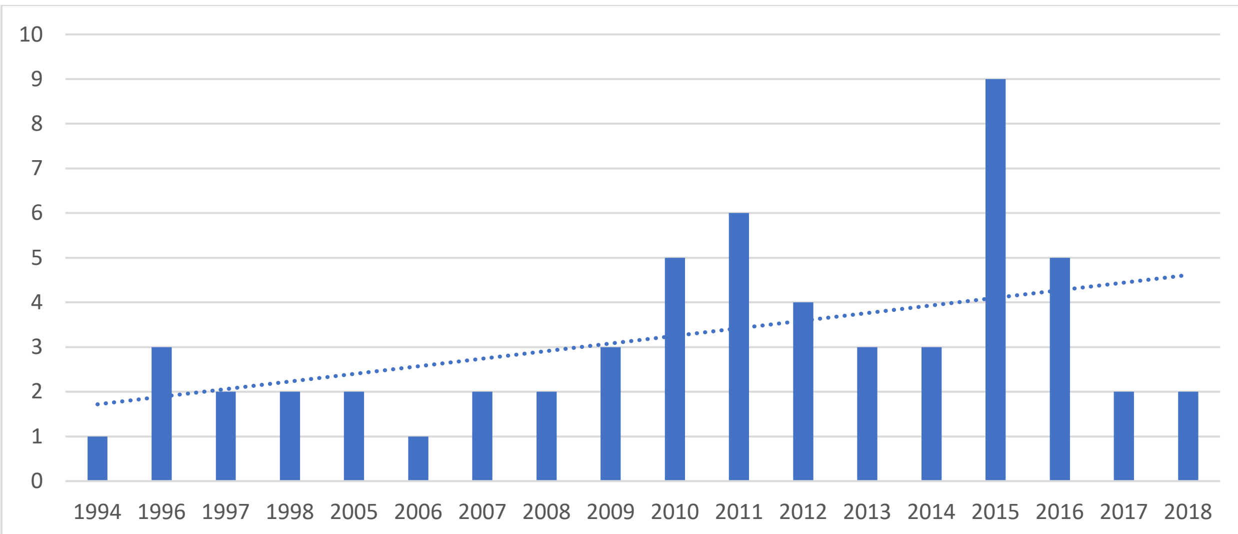

Figure 20. Number of SSM studies tied to operations management topics by year.

As shown, the major productive period for operations management research using SSM in the sampled articles was from 2010-2016. These articles coincided with the publication of Boardman and Sauser's 2008 book *Systems Thinking: Coping with 21st Century Problems,* which presented an extensive justification for using Boardman's version of soft systems methodology in various settings, along with detailed methods and examples for application with operations, organizations, and logistics problems with relationships to complex systems thinking more broadly. This period also produced several highly productive authors who employed SSM in operations research settings.

Author Frequency

While 111 authors were represented in the any order among the publications, only 17 conducted research using SSM for operations research more than once. Authors who have most frequently employed SSM to study operations management or adjacent topics are represented in Figure 21.

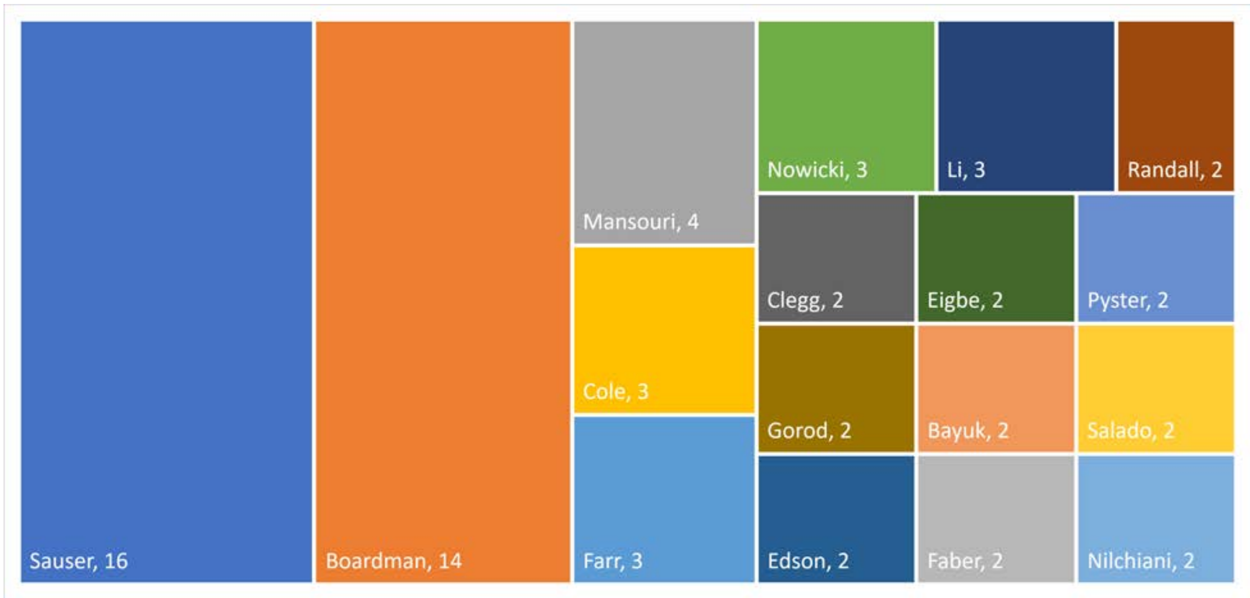

Figure 21. Author publication frequency from the sample 1994-2018 for those with two or more publications.

Boardman and Sauser, both authors of books on systems thinking and the use of soft systems methodology are the most heavily represented in the sample, accounting for around 53% of all operations research publications that employed SSM during the period.

Grounded Theory Findings

The results of the grounded theory analysis are presented in this section. Because this is an approach that requires a recursive discourse between inductive and deductive coding to develop categories, phenomenon identification, and gap analysis it is presented in accordance with the three categorization efforts. This approach produced empirically supported recommendations for improvements to understanding the value of SSM in operations strategy contexts.

Open Coding Results and Visualization

As part of organizing and determining how to analyze the cases (i.e. articles, chapters, proceedings) that served as the data corpus used to ground the findings, a general conceptual framework emerged across the publications. Figure 22 depicts the analytic level in terms of distance from the primary activity under study.

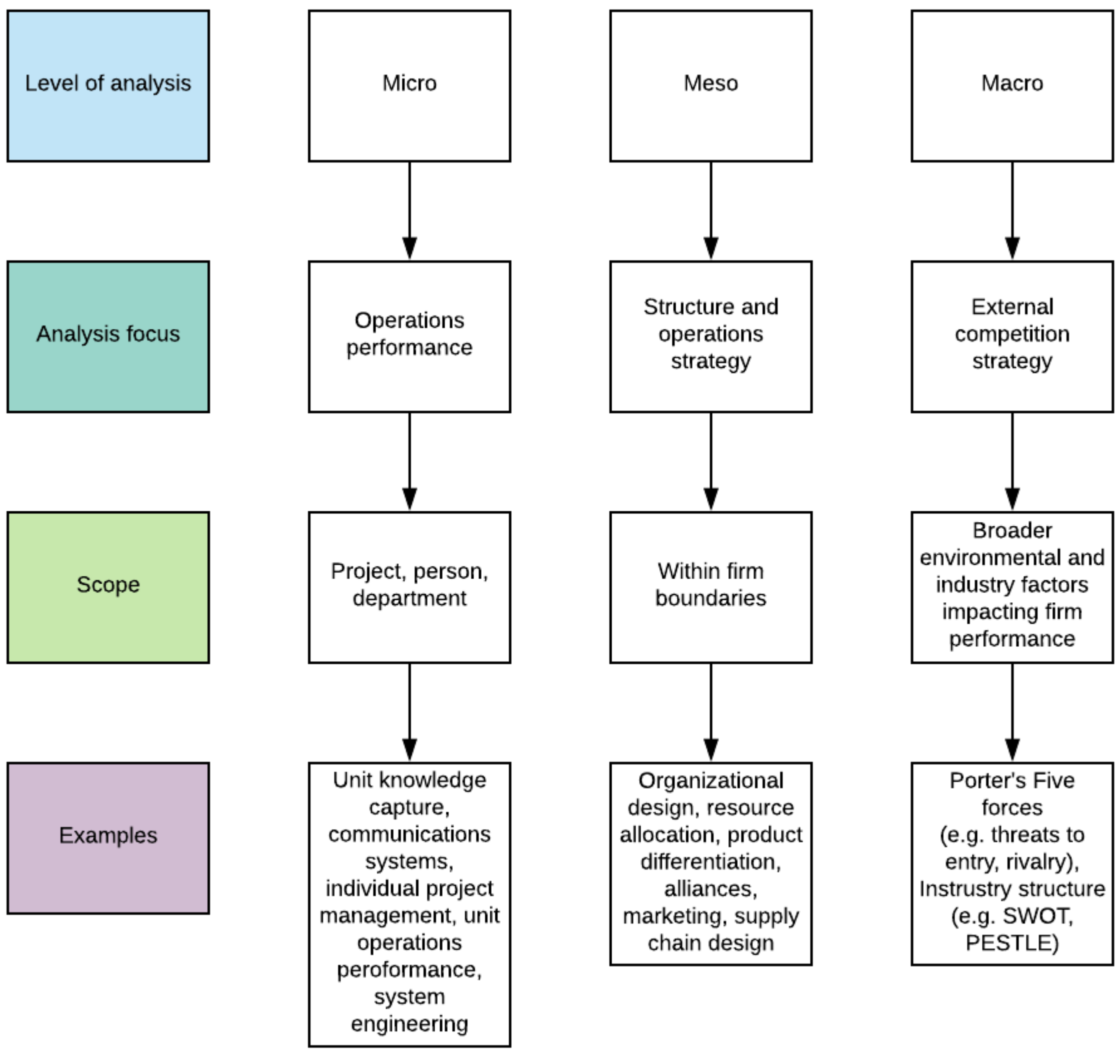

Figure 22. Levels of analysis model with focus, scope, and examples.

Publications with a primarily micro focus most commonly consisted of studies of concrete, though complex system processes and outcomes. By contrast, pieces with a meso or macro level view tended towards studies of strategy choices and related outcomes. The analysis focus at the micro level tended to be on operations performance rather than strategy or even discussion of strategic outcomes, with a scope in those studies of person(s), project(s), or department unit. Meso and macro level studies tended to be more abstracted in terms of studying or depicting strategy, with less clear ties between, for example how a business strategy of including more responsive supply chains impacted firm performance against market rivals or profits. Further, authors who chose a narrow scope for their research (e.g. project management improvement) may have mentioned a relationship to whole company performance, but this was poorly defined except in military and government system analyses. The scope of each study was substantially different among cases in terms of the size of the system under study, the number of related systems, and whether authors discussed how any level of strategy was impacted by recommended operations changes. In addition, the system change recommendations were only tested in around 8% of the publications, usually with simulation rather than real world application to compare pre and post-change system performance. With these issues in mind to frame the use of SSM in operations and strategy related research, axial coding revealed relations that could help explain these phenomena and reveal others.

Axial Coding Relationships and Frequencies Visualizations

In the next stage of the analysis, the publications were examined to determine the relationships of the topics of inquiry or research questions addressed regarding strategy at different levels. This provided a clearer understanding of where operations research using SSM has focused its attention and the degree to which the method has been applied to link operations and firm competitive strategy in the literature and research findings. Each code used to analyze the articles in the axial coding was fitted into a category, based on how business theorists constructed the fundamental concepts of business strategy in the literature (Barney & Hesterly, 2012; Rothaermel, 2013).

Macro- and Meso-Level Business Strategy

By linking the SSM research purposes to the firm and operations strategy, we discovered frequencies of use, connections across categories, and gaps in terms of how and whether the methodology steps resulted in system-level recommendations. Firm-level strategies tend towards using external views used to determine how the firm should choose to compete based on industry, competitors, and market conditions, helping to define the boundaries of the company in response to identified opportunities to explore or exploit in balance with threats to performance (Teece, Pisano, & Shuen, 1997). Figure 23 visualizes the data regarding those pieces that included connections to macro (firm or business) or meso (organizational) levels of description and recommendation.

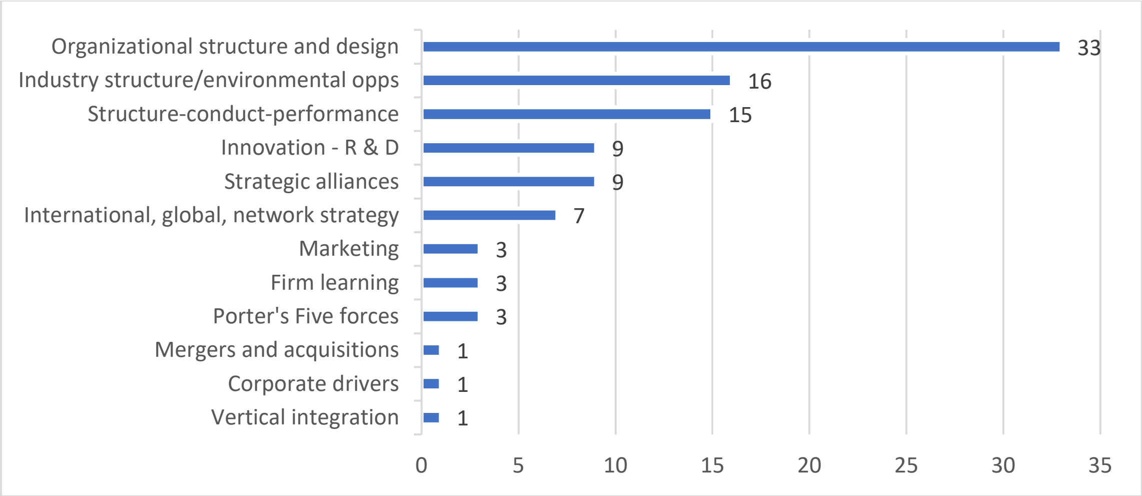

Figure 23. Firm and business strategy linked articles.

As noted, the coding revealed that the primary use of SSM for operations management research was to examine strategy and performance of organizations and units, with recommendations for how to change the design of the system hierarchy to improve efficacy and efficiency, especially as a means of process improvement with project management strategy.

The two main lenses that were used to examine organization competitive strategies at the broadest system view were the *structure, conduct, and performance* levels of firms in the market and *the industry structure and environmental opportunities* that exist for exploration or exploitation by the firm. While these lenses for analyzing operations performance were often mentioned at the outset and used to frame the need to improve operations strategy or performance, the findings and recommendations rarely returned to how the recommended system change at the operations level was expected to improve the firm's competitive advantage at the top strategy level. While Porter's *Five Forces* were mentioned as possible lens and coded as such, these were not used as a means of explaining system operations performance or strategy outcomes. Another macro-level strategy lens commonly used to evaluate organizational success includes a. *cost leadership, b. resource allocation for competitive advantage, and c. product differentiation.* These codes were infrequently mentioned in the operations research findings (n=3) but were included in the following figure.

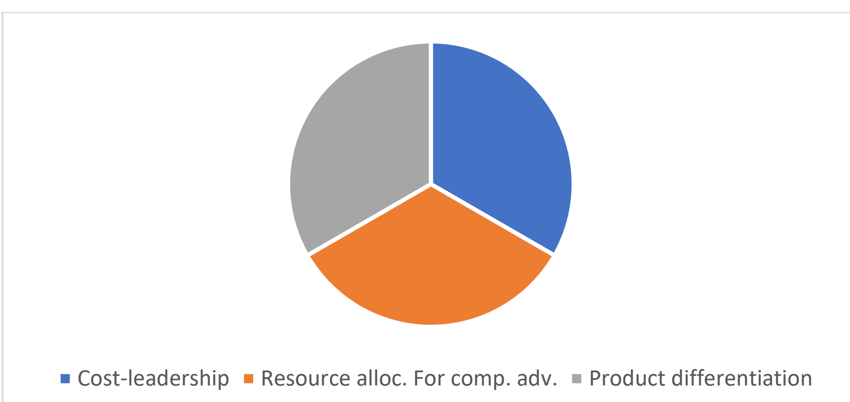

Figure 24. Firm-level strategy code distribution.

In each instance, the reference to macro level business strategy was limited to a passing mention, without making clear how expected operations performance gains at the micro level from system change were expected to positively support firm-level strategic outcomes. Improving these linkages in the SSM analysis and conceptual framework recommendations should increase the perceived value of the research to leaders working at the highest levels of strategy, though this has yet to be tested and reported in the literature.

Operations-level strategy results. The group of categories for this topic of inquiry originally included 17 constructs; however, only 15 categories were located in the cases. The coding results for those categories, which focused on operations management, logistics, and related topics, are included in Figure 25.

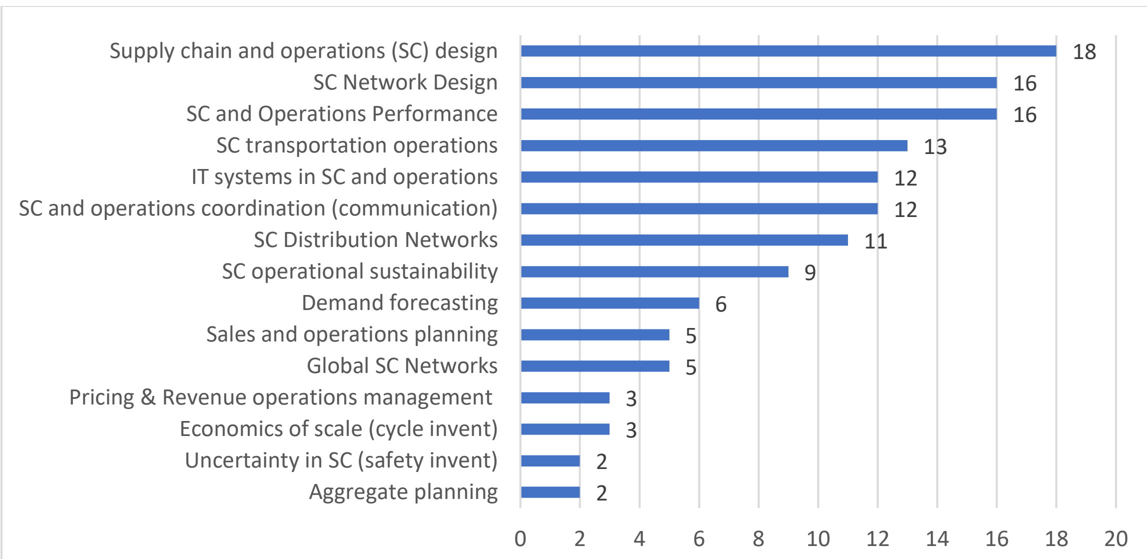

Figure 25. Axial coding results.

These axial coding results were compared with the emic, open categories to build a view of relationships used to clarify patterns found in the cases using selective coding as a means of clarifying the phenomena that emerged.

Selective Coding Results

The identified strategy relationships, operations research practices, and outcomes from the cases were discussed and clarified in the context of the open and axial coding results. These are included in Figure 26.

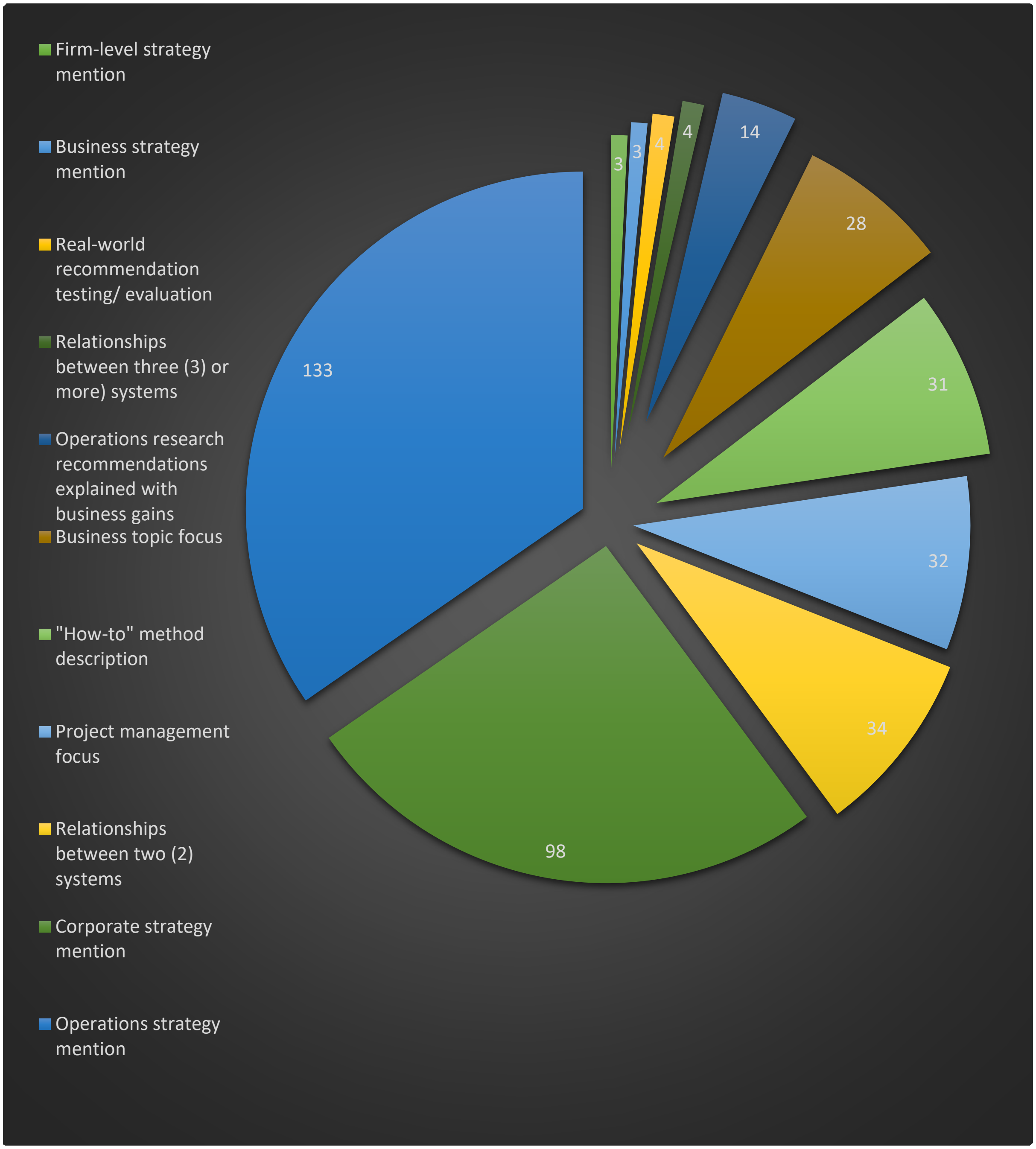

Figure 26. Selective codes, descriptions, and number of observations

From the coding outcomes a set of phenomena, grounded in the research cases, emerged. These patterns also linked to specific recommendations discussed in the next section.

Discussion and Implications

Two primary, umbrella phenomena were noted, arising from the grounded theory approach employed for this study. The first is *Scope, structure, and process challenges* for SSM with operations and strategy research. The second is *Performance and evaluation limitations* with how SSM has been employed for operations and connected strategy research. Three related, explanatory phenomena connected to each of these broader themes. Each is connected and influences one another across both umbrella themes to some degree, though varied across cases. The two umbrella and six explanatory phenomena are organized as follows:

- Scope, structure, and process challenges
    - SSM operations research has largely focused on projects rather than systems
    - Lack of examples for how to link operations and organizational strategy
    - A lack of standard process for operations research with SSM
- Performance and evaluation limitations
    - Disconnect between expected benefits of operations improvements and other strategic performance outcomes
    - The step six problem: A failure to test
    - Does SSM end, or is it a continuous cycle?

In the following sections, for each phenomenon, a recommendation to incorporate specific changes to the use of SSM in operations research are offered. These were tendencies and patterns that emerged; as with most research, there were exceptions that often serve as examples of best practices. Each also recommendation includes proposed future research.

Phenomenon 1: Scope, Structure, and Process Challenges with SSM for Operations and Strategy

This umbrella phenomenon poses a problem for the sustainability of SSM, because of how the approach has been historically used to intersect operations execution and firm-level performance strategies. This section presents three explanatory patterns that help explain this issue and how it impacts the value of the method for business and other organizations. Each is followed by a change recommendation to help overcome the challenge.

Explanatory Pattern 1: SSM Operations Research has Largely Focused on Project Management rather than Systems

Most operations research published in the cases reviewed here were focused on project management at a micro system level (n=32). While the authors often described the whole system early in the analytic process with SSM, the authors tended to focus on a single project without explicating the benefits of the recommended improvements to other parts of the system in their findings. While the operational gains' impact on strategy and performance at other levels of the system may be intuitive to an engineer, they are often not similarly clear to a manager in the C-suite of a major corporation who must decide how best to allocate limited resources. Further, a significant number of SSM publications were "how-to" pieces that explained how to apply the method in a narrow setting; but, these failed to incorporate real world findings that would show the value of the outcomes across systems and lead to other performance improvements. Only 14 studies explained operations research recommendations in the context of specific expected business or organizational (e.g. military, education) performance gains (e.g. profitability, reduced product defects) in terms of how these connected to strategy defined by top management teams.

Implication 1: Fewer "how-to" and project management studies, more focused on system strategy and performance. Arguing for the value of SSM as a valuable organizational research approach in business and other organizations requires better examples that complete the full cycle and expand beyond the project level to explain how a change to the system interacts with other elements to improve the performance of the whole. While “how-to” articles are necessary when a method is employed in a new setting, studies of project management fail to take advantage of the benefits of SSM with complex systems to depict interconnections across complex organizational systems and interfunctional strategies. Future studies should expand beyond the project management scope and tie findings to more complex, testable outcomes.

Explanatory Pattern 2: Lack of Worked Examples for How to Link Operations Findings to Organizational Strategy

While there were substantial “how-to” pieces on how to employ SSM steps in the use cases, there were few that tied the end recommendations to explaining how they help support organization-level performance or strategic outcomes with clear links to statistically significant firm improvements in market share or financial gains. Without such examples to work from as models, it is difficult for new users of SSM in operations management research projects to know if they are creating findings of corporate value or their outcomes have fidelity to the intentions of SSM as a research approach. Testing and building conceptual frameworks with SSM across strategies at different levels of the firm requires examples of how these relationships are expected to impact business and industry outcomes. Producing examples that clarify how to build connections across different levels of strategic abstraction is needed to allow analysts to better explain how suggested changes are expected to positively impact firm performance or may require change to how the company chooses to their strategy for competing against market rivals.

Implication 2: Provide a starting point for depicting operations and business systems. Knowing where to focus one’s attention as a researcher with “soft” or qualitative methods can be challenging at the outset. The subjectivity of complex systems can make it difficult to know where to start and how broad one's scope should be for depicting the complex system. It is easy to have to great a scope initially and add to much detail about system components, which then fails to reduce the complexity to a useful, communicable level that is intelligible to stakeholders. It is possible to constrain the analysts' view at the outset to a frame of reference (e.g. operations) or level of strategy (e.g. macro), as a guide that reduces cognitive load by reducing subjectivity and excessive choice. This could be done by breaking the complex system into pieces and determining how they fit across operations and strategies undertaking a Systemigram visualization to make clear the connections.

Example operations strategy framing for recommendation 1. As an example, the analyst may start with SSM analysis by examining a problem situation that begins with a focus on potential operations failure causes. Here, a digital product has shown excessive returns due to defects, but it is unclear why. The problem could be rooted in manufacturing, supplied materials, engineering, or other problem, though stakeholders reported that a change in firm and organizational strategy took place in the last year affecting supplier choices and lowered price point for resources used to manufacture the product to compete against low-cost rivals that emerged in the market in the last two years. The Systemigram outcomes produced using Boardman's SSM version is presented in Figure 27 to explain the system of interest.

However, it is difficult to comprehend the relationship between the collected data that supports the findings and the visualization presented in the figure and such connections are frequently unclear in most publications. Therefore, it may be beneficial to instead view system strategy and relationships that built to understanding the engineering and product defect problem one frame of reference at a time. For example, one could begin with a depiction of the *operations system* using a simple flowchart, as shown in Figure 28.

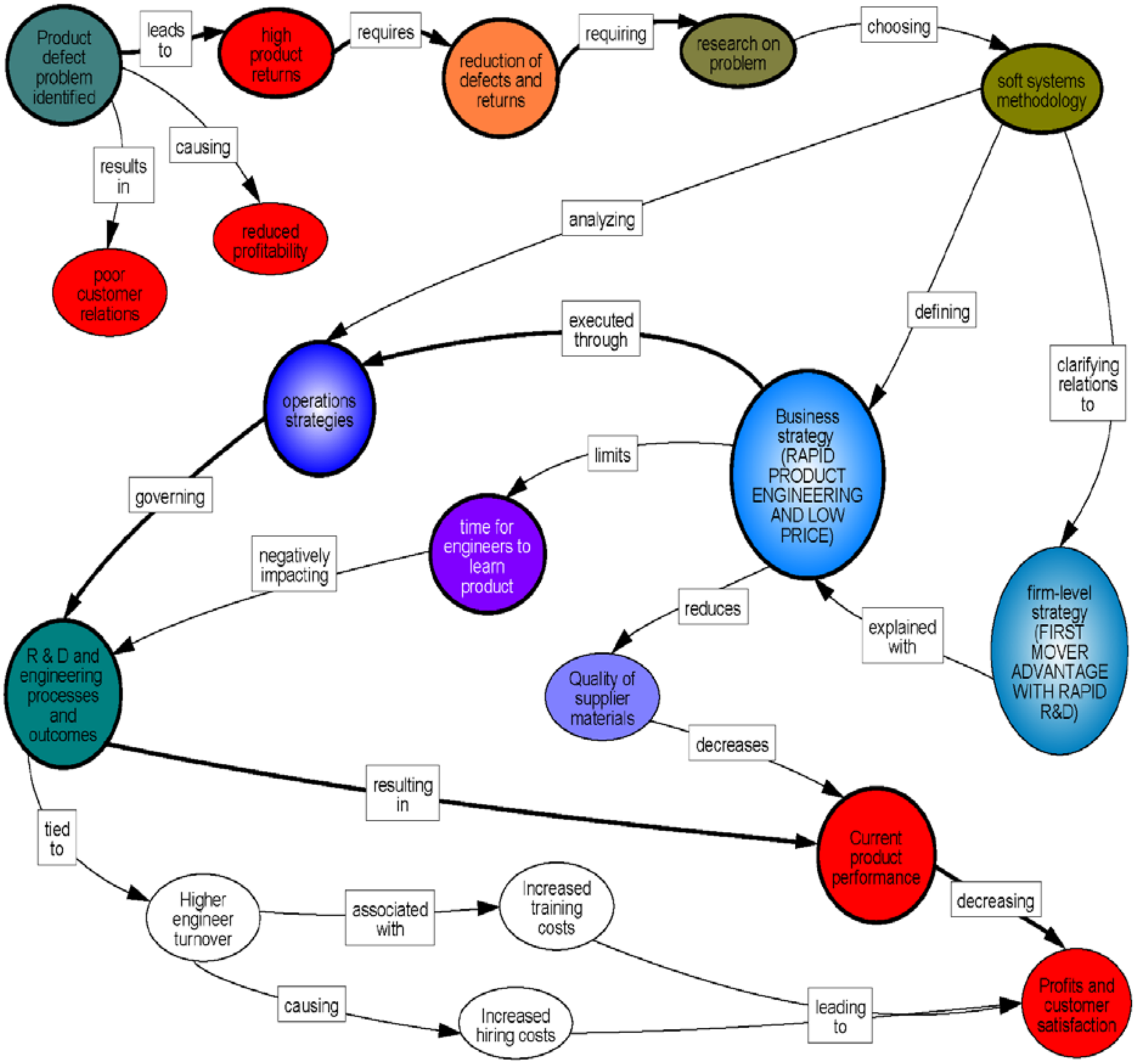

Figure 27. Systemigram visualization of operations problem linked to strategy analysis with product defect causation study example.

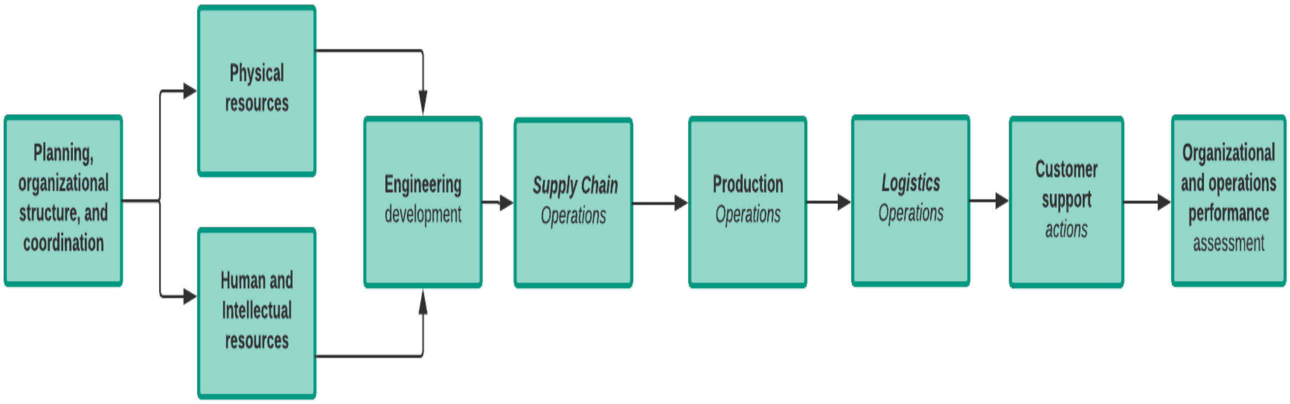

Figure 28. Proposed operations system analysis frame.

The results of analysis are used to depict the relationships across each operations component. They are explained linearly here at the micro-level system scope, which is necessary to identify where strategic change may be necessary. In the case of Figure 28, the micro-level operations engineering activities can be placed in the depiction to identify systems closest to the system of interest (SOI) to focus attention on what may be working as intended and what is not. This frame should then be extended to depict system relations found to exist between operations execution frame from Figure 28 and the business level strategy, as shown in Figure 29.

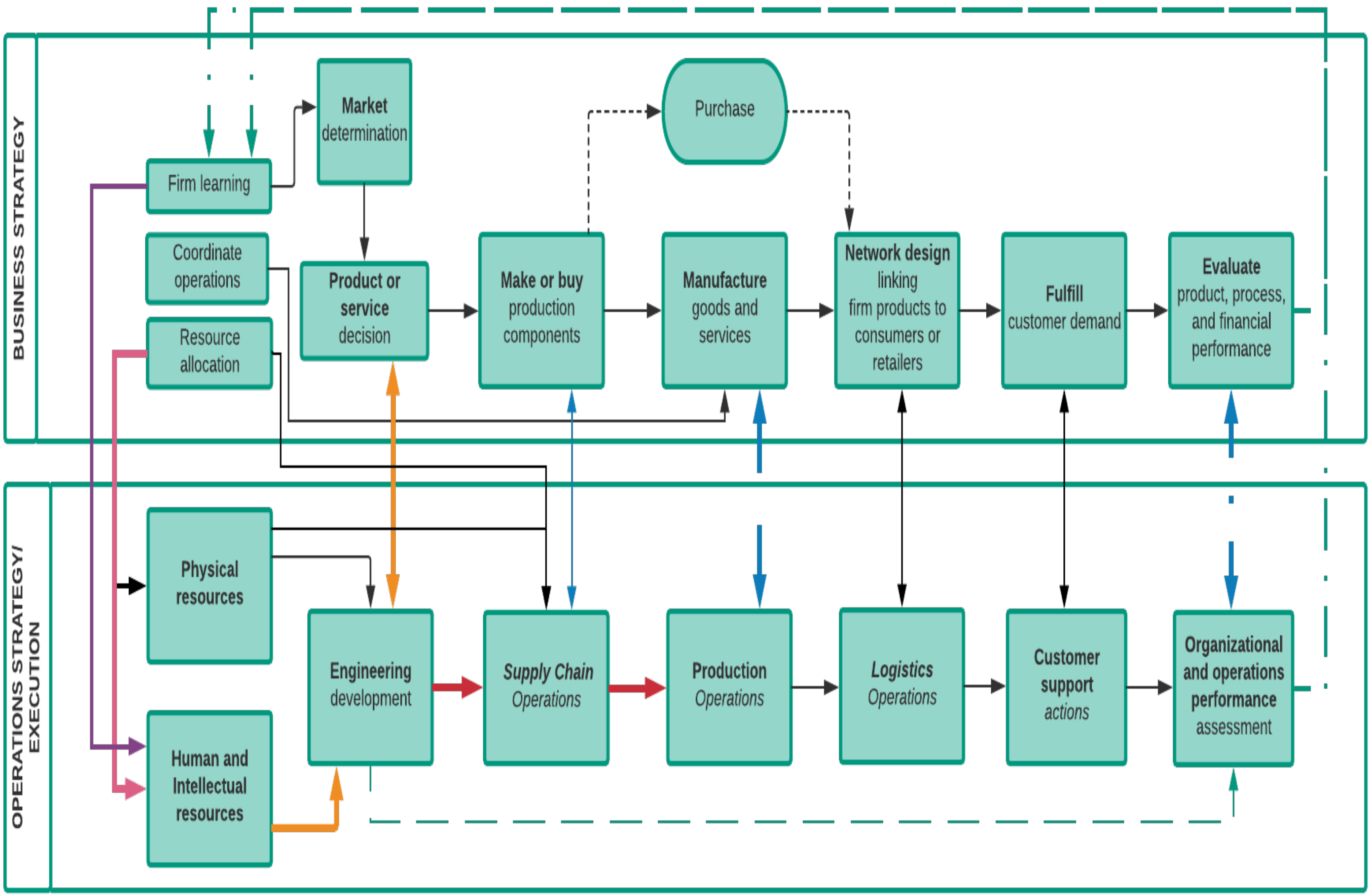

Figure 29. Example linkages created between operations and business strategy frames for the product defect problem.

These relationships can be explained narratively in the research outcome to make clearer why the Systemigram elements are present, providing evidence of relationships observed during the study. The analyst can depict the relationships between strategy and execution, highlighting intended strategy change (bold lines), type of relationship, defined in the Figure 39 legend.

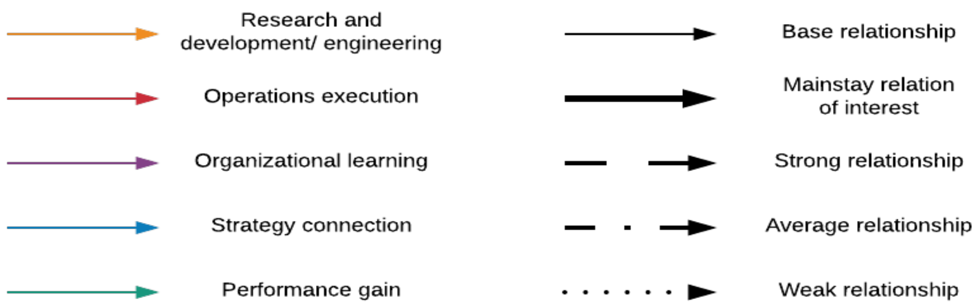

Figure 30. Legend for analysis coding by color and line type.

Note that the connections across strategies are added to show linkages between the more micro-level operations actions and the business (meso-level) strategies and resources to communicate expected relationships. The analyst can depict these system relations and expected strength of impact of changes on other levels of strategic from most abstract to least, shown in Figure 29.

From these expected relationships, arguments can be made for how suggested system changes will impact strategy, depending on the analytic scope, and how best to measure related performance outcomes. For example, if suggested changes to the current actions taken and process of firm learning are the focus of the operations research, the impacts on market determination may have been clear, but the relationship to engineering development must be clarified. Further, the analysts should explain how gains to organizational learning are tied to allocation of human and intellectual resources to engineer products with fewer defects or higher customer satisfaction. With these frames analyzed and connected, further relationships to firm strategy and performance could be explored.

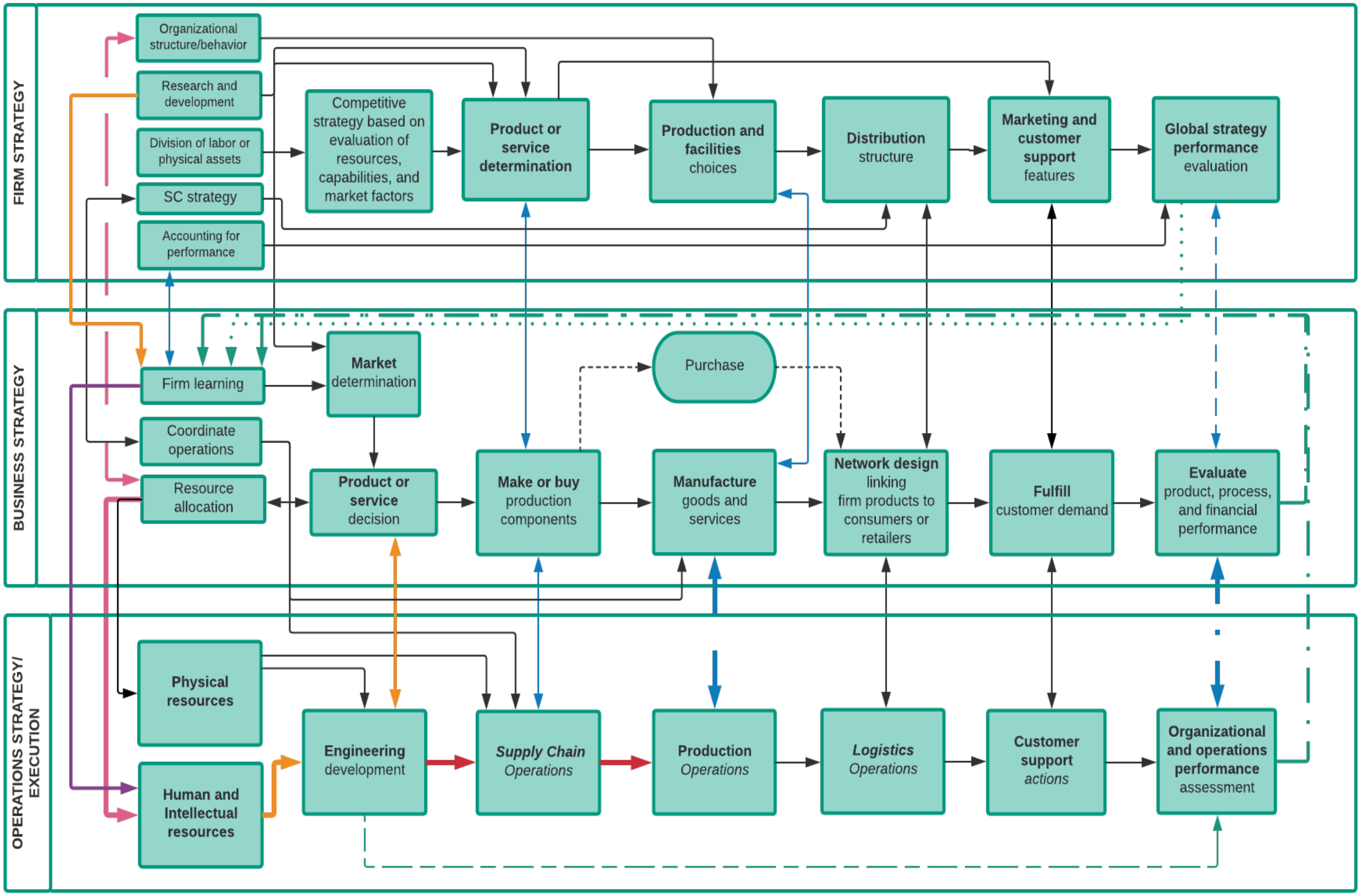

Figure 31. Visualization of operations, business, and firm performance interconnections for the strategy and product defect relationship problem.

The depiction could then be extended across three strategy levels, rooted in operations. Thus, the connections and relationships would be depicted across primary levels strategy components, related to how the organization is expected to compete in the market against rivals, as shown in Figure 31.

Across all levels in these frames, there is a performance evaluation at the conclusion tied to process and strategy components, in keeping with our other recommendations. SSM can help analysts structure not only a picture of the current system and recommendations for improvements, but also may help explain how performance is impacted by choices across the system. Doing so can support the development of relevant, valuable knowledge for decision-makers regarding whether strategy is effective and whether strategies at different levels of the firm are interfunctionally aligned in such a way that they work together. If the visualization of the system levels shows poor fit, it is a simpler task for analysts to show leaders how they may improve it and capture efficiencies that lead to profit and other desired organizational performance that result from strategic decisions, informed by solid research. Future research should test this approach with different operations and organizational problems to determine its value for addressing the linkage between operations and strategy outcomes.

Explanatory Pattern 3: Lack of Process Standardization in Operations Research with SSM

Across the studies, there was a lack of conceptual framing for how the phenomena of strategy and operations inform one another, complicating how analysts employ SSM for operations research due to limited standardization across processes. It is difficult to compare the findings of one operations-focused publication to another, because the steps are applied inconsistently, results are presented inconsistently in terms of scope, detail, and other information that could be used for decision making. While the flexibility of SSM is a strength, it was difficult to find commonalities in application and data presentation across the sampled pieces, weakening transfer across use cases. While most authors presented the Checkland or Boardman's steps, there was little evidence that most authors followed these through to completion. Most authors did not explain their results in terms of how they were expected to transfer from the operations activity and strategy level to meso level corporate-organizational internal structure. It was infrequent for authors to connect the operations improvements to how these supported firm and business-level strategy at the macro level. Further, while there were explanations of system functions and structure, primarily of the organization or project and these were concrete, when there were discussions of strategy, it tended to remain within the level at which analysis was conducted.

Implication 3: Create standard models for SSM analysis. Because firm-level strategy tends to be abstracted from concrete performance, an effort should be made to connect relevant phenomena to activities that have measurable outcomes in a coherent framework to explain better why changes should logically result in performance improvements not only at the local level, but across the organization. For example, if improvement of the interfunctional alignment of firm strategies is expected to improve efficiencies by providing the right resources and structure to the execution of strategy at the operations level, then authors should make this clear as they present their conceptualization of it. Analysis should also explain how they expect to measure the impacts of recommended change on relevant organizational metrics. In future research, comparison studies should be conducted to test process standardization by examining the same problem situation with both standard and traditional, more subjective applications of

SSM. Future studies should examine whether a more standard process for SSM analysis with operations topics improves adoption and use value.

Phenomenon 2: Performance and Evaluation Issues

This second umbrella phenomenon poses a problem for the sustainability of SSM as a viable research method in operations management and business contexts due to a lack of evaluation of the research outcomes to determine their empirical value to improve the performance of complex organizational systems to reach strategic goals. This section presents three explanatory patterns that provide context for specific aspects of this problem for SSM and how this intersects with its likely perceived use value. As with the first set, each pattern is followed by a recommendation to help overcome the challenge.

Explanatory Pattern 4: Disconnect between Expected Benefits of Operations Improvements and Other Strategic Performance Outcomes

How does the suggested system change positively benefit the firm’s broad strategic goals? This is a question unanswered by most research cases analyzed for this study. Failure to explain the benefit of the recommended system operations improvement across organization system levels, especially at the firm and business strategy levels – commonly only explain benefits at operations or business level. There is a need to explain how improving operations and corporate strategy or performance benefits the company’s ability to compete in the market against rivals. Logistics research cases, especially military focused pieces, tended to explain system relations in terms of how improvements to operations performance would positively impact other strategic outcomes for competitive advantage and organizational performance.

These few instances therefore served as strong examples; however, only a few of the authors conducted follow-up studies to show if the change worked, leading to the next gap.

Implication 4: Show how to connect operations and strategy. Proponents of SSM should provide more research-based examples with system change testing reported, presenting models of how these connections can be made should be done with different research topics (e.g. manufacturing, engineering, supply chain). This would give empirical evidence of improved performance based on business metrics appropriate to what should have changed and that it was significant. These models will have to be tested in future studies, to determine whether researchers found them to be valuable for producing their own outcomes.

Explanatory Pattern 5: The Step Six Problem: A Failure to Test

Popper (1965) offered the idea of falsifiability; that is, researchers must be able to determine the efficacy of a proposed solution in a real-world setting through hypothesis testing. Failure to test the recommended system improvements and report results was a significant gap in application of the method in the sampled articles. Most of the studies did not compare the described model to the real world, nor acted to mitigate the identified problem (step 7). That left a major question unanswered: did the new system operate better than the old after altered it, based on the research findings and change recommendations? In most of the publications, this query remained unaddressed, failing to take advantage of the benefits of SSM with complex systems to determine if the system recommendations were valuable to strategic or other valuable organizational outcomes. Other relevant questions to be asked in future studies include:

- Does the system perform better because of the recommended operations/system changes?
- At what level and for how long does the performance improvement last?

- How far across systems does the improvement transfer (e.g. close, proximal, distal, remote)?
    - What metrics best measure transfer of operations improvement to other systems?

By ending the research process at step six, many operations analysts fail to make the connections of their models to real world actions. This artificially limits the contribution of SSM and operations research when the findings could be more useful if the resulting knowledge was disseminated across the organization, leading to improved organizational knowledge (Nonaka, 1994).

Implication 5: Test suggested system changes against real world performance. If recommended changes to a firm's engineering process or product from firm learning in the Figure 31 example, when viewed from operations (micro) level, measurable improvements to performance should have been evident, using pre- post-test measures of returns, product defects, customer satisfaction, and firm revenues, indicating the success of the operations strategy change. At the macro level (i.e. firm, business performance), metrics should be tied to how well the company fares against competitors in industry, perhaps measured by market capture or change in revenues. Alignment across operations, corporate, and whole firm strategic change should be measured by improvements defined as valuable by the leadership; however, examples of how to do so in the business sphere with SSM were rare in the analyzed cases. The ability to take SSM depictions and create variables that allow prediction and measurement, using other research methods later, are needed and should increase the acceptance and adoption of the approach by an increased number of business managers and analysts. Providing examples of how SSM improves firm performance across systems using the language of value and performance common to corporate leaders should support that goal.

Explanatory Pattern 6: Does SSM End, or is it a Continuous Cycle?

SSM should be part of a cycle to ensure system performance is measured before and after recommended changes are made and further improvements should be identified as part of a continuous performance improvement process (Fullerton, Kennedy, & Widener, 2014). One reason that the performance of the suggested changes is not measured is likely psychological. Both Checkland and Boardman's versions of SSM conclude at the "Take Action," in Step 7, so there is no "test the performance of the new system" step. As with changing the spark plugs on an old truck and measuring whether there is better gas mileage, improved starting, or the "check engine" light no longer shows as metric indicators of performance, so too, SSM may benefit from the addition of such an evaluation component. Including this stage in the SSM process to determine the performance of a changed, complex organizational system provides researchers and managers with feedback on whether the operations research recommendations provided the expected benefits, and if not, the cycle continues in search of system improvement.

Implication 6: Add evaluation step with examples of system change and present SSM as a cycle. Therefore, we recommend the addition of an eighth step "Evaluate performance of changed system." This requires defining the desired and predicted level of performance for the system that should result from the change to measure a difference. This benchmark should be set prior to Step 7, used as part of defining the feasible change to the engineered system to determine if the process or strategy had value. This necessitates that the analyst declare the expected relationships among system and subsystems so that changes among them may be tested. The research outcomes should then inform future system modification as measurement informs recommended future changes. Further, rather than presenting SSM as a step-based process, it should be beneficial to present it to future operations researchers as a continuous cycle related to system performance improvement as shown in Figure 32.

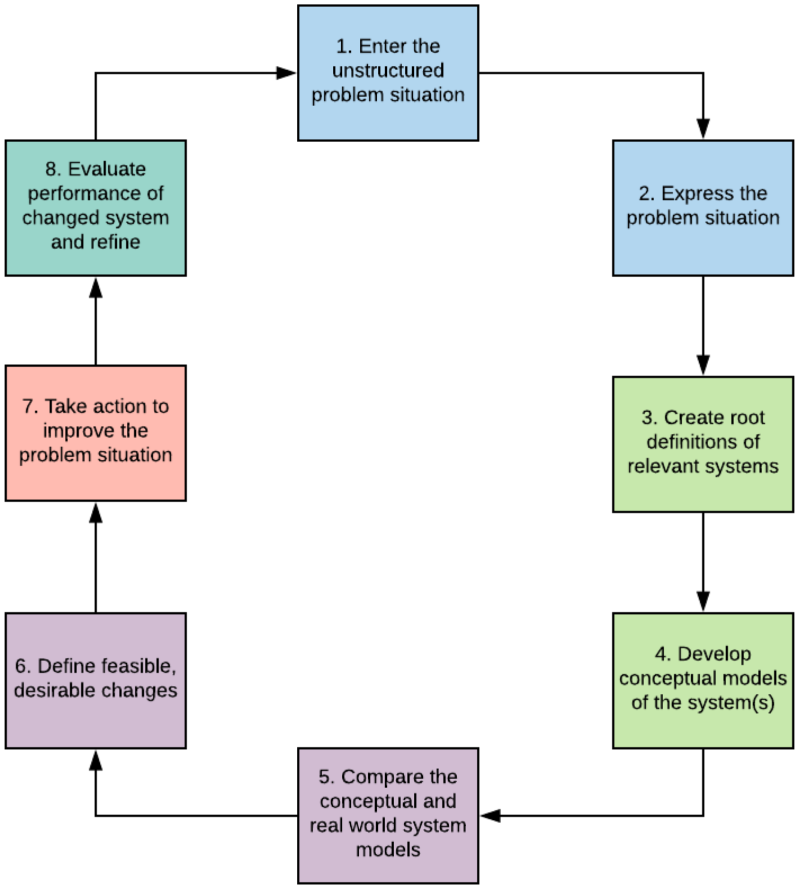

Figure 32. Eight step SSM model as a recursive cycle.

By adding an additional step that provides clear evaluation stage, researchers are admonished to test the performance of the changed system within the methodology. Further, by linking the evaluation outcomes as evidence and information that can be used for future improvement, it may be psychologically beneficial to teach analysts that system improvement is rarely complete, and they should continue to seek future improvements.

Conclusion

While soft systems methodology has been employed as an operations management approach for over three decades, as with any means of gaining knowledge, there are ways to improve process and efficiency. Further, for professionals struggling with complex problems in their businesses and other organizations, improving the usability of the approach should improve its adoption to allow for increased adoption that benefits additional users. The current versions of this method, primarily Checkland and Boardman's flavors have shown their utility in the past, yet significant challenges remain to increase the perceived value of the method across complex systems where strategy is involved. This is especially true when research recommendations are expected to improve performance, process, or competitive strategy when firm leaders require detailed information that can reduce risk in their decision and bolster the benefits of the proposed systemic change. By incorporating the recommendations suggested here, we believe that SSM use for operations research will provide clearer value to stakeholders at all levels of the firm and make the benefits of operations improvement more intelligible and useful in academic and business settings in the future.

CONCLUSION

Introduction and Review of Findings

This three-essay dissertation focused on understanding the impacts of soft systems methodology and related visualizations (Systemigrams), with a goal of identifying improvements that can be taken to increase their use in the field. Figure 33. shows the primary goals for the dissertation.

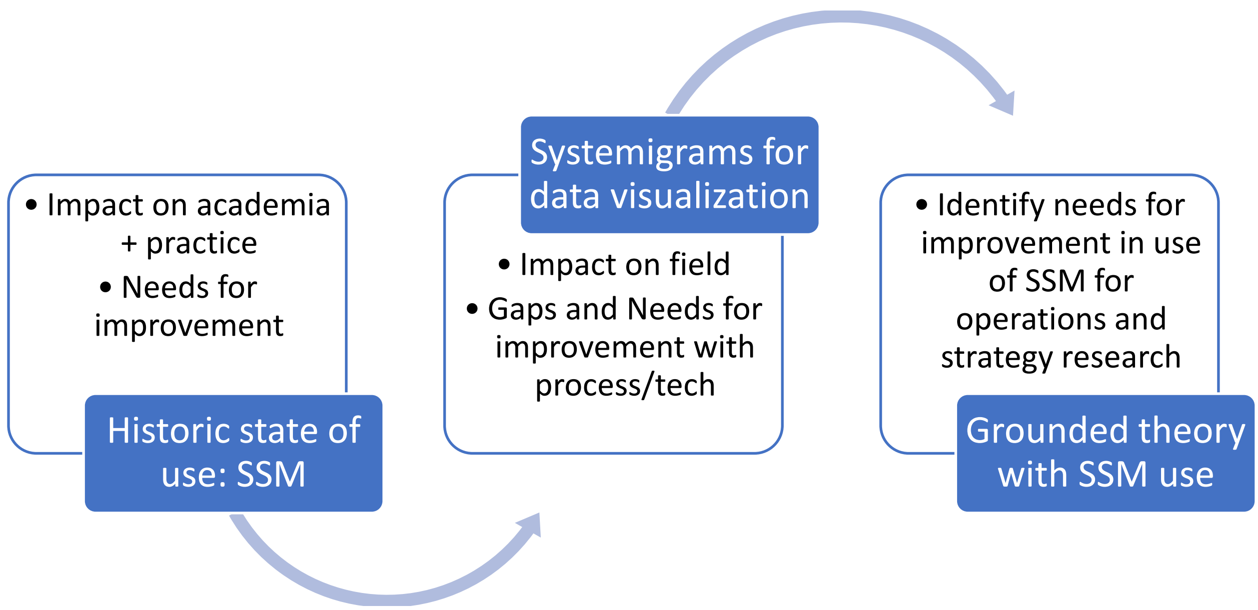

Figure 33. Dissertation research goals linkages.

Data obtained from the first two studies was used to inform the creation of the corpus of data used for the grounded theory study of SSM as an approach in the context of operations and business performance improvement using a with complex systems and situations.

First Study: Findings and Interpretation

In the first study, "Bibliographic and Visual Exploration of the Historic Impact of soft Systems Methodology on Theory and Research," bibliometric research found that found that SSM's largest recorded use was during a period from 1993-2015 (n = 227; 10.3 per year). Since that time, the number of related publications is significantly down during the 2016-2018 per year average *(n=8; 2.7 per year)*. Business and engineering disciplines accounted for 60% of all SSM-related research, indicating limited penetration in other social sciences disciplines, though physical, health, and learning sciences each showed some impact that could be capitalized on in the future with additional research examples. *Systems thinking and theory* was the largest category of research and writing, with *management science and operations research* and *information systems* being strongly represented in the literature, indicating the value of SSM for depicting complex problems in business and engineering disciplines. However, peer reviewed journals were somewhat weakly represented across all citations, with books and book chapters accounting for the bulk of impact on the field. *Systems Research and Behavioral Science* articles about or using SSM for research have had the most significant impact of all peer reviewed publications. As a strategy for growing SSM-related concepts and research, researchers should seek to publish in high impact journals like *Management Science* that have high Scimago journal impact factors, which could broaden readership and future impact.

Top SSM authors, Brian Sauser, Peter Checkland, John Boardman, and John Mingers accounted for 20% of all publications, yet it was Checkland that has had the most impact on all fields by a measure of citations, accounting for 77%. This disproportional impact indicates that there is significant respect for his contribution to the methodology, especially with his non-peer reviewed books. However, this is also an indication that additional work should be done to distribute the work of using SSM and growing academic discourse around it by more scholars. This could be done by growing the number of business, engineering, and other social science departments that teach SSM and variants like Boardman's SSM and systems dynamics, producing scholars that employ the methods for rigorous research in peer reviewed journals. This could be furthered by the instructional engineering of a broad, formal curriculum and additional textbooks with a simplified process and significant examples of the use of SSM in different fields and for different purposes. Learning research methods from brief descriptions in articles and chapters is challenging and was noted by survey participants as a barrier to using SSM with students. This could lead to increased research on a variety of real-world situations in multiple disciplines to grow the impact and acceptance of SSM, which of late has been trending downward in academic outlets. Increased publication in top journals should improve SSM's disciplinary visibility. While reviewing the articles used for the bibliometric analysis, some authors proffered that it would be helpful to create updated, easy to use, focused tools for SSM analysis and visualization to replace or supersede the venerable SystemiTool as the major data visualization technology for complex systems data presentation. More detailed discussion of that proposal is included in the following section.

Second Study: Findings and Interpretation

In the publications culled from the data mining process, the top authors writing about or publishing Systemigrams as data visualizations from qualitative or soft research methods were Sauser, Boardman, Farr, and Cloutier, accounting for around 50% of all citations in publications. The top destinations for disseminating knowledge about how to construct Systemigrams or as research outcomes by citation count were books (30%), *International Journal of Project Management (12%)*, *Procedia Computer Science (10%)*, followed by dissertations and theses (8%). The other highest peer reviewed contributions were found in three journals (6% each): *International Journal of Logistics Management*, *IEEE Transactions on Systems, Man, and Cybernetics*, and *Systems Engineering.* Combined, these outlets accounted for 88% of all publications that discussed or produced Systemigrams. This is a limited distribution in terms of outlets, likely limiting the impact of worked examples to a narrow band of disciplines. This hypothesis is supported by data on the publication analysis results tied to Scimago subject areas which were primarily in control and systems engineering (15), organizational behavior and human resource management (12), systems thinking and systems theory (12) and management science and operations research (9). These four topics combined to account for 48 of the 80 identified pieces. The other 32 articles covered sixteen other diverse index topics ranging from modeling and simulation to strategy and management, though each topic was not substantially addressed more than a few pieces.

Gaps in Published Systemigram Visualizations

The analysis of the published pieces identified problems with some of the Systemigrams or how they were employed in the articles. A major gap was that there were few research-based pieces, because many (32.5%) lacked actual application in a study. Instead, these were conceptual and either provided “how-to” descriptions regarding developing Systemigrams or hybrid Systemigrams that resulted from mixing different varieties of hard and soft systems methodologies. More data-based research visualizations of real-world situations with the resulting Systemigrams checked by stakeholders for accuracy and value are needed. Additionally, many diagrams presented as Systemigrams did not follow the rules and were often some other data visualization, sometimes limiting their usefulness for research dissemination and clouding their meaning to readers, leaving them abstracted. More examples of properly constructed Systemigrams in peer-reviewed journals are needed to reach potential users of this visualization technique and broader training in higher education would help increase their impact in business, engineering, and other social sciences fields.

Top Recommendations for Improvements with Systemigram Visualizations and SSM

The findings from this study indicate that the impact of Systemigram data visualization has been limited since its introduction. For Systemigrams to be more broadly used as data visualization outcomes for complex systems analysis requires change. The participants in the open-ended survey items noted that the process for data analysis and Systemigram development, with or without SystemiTool, requires better definition of frames and limited choices to focus problem situation analysis on a complex situation, such as strategic analysis (e.g. PESTLE) to test the performance of the visualized recommendations. Doing so would increase the value of the data visualization process by reducing some of the subjective nature of many soft systems methodologies that have an “open coding” approach where the user entirely defines the scope and dimensions of the problem with limited guidance as to what to attend to in the complex system. Further, respondents noted that it would be helpful to if available tools made it simpler to visualize complex scenes in method and digital tools. Further, they noted it would be beneficial if the existing primary data visualization tool (SystemiTool) had a simplified interface in future iterations.

Third Study: Grounded Theory Findings with SSM Use Discussion

The third essay produced a set of phenomena that would explain how and to what degree soft systems methodology was used to connect at different levels of organizational system analysis from operations (micro-) to business/organization (meso-) to whole firm (macro-level).

A major proposed value of SSM is that it can help leaders visualize the system interconnections across these levels to better understand what impacted the performance of the company in a competitive market and what factors lead to that outcome. The abductive analysis-supported, grounded theory study of 57 use cases produced descriptive and two major thematic outcomes supported by six explanatory patterns. These patterns were then used to define both recommendations for improvement and future research linked to those suggestions.

Descriptive Results used to Contextualize Grounded Findings

The descriptive data, reduced to include only studies that paired at least operations and one other strategy relationship, came from an original set of more than 350 SSM use cases. The major period for SSM research on operations management topics in the data that met our criteria was from 2009-2016 (n=39), accounting for 68% of the cases included in the study. This period followed the publication of a major reference work on how to use system thinking and SSM for research in 2008, which may account for the significant increase from the 1994-2008 period (n=19). Having models to work from makes an analyst’s task simpler, because they can imitate examples and ensure methodological fidelity. The top six authors in the use case sample were Sauser (n=16), Boardman (n=14), Mansouri (n=4), Cole (n=3), Farr (n=3), and Nowicki (n=3), with all other authors conducting two or fewer operations strategy studies leading to publication. Sauser and Boardman (2008) produced the aforementioned reference work tied to SSM, making their representation in the cases more than 50% including many different articles and other pieces.

Grounded Theory Outcomes

After concluding analysis that followed Corbin & Strauss' (1994) approach to grounded theory development (open, axial, and selective coding) to identify broad themes supported by specific patterns, two umbrella and six explanatory phenomena were identified in the use cases were as follows:

- Phenomenon 1: Scope, structure, and process challenges
  - Pattern 1: SSM operations research has largely focused on projects rather than systems
  - Pattern 2: Lack of examples for how to link operations and organizational strategy
  - Pattern 3: A lack of standard process for operations research with SSM
- Phenomenon 2: Performance and evaluation limitations
  - Pattern 4: Disconnect between expected benefits of operations improvements and other strategic performance outcomes
  - Pattern 5: The step six problem: A failure to test
  - Pattern 6: Does SSM end, or is it a continuous cycle?

To simplify, in the first phenomenon, we found that there were challenges resulting from inconsistent applications of SSM or BSSM in the operations research domain. This primarily appeared linked to a.) a lack of standard processes and b.) too few examples of operations research recommendations in the studies having clear links to other organization and firm strategies and expected outcomes. To overcome these issues,

For the second phenomenon, the authors and method itself limited the value of SSM for systemic change decisions when applied in operations and related, but broader strategy domains. This was due to a failure of authors to test their findings and recommended systemic (operations or strategy) changes in the real world. While some authors (n=4) simulated the recommendations, a lack of examples where operations changes were tested by real world practice likely limits their acceptance in academic and management spheres due to a lack of rigorous testing and evaluation. Without clear examples of how SSM directly impacted firm performance (e.g. market share growth, profits), organizational (e.g. improved organizational climate, lowered employee turnover resulting in lowered hiring costs), or operations gains (e.g. improved supply chain responsiveness to customer demand, lowered transportation costs), it will be hard to convince business analysts and academics to more broadly adopt and employ SSM of any variety, whether it is appropriate to the situation or not. This problem was likely in part due to the method itself ending at step seven where we are implored to “Take action.” However, with few examples of this step implemented, it is difficult to convince others of the methods efficacy for system improvement. Further, the lack of testing of SSM recommendations may be structural because there is no evaluation step in the method, which we propose as an eight component in the methodology. Further, that evaluation should be linked back to the first step as part of a cycle of performance improvement to help encourage sustained system research that leads to incremental improvements across operations and strategy over time, limiting the need to engage in sudden, dramatic wholesale systemic change that may lead to organizational resistance and a misalignment of strategy across firm, organization, and operations levels. While these findings and recommendations stemmed from a detailed process of analysis for all three studies contained in these essays, they are imperfect, and readers should consider the limitations of these research outcomes.

Limitations

While this study dissertation sought to exhaustively cover publications covering soft systems methodology and Systemigrams, there is no guarantee that all publications were discovered using the data mining tools or other searchers performed by the researcher. Further, this study was limited to pieces that could be reviewed and did not cover most conference papers for that reason. Further, the research methods such as content analysis are subjective in nature and so codes designated here could be interpreted differently by another researcher. However, since the purpose of the study was descriptive, non-generalizable research outcomes, this is within the normal limits of qualitative research (Lincoln & Guba, 2003; Ravitch & Mittenfelner Carl 2016). Readers are free to construe these findings within the limits of their own contexts and experiences. The conceptual framework constructed for concurrent systems methodology is necessarily abridged, due to journal page count limits, and so is not fully indicative of all developmental work created to underpin what is depicted in the third article. The structure of the three-article format is a limitation that in a traditional dissertation would not be as significantly present; however, all research outcomes are necessarily made concise in the interests of intelligibility and respect for the reader's time.

Future Research and Practice

The research agenda stemming from this dissertation have different foci because of the three-article format having three different outcomes. Therefore, each has different prospective research tied to soft systems methodology, Systemigrams, and grounded use cases with soft systems methodology. Further, there are non-research practices and technologies that contribute to improving the value of the techniques described in this dissertation such as improvements to process and digital tools. The following suggestions mirror the chronology of the articles contained here, beginning with future research on soft systems methodology.

Soft Systems Methodology Revision, Study, and Training

Soft systems methodology retains value as a means of understanding complex human systems. Future research should continue to map the value of new research that emerges over time and this can be integrated as examples of how to produce best-practice outcomes. Further, more worked research examples should be integrated into new textbooks on qualitative research methodologies in business to provide a resource for instructors in business schools that want to teach SSM from different perspectives and on different topics. This should help improve its acceptance and use for research in peer-reviewed journals in the future, by disseminating it more broadly to students.

Systemigram Studies across Disciplines

As a means of visualizing data, Systemigrams have contributed to the depictions of complex systems. Going forward, as the survey respondents noted, conceptual and research work should be done to improve the teaching of how to construct and use Systemigrams as a product of studies on complex systems. In addition, significant research that produces Systemigrams in multiple disciplines should be conducted to serve as examples of how these visualizations provide values for understanding problem situations and contribute to knowledge generation. Further, as future tools are developed to support Systemigram development, cloud-based, platform neutral approaches would be valuable to increase adoption and use.

Grounded Theory Recommendation Testing in Real World Settings

The grounded theory study itself offered several directions for future research to test the efficacy of the recommendations against real world system performance. Conducting research on a broader array of business and other organizational systems should help address the noted scope, structure, and process challenges by providing stronger models for new researchers to work from. This can broaden the adoption of SSM as a research approach in the social sciences, allowing it to be taught in methods courses in business engineering and beyond. The following section explains the two major contributions of the studies contained in this dissertation.

Major Contribution 1

The main contributions from these three studies, when synthesized may be viewed as depicted in Figure 34.

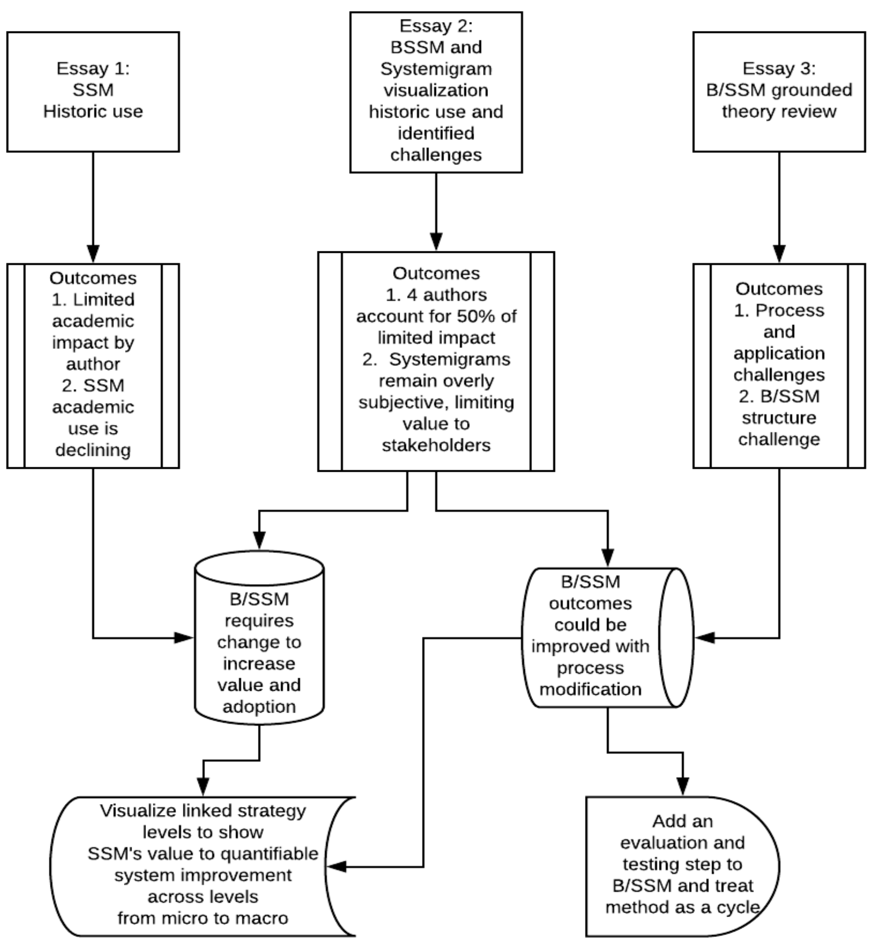

Figure 34. Synthesis of the three essays into primary contributions.

The first contribution focuses on the scope of how SSM has historically been used in academic studies. While project management is a valuable area for study, the studies examined here were primarily at the micro-level of strategy or practice. Because of this, they often failed to take advantage of the robust nature of SSM to explain relationships and the effects of suggested change across levels of strategy and practice. The operations management focused studies explored here often kept their findings narrowly focused to the micro-level potential gains. The authors of these pieces often failed to explain their value across the organizational system to achieve strategic goals and concrete, measurable outcomes for the whole firm as leaders seek to compete in a complex market. This state may reduce the method's perceived value, leading to lower adoption in both the academic literature and real-world practice. Future studies should therefore explain the relationship among expected and measurable operations performance increases at different strategic levels of the firm-as-system that resulted or are expected to result from recommended system changes as presented in Figure 35. However, to broaden adoption of SSM, the visual artifacts as research outcomes should also be explained regarding how those are expected to impact whole firm performance (see Figure 36), bridging soft and hard operations research methods and outcomes (Brown, Cooper, & Pidd, 2006).

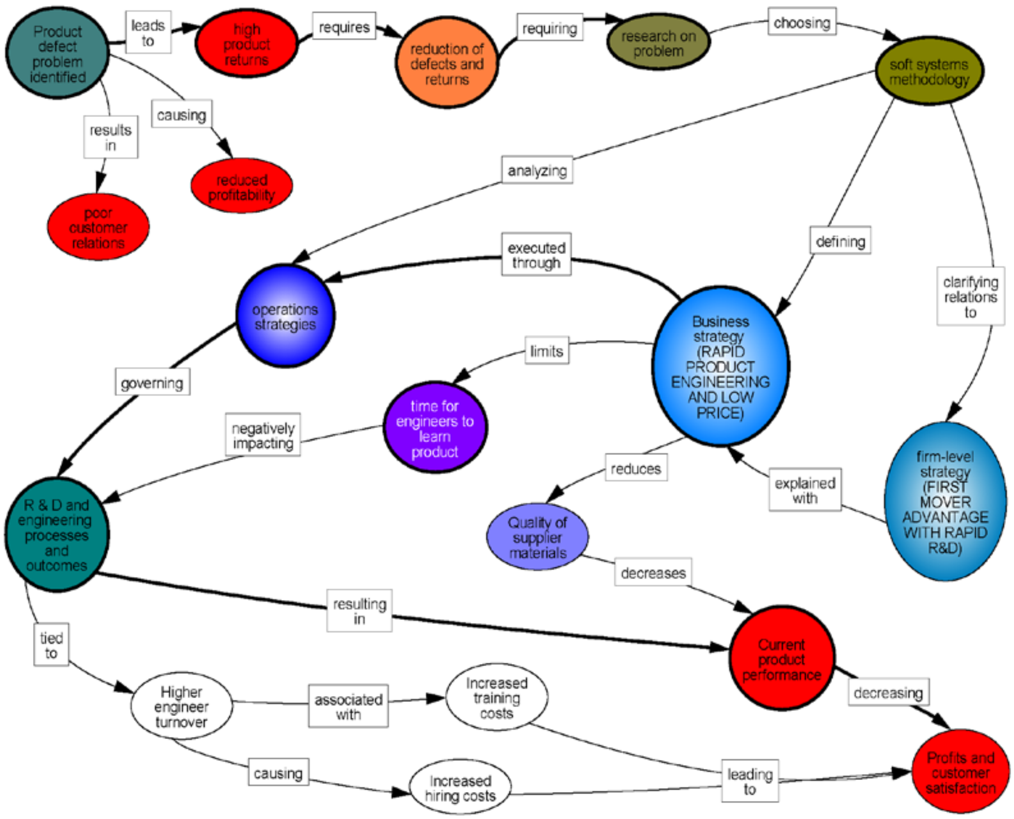

Figure 35. Systemigram visualization of operations problem linked to strategy analysis with product defect causation study example.

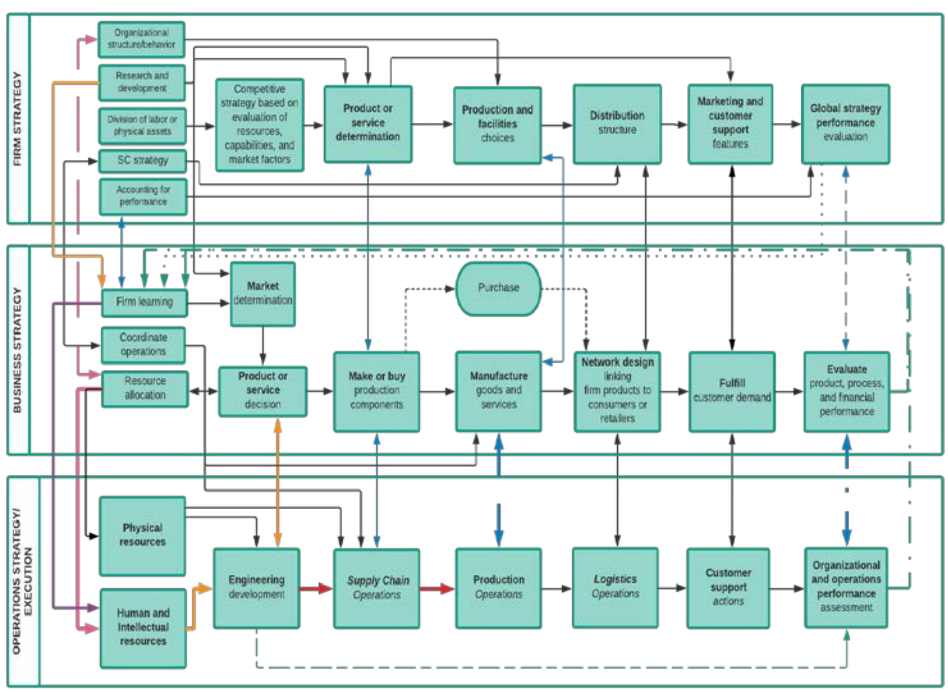

Figure 36. Visualization of micro- (operations), meso- (business), and macro- (firm) level relationships used to explain a Systemigram artifact.

This approach to creating explanatory linkages between the traditional BSSM-style Systemigram and visualizations should provide significant value to managers that may otherwise balk at the complexity and subjectivity they perceive in SSM as a research approach. Showing clear linkages through the visualizations across system and strategy levels communicates the relationships of operations, organizational structure, and whole firm in a manner that should increase the adoption of the method by researchers and business practitioners alike (Harrop, Gillies, & Wood-Harper, 2012). At this stage, a strong theoretical framework may be built and has value as a means of structuring thinking around complex systems and problems (Rosenberg, 2015). However, the framework and concepts remain abstract without testing their value against real world performance (Popper, 1965).

Major Contribution 2

A second outcome of this study was that the majority of researchers failed to test their proposed system changes produced by the SSM research against metrics against real world performance. This may, in part, be due to the steps of SSM itself which end at "Take action to improve the problem situation." The addition of an eighth step, "Evaluate performance of changed system" directs research analysts to go beyond "taking action" and report specified outcomes of the change. Adding this step requires the development of some form of measurable performance outcomes to compare the performance of the system in its current state to the performance after changes are instituted as is common in other engineering and change models to validate proposed system modifications (Warren., Stein, et al, 2009; Yang, Cao, Young, et al, 2015). This requires defining the desired and predicted level of performance for the system that should result from the change to measure a difference. Any predicted outcomes and measures should be set before stakeholders act to improve the system, included by the analysts as they define feasible change to the operations. Doing so will allow to determine if the change provided measurable value that improves the system most directly impacted (e.g. micro-, operations), as well as other levels of performance or strategic outcome in keeping with predictions that were informed by the SSM research. Another suggested addition to SSM research process, as recommended in the third essay, is to employ SSM as a continuous cycle that can be used to foster continuous system performance improvement (Figure 37).

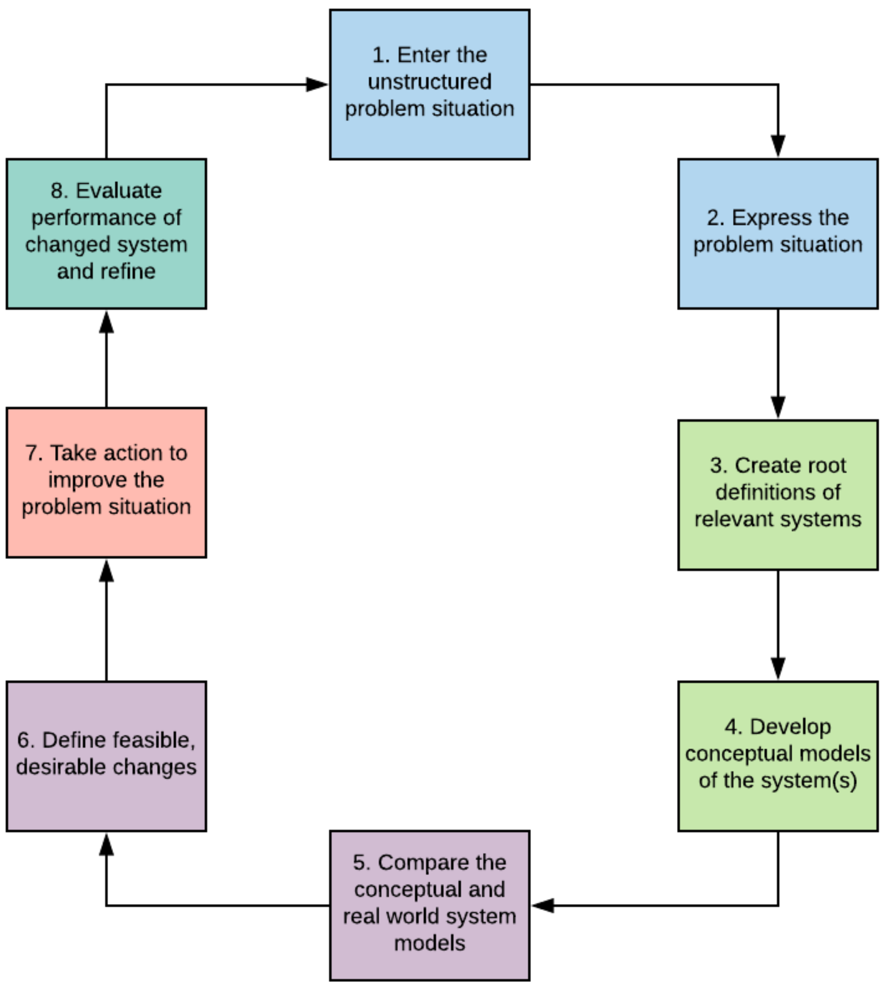

Figure 37. Eight step SSM model, presented as a recursive cycle.

This necessitates that the analyst explain why operations performance improvements should improve other outcomes beyond the micro-level, so that the efficacy of these changes can be measured for real-world impact, as is done with other products and services (Warren & Robinson, 2018). The research outcomes from SSM can then inform future system modification as measurement informs recommended future changes. Bridging the evaluation outcomes from this modified SSM process helps link the evidence gathered through the cycle in a manner that allows for testing of the current system, the impact of modifications, and can lead to continuous future improvement that provide significant value to all system stakeholders over time by improving performance and strategy in tandem (Janczak, 2005; Jenlink, Reigeluth, Carr, & Nelson, 1998).

Summation

Soft systems methodology and the Systemigram data visualization technique have had reasonable historic impact on the field's research approach and findings over the last nearly four decades. However, compared with other methodologies, it requires some changes to grow its acceptance and use in business, engineering, and other social sciences fields. The value of approaches like SSM provide managers with a more complete picture of their systems, an informational view that allows better decision-making. Numeric analysis of large data sets remains valuable where speed is crucial in the face of external competition. However, if the need is not dire and longer-term strategy is desired, then deeper, more considered logics are required. In that case, soft systems methods are valuable for seeking to understand one's own complex system, especially when seeking to improve the operational efficiency and effectiveness of organizations. However, ensuring this value requires time spent considering how changes may impact profitability and other outcomes important to the successful functioning of a firm. Testing recommended changes against performance at the system level where they are made (e.g.

operations, organizational structure) should also be considered in the context of how they impact other systems as a means of informing future improvements to strategy and execution.

Improvement to both the methods and tools for conducting analysis with today's massive firms is also necessary for firm survival in the future because information visibility is increasingly poor due to both the immense stores of data and the communications challenges that a growing number of employees and digital systems creates. In this dissertation, it was suggested that SSM be modified to better visualize linkages across operations strategy and performance outcomes found at the micro-level of firm activity be made to explain impacts on organizational structures and whole firm performance in the market. This should improve the explanatory power of the SSM research outcomes and change recommendations for leaders seeking to employ it to improve not only operations, but how they should or must change their organization (meso-) or competitive, firm-level (macro-) strategies to foster expected gains.

A second important finding from the studies was that SSM as a process lacks a crucial step, which is that of evaluation. Only a few studies reported that the analysts acted to improve the problem situation and findings from research with stakeholders to determine whether the recommended changes provided valuable outcomes. Those researchers that conducted follow-up evaluation of the SSM-suggested improvements ended their change task once the action step was completed and there has been no return to determine whether the system continues to perform better than before the changes were initiated. Therefore, it is recommended that the proposed eight step model be considered instead to be a continuous performance cycle as SSM research continues into the future as a means of ensuring evaluation outcomes inform future system improvements.

SSM has the propensity to explore problems with high complexity such as those found in operations and business strategy where there are multiple potential solutions and outcomes. However, this set of studies found that this has not been the common use of SSM and researchers in academia have tended to employ it at the micro-level more often than not and often failed to explain their findings in the context of other systems and strategies most likely to be impacted by recommended changes. When the complications rise to this level throughout a system, this state of affairs requires analysts spend more time mindfully considering, not only the state of the firm today, but the desired state in the future and the potential effects on different systems from proposed changes. SSM allows researchers to spend considerable time understanding each component through its appropriate lens and then finding the places where they merge and come into clear view that contributes to informed decision making not only for quarterly results, but sustainable growth against rivals over the long term. Soft systems methodology has shown promise to this end and, with some modifications, should have a bright future, contributing significant knowledge in academic research and business practice that can lead to competitive advantage.

REFERENCES

Abbey, J.D., Guide, V.D.R., and Souza, G.C. (2013), Delayed differentiation for multiple lifecycle products, Production and Operations Management, Vol. 22 No. 3, pp. 588-602.

Almeida Costa, A., Workiewicz, M., & Szulanski, G. (2016). On the Foundations of Organizational Knowledge. *Journal of Management Inquiry*, *25*(2), 223–231.

Anand, G., & Gray, J. V. (2017). Strategy and organization research in operations management. *Journal of Operations Management*, *53–56*, 1–8.

Arnette, A., & Brewer, B. (2017). The influence of strategy and concurrent engineering on design for procurement. *International Journal of Logistics Management*, *28*(2), 531–554.

Arnold, R. D., & Wade, J. P. (2015). A Definition of Systems Thinking: A Systems Approach. Procedia Computer Science, 44, 669–678.

Aslani, A., & Naaranoja, M. (2015). A systematic-qualitative research for diffusion of innovation in the primary healthcare centers. *Journal of Modelling in Management*, *10*(1), 105–117.

Badri, M.A., Davis, D. and Davis, D. (2000), “Operations strategy, environmental uncertainty and performance: A path analytic model of industries in developing countries,” Omega, Vol. 28 No. 2, pp. 155-73.

Banathy, B.H, & Jenlink, P. M. (2003). Systems inquiry and its application in education. *Handbook of Research for Educational Communications and Technology*, 37–58

Barab, S. (2006). Design-based research: A methodological toolkit for the learning scientist. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 153–169). New York: Cambridge University Press.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1–14.

Barney, J., & Hesterly, W. (2012). *Strategic management and competitive advantage: Concepts and Cases* (4th ed.). Boston, MA: Pearson.

Basden, A., & Wood-Harper, A. T. (2006). A philosophical discussion of the root definition in soft systems thinking: An enrichment of CATWOE. *Systems Research and Behavioral Science*.

Bayuk, J. L., Healey, J., Rohmeyer, P., Sachs, M. H., Schmidt, J., & Weiss, J. (2012). *Cyber Security Policy Guidebook*. *Cyber Security Policy Guidebook*.

Bergvall-Kåreborn, B., Mirijamdotter, A., & Basden, A. (2004). Basic principles of SSM modeling: An examination of CATWOE from a soft perspective. *Systemic Practice and Action Research*.

Blair, C. D., Boardman, J. T., & Sauser, B. J. (2007). Communicating strategic intent with systemigrams: Application to the network-enabled challenge. *Systems Engineering, 10*(4), 309–322.

Boardman, J. T. (1994). Process model for unifying systems engineering and project management. *Engineering Management*, *4*(1), 25–35.

Boardman, J. T., & Sauser, B. (2008). Systems Thinking: Coping with 21st Century Problems. *Journal of Public Health Management and Practice*, *11*(6), 550–3.

Boardman, J., & Sauser, B. (2008). *Systems Thinking: Coping with 21st Century Problems* (1st ed.). Boca Raton, FL: CRC Press.

Boardman, J., & Sauser, B. (2007). SystemiTool. Abingdon, UK: Taylor & Francis.

Bronfenbrenner, U. (1976). The Experimental Ecology of Education. *Educational Researcher*, *5*(9), 5–15.

Buffa, E.S. (1984), Meeting the Competitive Challenge: Manufacturing as a Competitive Weapon, Dow Jones-Irwin, Homewood, IL.

Brown, J., Cooper, C., & Pidd, M. (2006). A taxing problem: The complementary use of hard and soft OR in the public sector. *European Journal of Operational Research*, *172*(2), 666–679.

Capelo, C., Dias, F., & J. (2009). A system dynamics-based simulation experiment for testing mental model and performance effects of using the balanced scorecard. *System Dynamics Review, Vol. 25 No.1*, *25*(1), 1–34.

Caws, P. (2015). General Systems Theory: Its Past and Potential. *Systems Research and Behavioral Science*, *32*(5), 514–521.

Chandler, P., & Sweller, J. (1991). Cognitive Load Theory and the Format of Instruction. *Cognition and Instruction*, *8*(4), 293–332.

Checkland, P. (1981). *Systems Thinking, Systems Practice*. *Systems Thinking Systems Practice*.

Checkland, P. (1994). Systems Theory and Management Thinking. *American Behavioral Scientist*, *38*(2), 75–91.

Checkland, P. (1985). Achieving 'Desirable and Feasible' Change: An Application of Soft Systems Methodology. *The Journal of the Operational Research Society*, *36*(9), 821-831.

Checkland, P. (1994). Systems Theory and Management Thinking. *American Behavioral Scientist*, *38*(2), 75–91.

Checkland, P. (2000). Soft systems methodology: A thirty-year retrospective. Systems Research and Behavioral Science, 17, S11–S58.

Checkland, P., & Scholes, J. (1990). *Soft systems methodology in action*.

Checkland, P., & Poulter, J. (2010). Soft Systems Methodology. In *Systems Approaches to Managing Change: A Practical Guide* (pp. 191–242).

Christis, J. (2005). Theory and practice of soft systems methodology: A performative contradiction? *Systems Research and Behavioral Science*, *22*(1), 11–26.

Cloutier, R., Sauser, B., Bone, M., & Taylor, A. (2015). Transitioning systems thinking to model-based systems engineering: Systemigrams to SysML models. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *45*(4), 662–674.

Coase, R. (1937/1953). The nature of the firm. In G. J. Stigler & K. E. Boulding (Eds.), *Readings in price theory* (pp. 331–351). Chicago, IL: Irwin.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, *35*(1), 128–152.

Conroy, G., & Soltan, H. (1998). ConSERV, a project specific risk management concept. *International Journal of Project Management*, *16*(6), 353–366.

Cook-Davies, T. (2000). *Towards improved project management practice: Uncovering the evidence for effective practices through empirical research*. Leeds Metropolitan University.

Corbin, J. M. (2011). Grounded theory methodology. *Handbook of Qualitative Research*.

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*.

Creswell, J. W. (2014). Research design. Qualitative, quantitative and mixed methods approaches. *Research Design Qualitative Quantitative and Mixed Methods Approaches*.

Crichton-Sumners, C., Mansouri, M., & Sauser, B. (2013). Systems Thinking for Knowledge Transfer in Organic and Mechanistic Organizations. *Transportation Research Record: Journal of the Transportation Research Board*, *2399*, 112–120.

Denzin, N., & Lincoln, Y. (2003). The discipline and practice of qualitative research. (N. Denzin & Y. Lincoln, Eds.), *The Landscape of Qualitative Research: Theories and Issues*. Thousand Oaks, CA: Sage Publications.

Eisenhardt, K. M., & Zbaracki, M. J. (1992). Strategic decision making. *Strategic Management Journal*, *13*(2 S), 17–37.

Enrici, A., Apvrille, L., & Pacalet, R. (2017). A Model-Driven Engineering Methodology to Design Parallel and Distributed Embedded Systems. *ACM Transactions on Design Automation of Electronic Systems*, *22*(2), 1–25.

Faulkner, D., & Campbell, A. (2003). *The Oxford Handbook of Strategy*. (D. Faulkner & A. Campbell, Eds.) (1st ed.). Oxford, UK: Oxford University Press.

Fiorentino, R. (2016). Operations strategy: A firm boundary-based perspective. *Business Process Management Journal*, *22*(6), 1022–1043.

François, C. (1999). Systemics and Cybernetics in a Historical Perspective. *Systems Research and Behavioral Science*, *16* (November 1997), 203–219.

Fullerton, R. R., Kennedy, F. A., & Widener, S. K. (2014). Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices. *Journal of Operations Management*, *32*(7–8), 414–428.

Gamal Aboelmaged, M. (2012). Harvesting organizational knowledge and innovation practices: An empirical examination of their effects on operations strategy. *Business Process Management Journal*, *18*(5), 712–734.

Gorod, A., Sauser, B. J., & Boardman, J. T. (2008). System-of-Systems Engineering Management: A Review of Modern History and a Path Forward. *IEEE Systems Journal*, *2*(4), 484–499.

Hannan, M. T.; Freeman, J. (1984). Structural inertia and organizational change. *American Sociological Review*, *49*(2), 149–164

Harrop, N., Gillies, A., & Wood-Harper, A. T. (2012). Actors and clients: Why systems dynamics needs help from soft systems methodology and unbounded systems thinking. *Journal of the Operational Research Society*, *63*(12), 1788–1789.

Hayes, R.H. and Wheelwright, S.C. (1979b), The dynamics of process-product life cycles, Harvard Business Review, March-April, pp. 127-36.

Hayes, R.H. and Wheelwright, S.C. (1984), Restoring Our Competitive Edge, Wiley, New York, NY.

Hunt, S. D., & Morgan, R. M. (1995). The Comparative Advantage Theory of Competition. *Journal of Marketing*, *59*(2), 1.

Hitch, C. (2011). Soft Systems Methodology: A 50-Year Retrospective of OR / MS, *35*(2), 164–178.

Howick, S., & Ackermann, F. (2011). Mixing or methods in practice: Past, present and future directions. *European Journal of Operational Research*, *215*(3), 503–511.

Jacobides, M. G., & Billinger, S. (2006). Designing the Boundaries of the firm: From “Make, Buy, or Ally” to the dynamic benefits of vertical architecture. *Organization Science, 17*(2), 249–261.

Jacobs, G., van Witteloostuijn, A., & Christe-Zeyse, J. (2013). A theoretical framework of organizational change. *Journal of Organizational Change Management*, *26*(5), 772–792.

Janczak, S. (2005). The Strategic Decision-Making Process in Organizations. *Problems and Perspectives in Management*, (3), 58–70.

Janvrin, D. J., Raschke, R. L., & Dilla, W. N. (2014). Making sense of complex data using interactive data visualization. *Journal of Accounting Education*.

Jenlink, P. M. (1968). Systems inquiry and its application in education. General Systems, 37–58.

Jenlink, P. M., Reigeluth, C. M., Carr, A. A., & Nelson, L. M. (1998). Guidelines for facilitating systemic change in school districts. *Systems Research and Behavioral Science*, *15*(3), 217–233.

Khanchanapong, T., Prajogo, D., Sohal, A. S., Cooper, B. K., Yeung, A. C. L., & Cheng, T. C. E. (2014). The unique and complementary effects of manufacturing technologies and lean practices on manufacturing operational performance. *International Journal of Production Economics*, *153*, 191–203.

Khansari, N., Mostashari, A., & Mansouri, M. (2014). Impacting Sustainable Behavior and Planning in Smart City. *International Journal of Sustainable Land Use and Urban Planning*, *1*(2).

Kim, Y. and Lee, J. (1993), Manufacturing strategy and production systems: An integrated framework, Journal of Operations Management, Vol. 11 No. 1, pp. 3-15.

Kirk, D. (1995). Hard and soft systems: A common paradigm for operations\management. *International Journal of Contemporary Hospitality Management*, *7*(5), 13–16.

Kotiadis, K., & Mingers, J. (2006). Combining PSMs with hard or methods: The philosophical and practical challenges. *Journal of the Operational Research Society*, *57*(7), 856–867.

Kristal, M. M., Huang, X., & Roth, A. V. (2010). The effect of an ambidextrous supply chain strategy on combinative competitive capabilities and business performance. *Journal of Operations Management*, *28*(5), 415–429.

Laszlo, A., & Krippner, S. (1998). Systems Theories: Their Origins, Foundations, and Development. *Systems Theories and A Priori Aspects of Perception*, 47–74.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. (R. Pea & J. S. Brown, Eds.), *Learning in doing* (Vol. 95). Cambridge University Press.

Lincoln, Y., & Guba, E. G. (1985). *Naturalistic inquiry*. London: Sage.

Lindskog, M. (2012). Mythbusting in the logistics domain: A second look at systems theory usage. *Logistics Research*, *5*(1–2), 3–20.

Lurie, N. H., & Mason, C. H. (2007). Visual Representation: Implications for Decision Making. *Journal of Marketing*.

Meentemeyer, S. M., Sauser, B., & Boardman, J. (2009). Analysing a system of systems characterisation to define system of systems engineering practices. *International Journal of System of Systems Engineering*, *1*(3), 329.

Meng, T. K., Coleman, D. R., & Boardman, J. T. (1997). A Decision Support Modeling Framework for Assessment of Quality Performance in Computer-Integrated Manufacture. *Quality Engineering*, *10*(1), 97–113.

Milgrom, P., & Roberts, J. (1995). Complementarities and fit strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*, *19*(2–3), 179–208.

Miller, J.G. and Roth, A.V. (1994), “A taxonomy of manufacturing strategies,” Management Science, Vol. 40 No. 3, pp. 285-304.

Mingers, J. (1980). Towards an appropriate social theory for applied systems thinking - critical theory and soft systems methodology. *Journal of Applied Systems Analysis*, *7* (July 1980), 41–49.

Mingers, J., & Taylor, S. (1992). The Use of Soft Systems Methodology in Practice. *The Journal of the Operational Research Society*, *43*(4), 321–332.

Mingers, J., & Brocklesby, J. (1997). Multimethodology: Towards Theory and Practice for Mixing Methodologies. *International Journal of Management Science*, *25*(5), 489–509.

Mingers, J., & White, L. (2010). A review of the recent contribution of systems thinking to operational research and management science. *European Journal of Operational Research*, *207*(3), 1147–1161.

Mingers, J. (2011). Soft OR comes of age-but not everywhere! *Omega*, *39*(6), 729–741.

Mintzberg, H. (1990), Strategy formation: schools of thought, in Frederickson, J.W. (Ed.), Perspectives on Strategic Management, Harper Business, New York, NY, pp. 105-235.

Mintzberg, H., Raisinghani, D., & Theoret, A. (1976). The structure of “unstructured” decision processes. *Administrative Science Quarterly*, *21*(2), 246–275.

Ng, K., & Hase, S. (2008). Grounded suggestions for doing a grounded theory business research. *Electronic Journal of Business Research Methods*, *6*(2), 155–170.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. *Organisation Science*, *5*(1), 14–37.

Nonaka, K., Cvon Krogh, G., & Voelpel, S. (2006). *Organizational Knowledge Creation Theory: Evolutionary Paths and Future Advances*. *Organization Studies* (Vol. 27).

Oltra, M. J., & Flor, M. L. (2010). The moderating effect of business strategy on the relationship between operations strategy and firms' results. *International Journal of Operations and Production Management*, *30*(6), 612–638.

Onwuegbuzie, A. J., & Teddlie, C. (2003). A framework for analyzing data in mixed methods research. In *Handbook of Mixed Methods in Social and Behavioral Research* (pp. 351–383).

Piaszczyk, C. (2011). Model Based Systems Engineering with Department of Defense Architectural Framework. *Systems Engineering*, *14*(3), 305–326.

Pollack, J. (2009). Multimethodology in series and parallel: Strategic planning using hard and soft or. *Journal of the Operational Research Society*, *60*(2), 156–167.

Popper, K. (1965). *Conjectures and refutations*. New York: Basic Books.

Proches, C. N. G., & Bodhanya, S. (2015). An Application of Soft Systems Methodology in the Sugar Industry. *International Journal of Qualitative Methods*, *14*(1), 1–15.

Rainey, L. B., & Tolk, A. (2015). *Modeling and Simulation Support for System of Systems Engineering Applications*. New York: Wiley.

Randall, W. S., Nowicki, D. R., & Hawkins, T. G. (2011). Explaining the effectiveness of performance-based logistics: A quantitative examination. *International Journal of Logistics Management*, *22*(3), 324–348.

Ravitch, S., & Mittenfelner Carl, N. (2016). *Qualitative research: Bridging the conceptual, theoretical, and methodological* (1st ed.). Thousand Oaks, CA: Sage Publications, Inc.

Rhee, M. and Mehra, S. (2006), Aligning operations, marketing, and competitive strategies to enhance performance: An empirical test in the retail banking industry, Omega, Vol. 34, pp. 505-15.

Rindfleisch, A., & Heide, J. (1997). Transaction Cost Analysis: Past, Present, and Future Applications. *Journal of Marketing*, *61*(4), 30–54.

Roberts, L., Johnson, C., Shanmugam, R., Malhotra, S., Zinkgraf, S., Young, M., … Cameron, L. (2005). Computer Simulation and Six-Sigma Tools Applied to Process Improvement in an Emergency Department. *17th Annual Society for Health Systems Management Engineering Forum*.

Robson, C., & McCartan, K. (2016). Real world research (4th ed.). Chichester, West Sussex, United Kington: John Wiley & Sons.

Rosenberg, A. (2015). Philosophy of Social Science. (T. Curtain, Ed.) (5th ed.). New York: Westview Press.

Rothaermel, F. (2013). *Strategic management: Concepts and cases*. New York: McGraw-Hill Irwin.

Rosenzweig, E.D. and Easton, G.S. (2010), Tradeoffs in manufacturing? A meta-analysis and critique of the literature, Production and Operations Management, Vol. 19 No. 2, pp. 127-141.

Santos, F. M., & Eisenhardt, K. M. (2005). Organizational boundaries and theories of organization. *Organizational Science*, *16*(5), 491–508.

Sauser, B., Boardman, J., & Verma, D. (2010). Systomics: Toward a biology of system of systems. In *IEEE Transactions on Systems, Man, and Cybernetics Part A: Systems and Humans* (Vol. 40, pp. 803–814).

Saxena, S., Xing, Y., & Pecht, M. (2018). A unique failure mechanism in the Nexus 6P lithium-ion battery. *Energies*, *11*(4), 1–2.

Schroeder, R.G. (1984), "Operations strategy: Missing link in corporate planning", Management Review, Vol. 73 No. 8, pp. 20-3.

Schroeder, R.G., Bates, K.A. and Junttila, M.A. (2002), A resource-based view of manufacturing strategy and the relationship to manufacturing performance, Strategic Management Journal, Vol. 23 No. 2, pp. 89-104.

Schroeder, R.G. (1984), Operations strategy: Missing link in corporate planning, Management Review, Vol. 73 No. 8, pp. 20-3.

Schroeder, R.G., Bates, K.A. and Junttila, M.A. (2002), A resource-based view of manufacturing strategy and the relationship to manufacturing performance, Strategic Management Journal, Vol. 23 No. 2, pp. 89-104

Schwenk, C. R. (1984). Cognitive Simplification Processes in Strategic Decision-making. *Strategic Management Journal*, *5*(2), 111–128.

Sewchurran, K., & Petkov, D. (2007). A systemic framework for business process modeling combining soft systems methodology and UML. *Information Resources Management Journal*, *20*(3), 46–62.

Sherman, D. G., Cole, A. J., & Boardman, J. T. (1996). Assisting cultural reform in a projects-based company using systemigrams. *International Journal of Project Management*, *14*(1),

Simonette, M. J., Rodrigues, A. M. D. A., Seno, W. P., Plínio Franco Thomaz, Navarro, F. J. K. G., Martinelli, D. P., … Hardman, J. (2008). Efetividade Do Processo De Comunicação Com Base Na Teoria Do Comportamento Informacional: O Caso De Um Organismo Internacional Da Área Da Saúde Pública Sediado No Brasil. *Systems Research and Behavioral Science*, *8*(3), 27–42.

Skinner, W. (1969), Manufacturing-missing link in corporate strategy, Harvard Business Review, May-June, pp. 136-45.

Smith, W. K. (2014). Dynamic decision making: A model of senior leaders managing strategic paradoxes. *Academy of Management Journal*, *57*(6), 1592–1623.

St. John, C.H., Cannon, A.R. and Pouder, R.W. (2001), Change drivers in the new millennium: implications for manufacturing strategy research, Journal of Operations Management, Vol. 19 No. 2, pp. 143-60.

Stobaugh, R. and Telesio, P. (1983), Match manufacturing policies and product strategy, Harvard Business Review, March-April, pp. 113-20.

Stonebraker, P.W. and Leong, K.G. (1994), Operations Strategy. Focusing Competitive Excellence, Allyn and Bacon, Boston, MA.

Stowell, F., & West, D. (1994). 'Soft' systems thinking, information systems and client-led design. *Information Systems Journal*, (4), 117–127Strauss, A., & Corbin, J. (1994/2008). *Basics of qualitative research: Grounded theory procedures and techniques. Newbury*.

Swamidass, P. and Newell, W. (1987), Manufacturing strategy, environmental uncertainty and performance: A path analytic model, Management Science, Vol. 33, pp. 509-24.

Tako, A. A., & Kotiadis, K. (2015). PartiSim: A multi-methodology framework to support facilitated simulation modelling in healthcare. *European Journal of Operational Research*, *244*(2), 555–564.

Teck Hui, L. (2004). Business timeliness: The intersections of strategy and operations management. *International Journal of Operations & Production Management*, *24*(6), 605–624.

Teece, D. D., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533.

Thompson, J.D., 1967. Organizations in action. McGraw-Hill, New York.

Tuna'lv, C. (1992), Manufacturing strategy – plans and business performance, International Journal of Operations & Production Management, Vol. 12 No. 3, pp. 4-24.

Wagner, S. M., Grosse-Ruyken, P. T., & Erhun, F. (2012). The link between supply chain fit and financial performance of the firm. *Journal of Operations Management*, *30*(4), 340–353.

Ward, D., Duray, R., Leong, K. and Sum, C.C. (1995), Business environment, operations strategy and performance: An empirical study of Singapore manufacturers, Journal of Operations Management, Vol. 13 No. 2, pp. 99-115.

Ward, P.T. and Duray, R. (2000), Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy, Journal of Operations Management, Vol. 18 No. 2, pp. 123-38.

Warren, S. J., Stein, R., Dondlinger, M., & Barab, S. (2009). A Look Inside a MUVE Design Process: Blending Instructional Design and Game Principles to Target Writing Skills. *Journal of Educational Computing Research*, *40*(3), 295–321.

Warren, S. J., & Robinson, H. (2018). The product life-cycle of online courses and student engagement: An empirical example from an undergraduate distance learning course. *American Journal of Distance Education*, *32*(3).

Wheelwright, S.C. (1978), “Reflecting corporate strategy in manufacturing decisions,” Business Horizons, February, pp. 57-66.

Wheelwright, S.C. and Hayes, R.H. (1985), Competing through manufacturing, Harvard Business Review, January-February, pp. 99-109.

Williamson, O. E. (1981). The Economics of Organization: The Transaction Cost Approach. *American Journal of Sociology*, *87*(3), 548–577.

Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. *Journal of Law and Economics*, *22*(2), 233–261.

Williamson, O. E. (2010). Transaction Cost Economics: The Origins. *Journal of Retailing*. https://doi.org/10.1016/j.jretai.2010.07.006

Vickery, S.K., Droge, C. and Markland, R.E. (1994), Strategic production competence: Convergent, discriminant and predictive validity. Production and Operations Management, Vol. 3 No. 4, pp. 308-18.

Volberda, H. (2003). Strategic Flexibility Creating Dynamic Competitive Advantage. In D. Faulkner & A. Campbell (Eds.), *The Oxford Handbook of Strategy* (1st ed., pp. 939–998). Oxford, UK: Oxford University Press.

Von Bertalanffy, L. (1968). General System Theory. *Georg. Braziller New York*, *1*, 289.

Von Bertalanffy, L. (1950). An outline of general system theory. *British Journal for the Philosophy of Science*, *1*(2), 134–165.

Yang, F., Cao, N., Young, L., Howard, J., Logan, W., Arbuckle, T., … Ford, E. (2015). Validating FMEA output against incident learning data: A study in stereotactic body radiation therapy. *Medical Physics*, *42*(6), 2777–2785.

Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research. *Journal of Management*.