

Review of Lean Research Studies and Relationship to the Toyota Production Research Framework

Francois Jacobs, Ph.D.
California Baptist University
Riverside, California

The objective of this study was to align the International Group of Lean Construction (IGLC) conference research studies against the Toyota Production System (TPS) to determine how lean research in construction align with the TPS framework as well as to determine if lean research in construction stems from a conceptual versus applied research framework. Content analysis was chosen as the research methodology analyzing 592 IGLC research studies from 1996 through 2009 against the TPS framework. The analysis revealed that lean research in construction did not align exclusively around the TPS framework. From 592 studies analyzed, 241 (40%) were classified within the four overarching TPS categories having the 14 TPS principles; 351 (60%) were classified outside the framework as fitting in one of 15 other important proxy lean related research categories. In addition the study revealed a misbalance between conceptual and applied research frameworks in construction. This study has particular implications in knowledge and practice. Critical discussion on the preconditions for, and limits of, lean research in this study promise to contribute to a stronger foundation for lean research in the built environment, through awareness of the research underpinning in lean construction.

Key Words: Lean Construction, Research, Toyota Production System, Applied Research

Introduction

Lean construction research started gaining recognition in 1993 with the formation of the International Group of Lean Construction (IGLC). According to da CL Alves & Tsao (2007), the IGLC conference was often a venue of choice for lean researchers in construction as well as for practitioners in displaying their work and discuss different facets of lean as it applies to the construction industry. The purpose of this study was to analyze these research efforts against the Toyota Production System (TPS) to determine if lean research in construction is representative of the TPS framework. In addition, the study further intended to determine if lean research in construction stem from a conceptual versus applied underpinning.

The TPS framework has been described as a system designed to provide tools for workers to continually improve their work (Liker, 2004). Taiichi Ohno, the father of the TPS framework, indicated that copying an existing model or method like the TPS framework without understanding its importance to, or role in increased production output, can become dangerous (Liker, 2004, p.xx). In other words, copying and implementing Lean verbatim from manufacturing to construction might have unforeseen consequences. Therefore lean in construction should be viewed as an ongoing improvement process that must adapt to the construction operating platform. Limited research in this area has been conducted which this study intended to investigate.

Research in an applied discipline requires two kinds of expertise as it pertains to the field of inquiry: knowledge and experience (Lynham, 2002). In an applied discipline like construction, sound research stem from interplay between theory, research, and practice. Interplay between theory, research, and practice is ongoing and interchangeable between the conceptual development, operationalization, confirmation/disconfirmation, and application phases as put forth in the "Research Theory Development Model" illustrated in Figure 1.

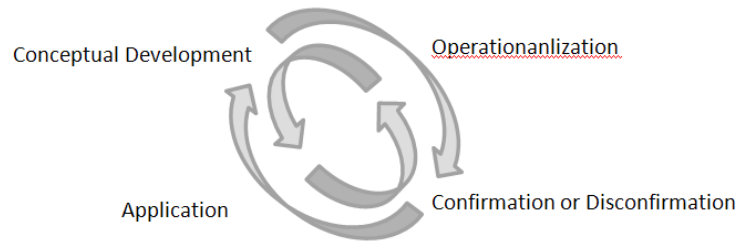


Figure 1: Research Theory Development Model (Lynham, 2002)

An introduction on these interchangeable phases are listed following; the conceptual development phase requires a researcher to formulate an initial idea in a way that depicts current, best, most informed understanding, and explanation of a phenomenon, issue, or problem in a relevant world context (Dubin, 1978). The purpose of this phase is therefore to develop an informed conceptual framework that provides initial understanding and explanation of the nature and dynamics associated with a research issue, problem, and/or phenomenon (Lynham, 2002). The operationanlization phase provides an essential connection between conceptualization and practice (Lynham, 2002). It is during this phase that research gets tested in a real world context and where theory gets applied. During the confirmation/disconfirmation phase planning, design, implementation, and evaluation of research gets confirmed by supporting the foundation of a future research agenda (Lynham, 2002). During the application phase the study, understanding, and inquiry of the research are viewed as ongoing (Lynham, 2002). According to Fellows and Liu (2003) a discipline or profession is established by developing a body of knowledge, unique to its operating platform which is produced through sound research. Therefore the importance of a sound lean research platform in construction should not be ignored.

Methodology

This study can be viewed as an empirical research endeavor, with an emphasis on deductive coding, seeking to establish if lean research in construction aligns with the TPS theoretical framework. A total of 592 IGLC research studies were analyzed for emergent research themes through process analysis between 1996 and 2009. Content analysis was chosen as the preferred methodology in conducting the analysis which utilized a set of procedures to make valid inferences from IGLC research studies. Figure 2 represents the research framework consisting of a four phase sequence utilized in this study.

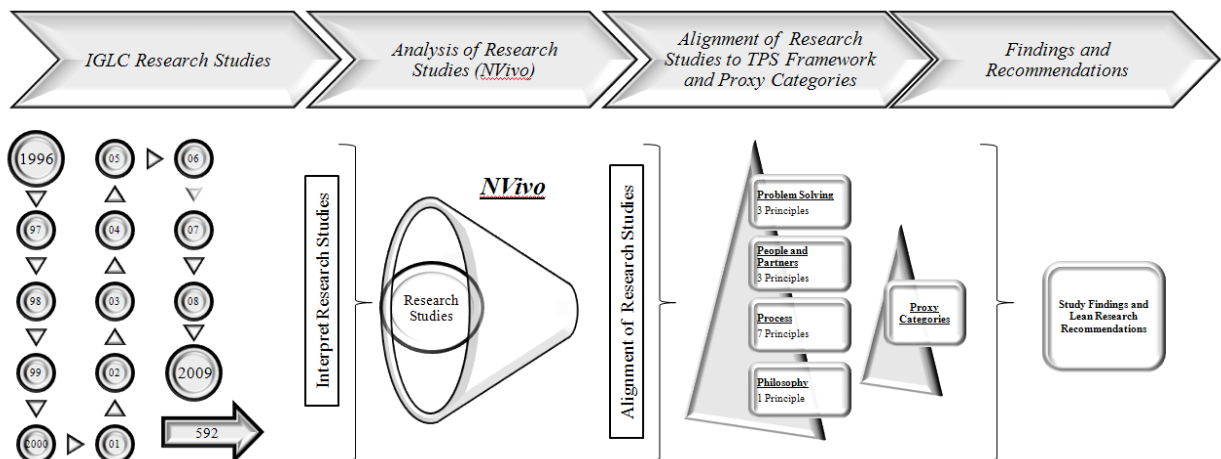


Figure 2: Research Framework: Representation of the Research Steps in This Study.

The scale on which this study took place required the utilization of qualitative data analysis software. NVivo was utilized for organizational as well as quality purposes in dealing with the large volume of research literature. The following six figures, labeled A through G, illustrate the NVivo analysis sequence deployed in this study.

- 1) All IGLC research studies between 1996 and 2009 were converted to researchable files from .pdf to Microsoft .doc. A total of 592 research studies were uploaded into NVivo as indicated by A in Figure 3.
- 2) After uploading the documents, each research study could be viewed electronically as illustrated by B in Figure 3.

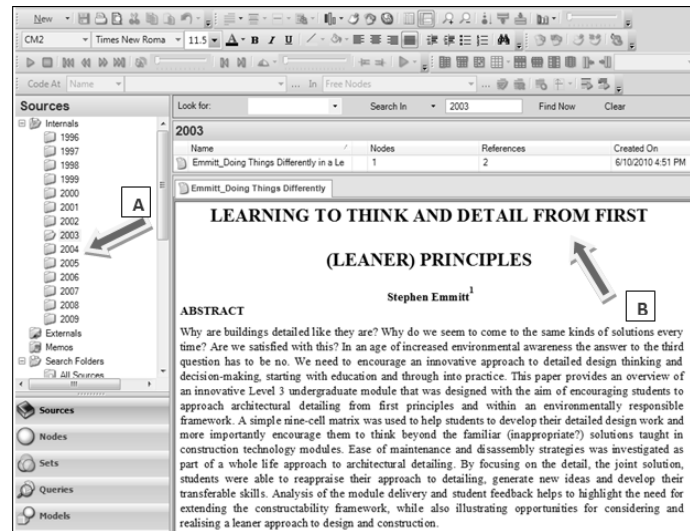


Figure 3: Display of NVivo interface.

- 3) Each research study was classified into one of 19 research categories according to its research intent. An NVivo function “Tree Nodes” indicated by C in Figure 4, allowed the researcher to create Proxy categories during the course of analysis based on the research intent of each study. Upon analysis, each research study was classified within a specific category as indicated by D in Figure 4.

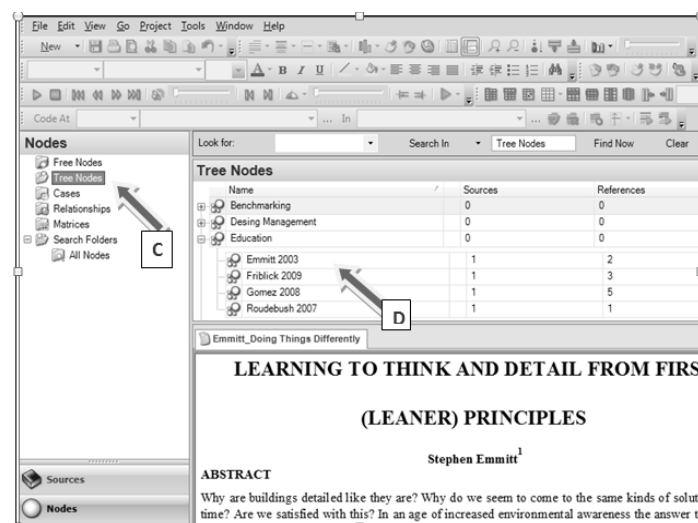


Figure 4: Display of NVivo interface.

- 4) An electronic reference list was created in support of the classification criteria. The reference number “2” indicates that two references were created for the Emmitt research study as illustrated in E in Figure 5. References provided support in why studies were classified within specific research categories. An example of an electronic reference list is displayed below E in Figure 5.

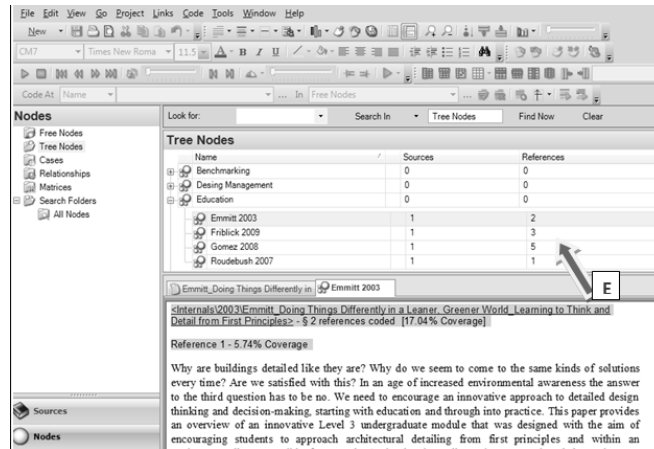


Figure 5: Display of NVivo interface.

- 5) In tandem with NVivo, a separate Excel database was constructed as indicated in F of Figure 6. The reason for this was twofold: as data backup and for graph creation which is a less desirable utility within NVivo.

The screenshot shows an Excel spreadsheet with a table of research studies. The table has columns for Year, Title, Author, Country, Case Study, Philosophy, Process, People and Partners, Problem Solving, Theory, Design Management, IT, Waste, and Education. Two rows are visible, corresponding to the studies mentioned in the text. A box labeled 'F' points to the 'Education' column of the second row.

Year	Title	Author	Country	Case Study	Philosophy	Process	People and Partners	Problem Solving	Theory	Design Management	IT	Waste	Education
2003	LEARNING TO THINK AND DETAIL FROM FIRST LEANER PRINCIPLES	Stephen Emmitt	Denmark										1
2003	USING BUFFERS TO MANAGE PRODUCTION: A CASE STUDY OF THE PENTAGON RENOVATION PROJECT	Michael J. Horner, John I. Messner, David R. Riley, and Michael H. Palski	US			1							

Figure 6: Display of Excel database.

- 6) Upon analysis and classification of the research studies, interpretative representations in graph format accompanied the finding section as illustrated in Figure 7.

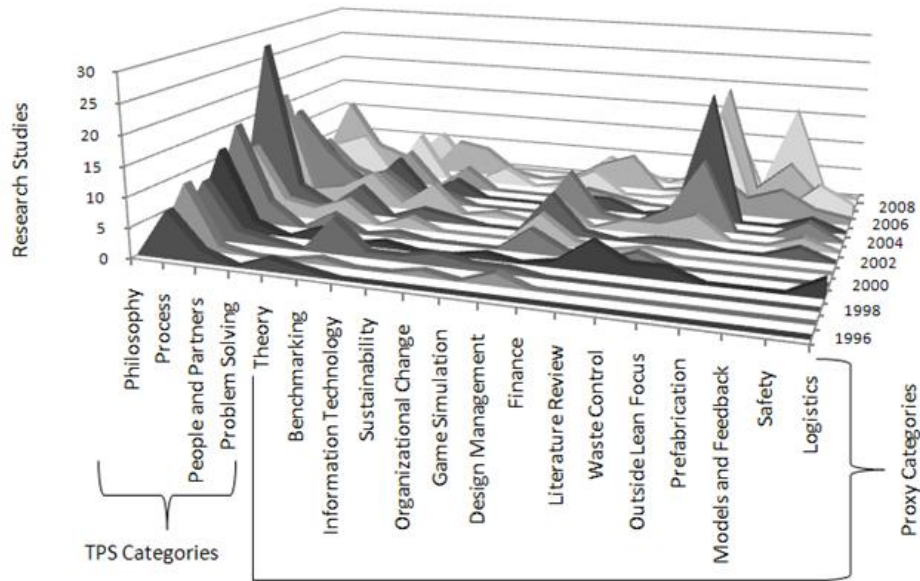


Figure 7: Lean Research Trends between 1996 and 2009

Each research study was reconciled against the (TPS) framework which included the following four categories of Long Term Philosophy, The Right Process, Invest in People and Partners, and Continuous Problems Solving. The study analyzed 592 IGLC research studies within one of 19 research categories based on its research intent. Besides the four TPS categories, 15 lean related proxy categories were created by the researcher during the course of the study based on merging themes during the analysis process. A list of definitions on the 19 categories is illustrated in Table 1.

Table 1:

Clarification of Research Categories

Research Categories	Definition
Philosophy	TPS Category
Process	TPS Category
People and Partners	TPS Category
Problem Solving	TPS Category
Theory	Theory development research associated with lean construction
Benchmarking	Compared construction processes and performances against that of other industries
Information Technology	Use of computers and telecommunication in construction
Sustainability	Architectural property which allows continued viability in construction
Organizational Change	Undergone internal transformations within companies
Game Simulation	Various activities in "Real Life" in the form of games
Design Management	Integration of construction design into management and vice versa
Finance	Construction activities associated with providing funds and capital
Literature Review	Body of lean text to review critical points of lean and construction
Waste Control	Measures of waste in construction
Outside Lean Focus	No relevance to other 18 categories in lean construction
Prefabrication	Manufacturing of sections of a building at a factory
Models and Feedback	Lean production models and feedback on applied applications in construction
Safety	Safety systems in construction
Logistics	Handling of operations in construction

Lastly, a research method category outline was created which included the following four research method categories; Theoretical Research, Case Studies, Action Research, and Structured Interviews as illustrated in Table 2.

Table 2:

Research Method Categories with Definitions in Relation to IGLC Research Studies

Research Method	Definition	Applied in this Study
Theoretical Research	Theoretical research provides detailed descriptions and explanations of a phenomenon studied rather than providing and analyzing statistics.	In this study lean researchers created an inquiry around the phenomenon of lean theory in construction.
Case Study	Case Study research is a type of qualitative research and is based on an in-depth investigation of a single individual, group, or event to explore causation in order to find underlying problems.	In this study lean researchers applied lean theory on projects in the construction field.
Action Research	Action research is a type of qualitative research and is a reflective process of progressive problem solving led by individuals working with others in teams or as part of a “community of practice” to improve the way they address issues and solve problems.	In this study lean researchers engaged in problem solving methods in an attempt to improve construction processes.
Structured Interviews	Structured interviews, another form of qualitative research, ask people questions during an interview process. The interviewer usually has a framework of themes to be explored.	In this study lean researchers interviewed various players within the construction field.

These categories allowed the researcher to classify all studies within a specific research grouping based on the outlines in Tables 1 and 2.

Reliability

The study addressed two types of reliability—stability and reproducibility which according to Stemler (2001) are unique to content analysis. Stability refers to the results of content classification, when the same content is coded more than once by the same coder in the same fashion (Stemler, 2001). Upon completion of the research analysis the researcher randomly selected 5% of the analyzed proceedings (30 proceedings), which were then re-analyzed by the researcher in the same manner as before. An Intrarater stability coefficient of 96% was obtained which indicated a strong reliability factor within content classification (Krippendorff, 2004). Reproducibility refers to the extent to which content classification produces the same results when the same text is coded by more than one coder. An external interrater evaluator was utilized to analyze 10% (60 proceedings) of previously analyzed research studies by the researcher. This individual had no connection to the study and was purely contracted based on her construction and qualitative research background. An interrater reliability coefficient of 92% was obtained which indicated a strong reproducibility factor (Krippendorff, 2004).

Results

The following sections reiterate the study outcomes through alignment of IGLC research studies against the TPS framework as well as the classification of research methods used in lean construction research between 1996 and 2009 at IGLC conferences.

Alignment of Research Studies against the TPS Framework

Figure 8 represents the distribution of IGLC research studies in either TPS or proxy categories by definition as illustrated in Figure 1. It is evident from the breakdown that IGLC research studies did not align exclusively around the TPS framework. From 592 research studies analyzed, 241(40%) were classified within the TPS framework consisting of four categories namely Philosophy, Process, People and Partners and Problem Solving and 351 (60%) research studies were classified outside the TPS framework consisting of 15 proxy research categories as introduced in Table 1.

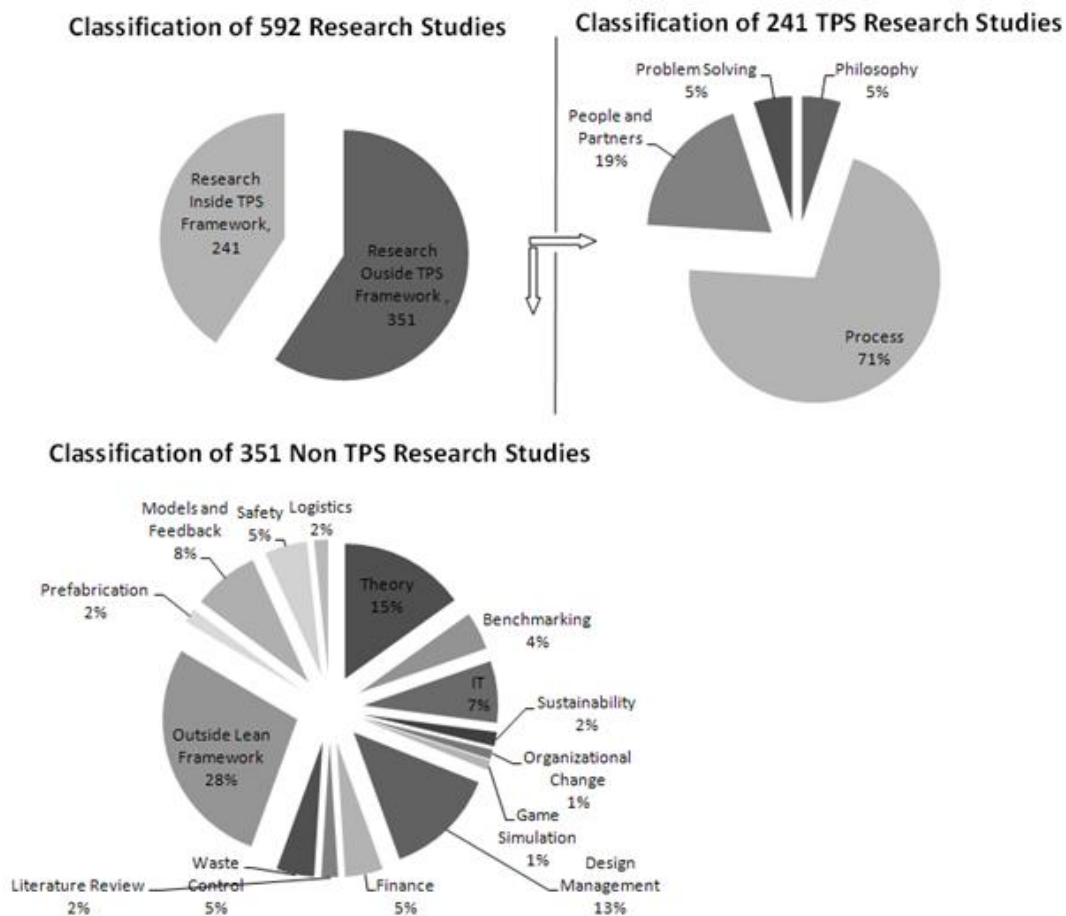


Figure 8: Distribution of Analyzed Research Studies to TPS or Proxy Categories.

The 40% TPS research studies further revealed an unequal research representation among the four TPS framework categories as illustrated in Figure 8. Research studies within the TPS framework revealed that Philosophy and Problem Solving each represented 5% of lean research, People and Partners 19%, and Process 71% respectively.

Conceptual Versus Applied Research in Lean Construction

The 592 IGLC research studies were further grouped in one of four research method categories as introduced in Table 2. Research methods in lean construction revealed that 71% of research studies were classified as theoretical by definition, 27% as case studies, and 1% classified as action and interview research as illustrated in Figure 9.

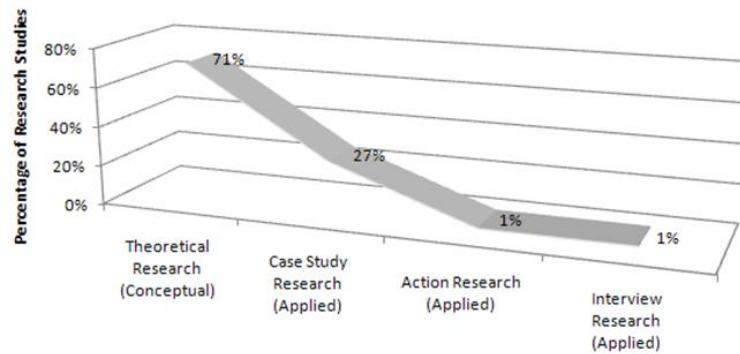


Figure 9. Research Method Breakdown.

This research method breakdown revealed a lack of applied lean research in construction during the last 14 years.

Discussion

Results obtained in this study demonstrated that there were selective research agendas and interests among lean researchers at IGLC conferences. IGLC conferences offer an open research forum allowing researchers to contribute within their respective research fields. Despite this open forum, or possibly because of it, multiple TPS principles lack research representation at these conferences. The study further indicated that lean research deviated from the TPS framework over time. This provided support that a need for lean related research exists outside the TPS framework for broader applied functionality to the construction operating platform which further indicated that lean research in construction has surpassed confinement to the TPS framework, which demonstrates that a need exist to conduct lean research unique to the construction industry's operating platform. In addition the study revealed that lean research in construction stems from a theoretical research platform as supposed from an applied research platform. Students, faculty, and practitioners in a classroom setting are direct consumers of research. The benefit of this study is to inform these consumers by emphasizing that lean research is an integrated dynamic of theory, practice and research in support of the Theory Development Model. This study distilled previous lean research studies into an understanding of a balanced research platform in construction. This awareness will help provide students who enter the workforce with a better understanding of the lean research foundation in construction. Lastly the study demonstrated that lean research in construction is representative of a conceptual versus applied research underpinning.

The success of lean research in construction largely depends on resolving the question posed by this study, which identified where lean research has focused in relation to the TPS framework. Through this understanding we can now move forward with confidence that there may be many supporting scenarios for lean research outside the TPS framework.

References

- da CL Alves, T. & Tsao, C. (2007). Lean construction—2000 to 2006. *Lean Construction Journal*, 46. Retrieved from <http://www.leanconstruction.org/lcj/paper.html>
- Dubin, R. (1978). *Theory building*: New York: Free Press.
- Fellows, R., & Liu, A. (2003). *Research methods for construction*. Oxford, UK: Blackwell Publishing Company.
- Green, S. (1999). The missing arguments of lean construction. *Construction Management and Economics*, 17(2), 133-137. doi:10.1080/014461999371637
- Krippendorff, K. (2004). *Content Analysis: An introduction to its methodology*. London: Sage Publications Inc. doi:10.2307/2289192

Liker, J. (2004). *The Toyota way: 14 management principles from the world's greatest manufacturer*: New York: McGraw-Hill Professional

Lynham, S. (2002). The general method of theory-building research in applied disciplines. *Advances in Developing Human Resources*, 4(3), p 221- 222. [doi:10.1177/15222302004003002](https://doi.org/10.1177/15222302004003002)

Quinn, R. (2004). *Building the bridge as you walk on it*. San Francisco, CA: Jossey Bass

Stemler, S. (2001). An overview of content analysis. *Practical Assessment, Research, & Evaluation*, 7(17), 1-10