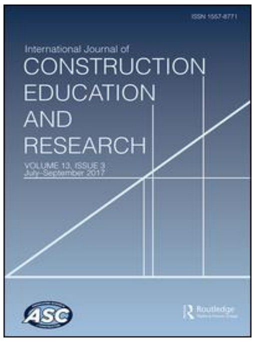

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Andrew P. McCoy PH.D. , Lance Saunders , Brian Kleiner PH.D. & Nick Blismas PH.D.

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Application of Safety Project Interview Data to a Cyclical Research Model of Translation

ANDREW P. McCOY, Ph.D., LANCE SAUNDERS, AND BRIAN KLEINER, Ph.D.

Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA

NICK BLISMAS, Ph.D.

Royal Melbourne Institute of Technology, Melbourne, Australia

There is growing debate over the need for academic research to produce applied. For example, funding agencies, such as the National Institute of Occupational Safety and Health (NIOSH) are emphasizing direct relationships with industry, and the need to contain research methods that are targeted, useful, and mutually beneficial. Applied academic research does not always translate into successful industry practice, let alone adoption, and vice versa. Many studies have explored barriers based on either academic or industrial variables, or both. Several attempts have been made to analyze barriers and propose solutions to address the translation of applied research into practice. One previously designed model, by researchers from the Royal Melbourne Institute of Technology (RMIT) and Virginia Tech, in particular, considers translation as an iterative approach to establish research-to-practice-to-research (r2p2r) as a "translational research model," creating an iterative relationship between academia and industry. While this model is currently theoretical in nature, this work proposes a process for collecting, translating and demonstrating reliability of data, along the previous r2p2r cycle, for 9 in-depth interviews of applied safety research pilot projects. Ultimately, this work is to set the stage for further insight into impediments and fragmentation between academic research and industry adoption in practice.

Keywords industry, innovation, pilot projects, r2p2r, research translation

Introduction

Academic research is multifaceted, from fundamental (basic) discovery to applied outcomes, fostering a breadth of outcomes that satisfy society's needs. When needed, the potential exists for a mutually beneficial partnership between academia, industry, and government that can help translate innovation to society (Butcher & Jeffrey, 2005). Differing from basic scientific discovery, applied research, by definition, typically implies a solution through pragmatic outputs. However, several barriers exist related to the pragmatism of translation of research results into industry

Address correspondence to Andrew P. McCoy, Virginia Tech, Building Construction, 410B Bishop Favrao Hall, Blacksburg, VA 24061. E-mail: apmccoy@vt.edu

implementation. What are the possible reasons that research outcomes from applied academic projects do not successfully relate directly to industry? This question has been posed many times, and both academic research institutions and the industry have been analyzed for possible barriers or variables that may lead to a better understanding of mutual benefits through applied research. Some studies have theorized and determined that the root cause of the issue is academic arrogance (Destler, 2008). Other research has suggested that certain barriers may originate from fundamental differences between industry and academia, drawing connections to industry partners (Mudambi & Swift, 2009). After viewing both sides, it has become apparent that there is a combination of these barriers and variables at the root of the situation. Therefore, a systematic approach to analyzing applied research aims and outcomes, taking both industry and research perspectives into consideration, is needed to better understand and translate the underlying issues.

Blismas and colleagues (2009) addressed this topic and proposed a cyclical model of research translation, incorporating a research-to-practice-to-research (r2p2r) basis for the model to create an iterative relationship between research institutions and industry. This model applied a systematic approach to analyzing academic research into applied outcomes and establishing the basis for a comparative analysis between the Architecture, Engineering and Construction (AEC) industry and academia.

More information is needed to more adequately understand how these relationships develop and function. In particular, a National Academies Review of the National Institute of Occupational Safety and Health (NIOSH), including the Construction Program, concluded that across sectors, NIOSH research needed to demonstrate more "relevance" and "impact" relative to industry. It is recognized that within the NIH taxonomy that NIOSH uses, there is a range of project types from exploratory to more applied. As a general prescription, NIOSH has been emphasizing, with its intramural and extramural researchers, the need to translate results to practice. Using NIOSH project-based information, aims and outcomes of work might be used to better recommend translation of research efforts into industry practice and vice versa, per the continuous improvement of iteration. The goal of this paper is to build upon the existing body of work that has been investigating this very topic of translating research into industry practice. In the United States, researchers at the Royal Melbourne Institute of Technology (RMIT) and Virginia Tech (Blismas *et al.*, 2009) previously developed a cyclical translational research model to examine the translation process.

Blismas and colleagues (2009) concluded that further development was dependent on project-based, anecdotal evidence. This work proposes a process for: 1) collecting multiple types of data; presenting these data in a format that could reduce disconnects (reinforce translation) in academia and industry; and 3) demonstrating reliability of data within the translation model. The work relies on anecdotal evidence from 9 safety research projects at Virginia Tech, a limited set that were part of a NIOSH family of projects, in the hopes of later expanded the work to include industry-based work. Data for this work was collected through an in-depth interview process from recent Center for Innovation in Construction Safety and Health Research (CICSHR) Granata Pilot Research Projects. The CICSHR Granata Pilot Projects investigated a range of research topics with a focus on several NIOSH construction safety aims. The overall goal of the pilot program is to establish outcomes, through these projects, for further funded research opportunities guided by the National Occupational Research Agenda (NORA) of NIOSH. The pilot program is an ideal candidate for study of the need for emerging research that targets industry concerns.

Background

Interaction Between Academia and Industry

Previous studies have researched the relationship between academia and industry. This research shows the potential for useful knowledge to be gained from a relationship of interaction and learning among researchers, industry, and government (Polt *et al.*, 2001). The academic environment is unique, providing a wide range of potential services and knowledge (McAdam & McAdam, 2008). Because of this potential, industry has been known to seek out universities for potential scientific knowledge and experience, and universities often seek funding for further research (Crespo & Dridi, 2007). For both academia and industry to form partnerships in pursuit of a competitive advantage through industry partners is a natural fit (Blismas *et al.*, 2009).

However, numerous barriers from both academia and industry have become obstacles to effective partnership opportunities (von Hippel, 2005). Academicians are known for their share of issues that impede effective partnerships: they often have differences in culture and incentives relative to industry (Butcher & Jeffrey, 2005); they are disillusioned by industry (Henderson *et al.*, 2006); they have unrealistic demands (Destler, 2008); they are unwilling to research outside initiated projects (Destler, 2008); and they ineffectively communicate research findings (Bielak *et al.*, 2008). From another perspective, industry is not exempt from factors that become obstacles to effective partnerships between academia and industry. Industry shares responsibility for several of these factors: industry often turns to consultants given differences in values (Mudambi & Swift, 2009); industry requires quick outcomes to gain a competitive edge (Destler, 2008); industry is reluctant to commit to long-term R&D given short-term shareholder expectations; and industry often changes its expectations relatively quickly (Henderson *et al.*, 2006). A reality for both managers and researchers is that many organizations are linked to events where the surrounding environments are changing at a dynamic rate and thus more action-oriented and responsive research is needed (Cunningham, 1993).

Several obstacles are rooted in academia that often impede an effective partnership between academia and industry. According to Butcher and Jeffrey (2005), the values, purpose, culture, procedures, and incentives often differ for industry and impede partnerships. Destler (2008) described unrealistic royalties and intellectual property demands that university lawyers seek in collaborative projects with industry, leading to unsuccessful opportunities. The right to publish is often experienced as an obstacle. Destler also emphasized that meeting their own professional goals and aspirations of research often motivates researchers of academic institutions. In addition, these researchers tend not to be as open to conducting research based on ideas that are not their own. The pace with which research projects are conducted, as shown by a typical Research Council grant, is much slower than the industry and such projects are time-consuming. Another major issue with the academic environment is the communication methods used to disseminate research findings and conclusions. Outputs from academia are mostly communicated through peer-reviewed journals and publications targeted primarily to societies of scholars. The reward system reinforces this. Communicating through peer-reviewed journals is simply not an effective way to interact with industry given the lack of accessibility by potential industry partners. Bielak and colleagues (2008) explained that researchers are given more praise for research that is peer-reviewed by other academics and competitive grant awards. Industry-based research often does not receive much praise and thus does not receive as much attention by researchers. Finally, given the sparse research outcomes encountered by researchers who work with industry, partaking in training and consultancy results in disillusionment on the part of the researcher (Henderson *et al.*, 2006).

On the other hand, industry, perhaps inadvertently, contributes several factors that impede effective partnerships with academia. Mudambi and Swift (2009) described the differences in belief systems between researchers and managers, shedding light on some of the potential differences between industry and academia. The core values and cultures differ between the two sides, pushing industry to entertain consultancy rather than invest in partnerships with academia. This is primarily the result of the similarities between the values of industry and consultancy. It is also the result of the quick turnaround that consultancy offers that academia often cannot. Destler (2008) reinforced this relationship and need for a fast turnaround from industry that allows them to remain competitive within their environment. Another factor that creates the need for a quick return is short-term shareholder expectations within the industry. Henderson and colleagues (2006) found that industry often needs to reel back goals set forth at the beginnings of projects because of increases in business pressures, the dynamic structure of business models, and updated time constraints. Even if a partnership between industry and academia is established, any of these factors can play a role in reducing the effectiveness of the partnered research.

Understanding that both industry and academia play a role in impeding potential effective partnerships through numerous inherent factors, research into the relationship between the two and potential solutions to these issues can be argued as necessary (Blismas *et al.*, 2009). Bielak and colleagues (2008) argued that a linear model of research translation is not necessarily the solution to effective dissemination and adoption by a wider industry audience. Blismas, McCoy, and Lingard suggested that new models of cyclic translational research of "research-to-practice-to-research" might be more effective (Blismas *et al.*, 2009). The concepts of the model integrate industry best practices and a research knowledge base to achieve a more effective partnership between industry and academia.

Cyclical Research Translation Model (r2p2r)

Traditional models of research translation to practice are generally linear in approach. It has been the norm for research projects to follow these models given the more scientific nature of the research targeted toward industry, especially the construction industry. However, Bielak and coworkers (2008) argued that a linear model is not necessarily the best application of research translation between research institutions and industry. Today, research projects are increasingly non-basic in nature (Cunningham, 1993), and aim to solve practical problems. As a result, such work might contain non-traditional bearings, or beginning and ending points that reflect a dynamic environment, such as construction, that commonly changes. Applied research might also require more action-oriented and responsive methods for arriving in the world of practice. For example, in construction research, the most common traditional methods for translation of research findings are through peer-reviewed publications, industry booklets or pamphlets, workshops, and continuing education programs or training modules (Blismas *et al.*, 2009).

Another approach to translation of research findings is the non-linear approach of problem identification, analysis, communication, and interaction (Butcher & Jeffrey, 2005). A model developed by Blismas and colleagues (2009) based on Ledford (2008), is a cyclical model of translational research built on the premise of improving the translation of research findings to practice from older, previous models of translation. The model itself is depicted as a circle divided into two halves with three divisions each, for six separate areas within the model (Figure 1).

The model does not have an obvious starting point, as perhaps a linear model would, previous work found that research often begins at the top of the chart, with Investigation, which is often undertaken by publicly funded researchers, and often responds to questions derived from practice. The cyclical model is divided into six main areas of focus: investigation, verification, translation, implementation, evaluation, and reformulation. Blismas and colleagues (2009) provided definitions and explanations for each category in cyclic order. The proposal of further informed research based primarily on evaluation and the development of existing work is what forms the category of reformulation. Investigation is comprised of research to investigate a research question and develop a theory based on the research. The next step in the process is verification, or to verify trial findings and theory from investigation in the field. These three categories, as seen in Figure 1, are the "research" half of the cyclical research translation model. The translation of the research to industry occurs between verification and translation, as represented by the bold line in the

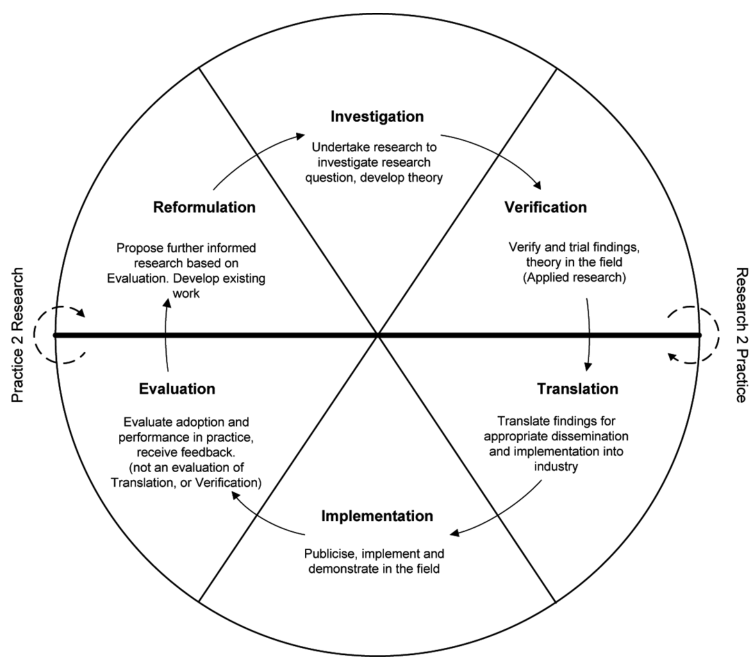

Figure 1. Cyclical model of research translation (Blismas *et al.*, 2009).

model. With this dichotomous model, the action research tradition is continued. More specifically, the approach described here is consistent with Cunningham's (1993) action research process that links action research with change management elements that are normally part of organizational development and strategic planning processes. Translation converts research findings for appropriate dissemination and implementation into the targeted industry or the public. Implementation is next in the process, and is the publication, implementation, and demonstration of the resultant idea/product in the targeted field of application. The proceeding step in the model is evaluation, which evaluates adoption and performance of idea/product in practice, and receives feedback from implementation (Blismas *et al.*, 2009). Translation, implementation, and evaluation are the three categories that comprise the "industry" half of the cyclical model. As shown, there is no clear starting or ending point within the model, as evaluation is designed here to translate back to reformulation. Still, traditional "starting" points might be delineated through the dotted half-circle for reference. Blismas and colleagues (2009) also argued that this new translational research model is effective because of the joining of the two halves along the centerline. This allows for industry and academia to constantly assess obstacles to the research and redefine the relationship between them as needed. It is also argued that for this model to be effective, researchers must maintain awareness of the position of the research within the model, and effective communication and interaction between the two sides must be significant (Blismas *et al.*, 2009).

Presently, some argue that for many current research projects, the iterative cycle of translation, as shown here, is not complete. One reason proposed is that researchers are often unable to properly communicate the implications of their basic research to outside the academic society (Roland, 2005). Blismas and colleagues (2009) reiterated that academics have become highly skilled in conveying in publications the processes and findings of research projects undertaken, but may in fact be increasing the disconnect between themselves and potential users of the research. One goal of this work is to close this disconnect, not widen it. Therefore, researchers must be aware of and communicate larger goals toward bridging the translational gap.

Blismas and colleagues (2009) argued additional reasons and factors that impede the effective completion of the translational research cycle based on a lack of feedback mechanisms for research that analyzes and evaluates actual implementations of the research; traditional academic processes based on linear models that encourage the disconnect between industry and academia; and the industry's need for quick "consultancy-type" project timelines given the nature of its operations, more specifically the AEC industry and its uncertainty toward the benefits of academic research (Barrow *et al.*, 2003). These factors alone, or in combination, can result in failed completion of the cycle.

Cyclical translational research models, specifically the model designed by Blismas and colleagues (2009), aim to improve the interaction (translation) between researchers and industry adopters by analyzing research projects targeted toward industry, applying them to the developed model, and interpreting the findings to further develop the model and improve potential partnerships between academia and industry. Previous work from the Royal Melbourne Institute of Technology (RMIT) and Virginia Tech's Center for Innovation in Construction Safety and Health Research (CICSHR) examined the relationship between industry and academia in the field of construction. In particular, previous work explored the barriers to the transfer of research outcomes into industry practice through a cyclical model of translational research as a useful mechanism for understanding the position of one's research. Not much work has been conducted utilizing this new model, and a need exists for more information to populate the model in the future.

RMIT University Safety Research Projects

Based on Blismas and colleagues (2009), the School of Property, Construction and Project Management at RMIT recently utilized the model towards completed safety research projects. These projects were useful for understanding the process of positioning research within the translational cycle of the r2p2r translation model. Previous work at RMIT superimposed their safety research projects onto the model, showing that even those projects viewed as highly translational in their design, were deficient in at least 50% of the cycle. Through this process, recent safety research proposals and goals have been subjected to a test along the model and adjusted therefrom. However, lack of funding to continue the work beyond the Implementation phase of the cycle has meant that the success or impact of the work remained largely unknown. Further development was therefore dependent on project-based, anecdotal evidence, the purpose of this work.

CICSHR Granata Pilot Research Projects

Virginia Tech's Center for Innovation in Construction Safety and Health Research (CICSHR) Granata Pilot Research Projects were a group of pilot research projects, thirteen in total, funded in part by a grant from the National Institute of Occupational Safety and Health (NIOSH). New projects are awarded each year. Each project addresses at least one of the National Occupational Research Agenda's (NORA) strategic goals related to construction, in conjunction with NIOSH (NORA, 2008). The strategic goals set by NORA cover construction-specific safety concerns, including falls, electrocutions, struck-by hazards, hearing losses, silica exposure, welding fumes and illnesses, musculoskeletal issues, culture, safety, organization, training and education, disparities in health and safety, hazard prevention, surveillance, and raising awareness (NORA, 2008). Each interview documents such information for safety pilot grants, aligned with at least one NORA strategic goal, through project aims set forth by researchers' proposals and reported outcomes.

Purpose and Objectives

The main objective of this work is to establish a standard process for collecting, translating and demonstrating reliability of data along the translation model using anecdotal evidence from 9 safety research projects at Virginia Tech. More specifically, this project aims to build upon the growing body of qualitative and quantitative information validating cyclical translational research models being developed to address successful interaction between academia and industry. The specific objectives of this project were:

1. Distilling aims and outcomes of CICSHR Pilot Research Projects from reported deliverables and aims as reported by proposals for the work;
2. As a research team, mapping reported aims and outcomes of selected Pilot Research Projects along the areas of the translation model developed by Blismas and colleagues (2009);

3. Measuring, through interviews of principal investigators of Pilot Research Projects (n = 9), agreement of the teams' placement of aims and outcomes along the model.
4. Verifying, through interviews of the same principal investigators, perceived priority, for the pilot research, of stages within the model.
5. Articulating an effective research process for establishing reliability of data among various respondents and multiple areas of the model.

Methodology and Research Plan

Methodology

Currently, and based on previous work, both qualitative and quantitative data are available for r2p2r modeling and need to be considered in future processes. Therefore, the project collected both types of data through interviews of principal investigators within safety for translational research.

The subjects of this study were the CICSHR Granata Pilot Research Projects. The body of projects selected for study was a group of nine (n = 9) projects targeting various topics within the field of construction industry safety. Pilot projects are small scaled-NIOSH funded projects, targeting specific NORA goals and intended to result in future research opportunities. Further, the Pilot Research Projects' aims and outcomes targeted specific state-of-the-art construction industry issues, all pertinent to industry adoption and diffusion (i.e., forms of translation).

Pilot Research Project proposals provided the base data needed to map within the r2p2r cyclical translational research model (Figure 1). Data validation required that pilot project principal investigators examine the research teams' interpretation of project aims' and outcomes' location within the model, then provide a perceived value of priority for that part of the study. For this reason, and given the need for a system that captures both qualitative and quantitative information in future studies, semi-structured interviews were chosen as the method for operationalizing this work.

Interviews were designed to establish and verify relationships among NORA goals, project aims, and project outcomes (Table 1). The interviews were also

Table 1. Example relationship table of NORA goals, project aims, and project outcomes

Specific Pilot Project Title	NORA Goal Number	NORA Goal Title	Specific Project Aim	Expected Project Outcome	Reported Project Outcome
Pilot Case Study #1	12	Disparities	Project Aim 1	Proposal Outcome 1	Reported Outcome 1
	12	Disparities	Project Aim 2	Proposal Outcome 2	Reported Outcome 2
	12	Disparities	Project Aim 2	Proposal Outcome 3	Reported Outcome 3
	12	Disparities	Project Aim 3	Proposal Outcome 4	Reported Outcome 4
	Ibid.	*Ibid.*	*Ibid.*	*Ibid.*	*Ibid.*

designed to establish and verify the position of each project aim, as well as project outcome separately, within the r2p2r model (Table 2). Interviews provided a quantitative numerical value as well (from 1 to 3: 1 – low priority for pilot project, 2 – medium priority for pilot project, 3 – high priority for pilot project) for each project aim or project outcome's occurrence within the r2p2r model (Table 2).

Interview Participation

The interview participants were provided with several important pieces of information ahead of each scheduled interview for the semi-structured data collection. This information included the following, along with the specific interview questions of the same nature:

1. A Diagram and definitions of the r2p2r cyclical translational research model; verification of understanding and agreement/disagreement with the model and definitions were gained from each participant in the interview (Figure 1);
2. A research-team-interpreted placement of NORA goals, project aims, *and* outcomes (using an "X") for pilot projects being interviewed (Table 1), including separated (1) project aims chart *and* (2) outcomes charts (Table 2) [for illustration, the translation model was represented in table format, separated by the two main categories of Research and Practice, to facilitate ease of data collection];
3. Both a (1) project aims chart *and* (2) outcomes chart (Table 3), each blank when distributed, for participant perceived priority for his or her project.

Participants were provided with the organizational chart of NORA goals, project aims, and outcomes, as well as the project aims and outcomes charts interpreted ahead of time by the research team to keep the duration of the interviews as short as possible and to help describe to participants the type of information required. All aspects, including NORA goals, project aims, and outcomes, the relationship among the three categories, and their placement within the model, were subject to modification and verified by each survey participant at the time of the interview. The semi-structured format allowed for focused discussions on the model and its use as well, better educating participants in the process.

Application of r2p2r Cyclical Translational Research Model

The application of the model to the Pilot Research Projects, referred to for the remainder of this section as interviews (1–9), was key to determining where each case existed in the translational model. The boxed region in Table 4 shows the processes of assigning average weights by project to the r2p2r model. The presence of a number ranging from 1 to 3 indicates both *the occurrence* within the model category and the weighted priority *reported by the participant* for that occurrence. Thus, the lack of a number in the table indicates the lack of an occurrence and weight for an aim or outcome.

The two categories of information calculated at the bottom of Table 3 are the average occurrence number (*i.e.*, frequency) and the average rating per occurrence. The average occurrence number is based on the number of occurrences for each column (*i.e.*, the 3 above in reformulation would be considered 1 occurrence) that relates to the model. That number was then divided by the total number of possible

Table 2. Example of interview-reported aims (or outcomes), including a weighted value for location within r2p2r model

Specific Project Aims & Outcomes	Research			Practice		
	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
1. Project 1Aim or Outcome Location		X	X	X	X	
1. Project 1Aim or Outcome Priority Ranking		3	2	2	1	
2. Project 1Aim or Outcome Location		X	X	X		
2. Project 1Aim or Outcome Priority Ranking		2	2	1		
3. Project 1Aim or Outcome Location	X	X	X	X	X	X
3. Project 1Aim or Outcome Priority Ranking	3	3	3	2	1	1
4. Project 1Aim or Outcome Location	X					X
4. Project 1Aim or Outcome Priority Ranking	2					1

Note: Sequence continues for all aims and reported outcomes.

Table 3. Example of average information based on cyclical translational research model quantitative data

	Research			Practice		
Project Aims	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
1. Project Aim or Outcome 1		3	2	2	1	
2. Project Aim or Outcome 2		2	2	1		
3. Project Aim or Outcome 3	3	3	3	2	1	1
4. Project Aim or Outcome 4	2					1
Average occurrence number	0.5	0.8	0.8	0.8	0.5	0.5
Average rating per occurrence	2.5	2.7	2.3	1.7	1.0	1.0

Table 4. Interview results of project aim's occurrence and ratings, with averages

	Research			Practice		
Interview Number	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
Interview (1) Average Occurrence	0.5	0.8	0.8	0.8	0.5	0.5
Interview (1) Average Rating	2.5	2.7	2.3	1.7	1.0	1.0
Interview (2) Average Occurrence	0.0	1.0	1.0	1.0	1.0	0.0
Interview (2) Average Rating	N/a	3.0	3.0	2.0	1.0	N/a
Interview (3) Average Occurrence	0.3	1.0	1.0	0.6	0.6	0.3
Interview (3) Average Rating	3.0	2.0	2.0	2.5	2.5	3.0
Interview (4) Average Occurrence	0.0	1.0	1.0	0.0	0.0	0.0
Interview (4) Average Rating	N/a	3.0	2.0	N/a	N/a	N/a
Interview (5) Average Occurrence	0.0	1.0	1.0	0.0	0.0	0.0
Interview (5) Average Rating	N/a	3.0	2.0	N/a	N/a	N/a
Interview (6) Average Occurrence	0.2	1.0	1.0	0.4	0.2	0.2
Interview (6) Average Rating	3.0	2.8	2.8	2.0	3.0	3.0
Interview (7) Average Occurrence	0.2	0.6	0.8	0.6	0.6	0.4
Interview (7) Average Rating	3.0	2.0	2.0	2.3	2.0	3.0
Interview (8) Average Occurrence	0.5	0.5	0.5	0.5	0.0	0.0
Interview (8) Average Rating	2.0	3.0	3.0	3.0	N/a	N/a
Interview (9) Average Occurrence	0.3	0.8	0.8	0.3	0.0	0.3
Interview (9) Average Rating	2.0	3.0	3.0	1.0	N/a	2.0
Aims' Average Occurrence across Interviews	0.2	0.9	0.9	0.5	0.3	0.2
Aims' Average Rating across Interviews	2.6	2.7	2.5	2.1	1.9	2.4

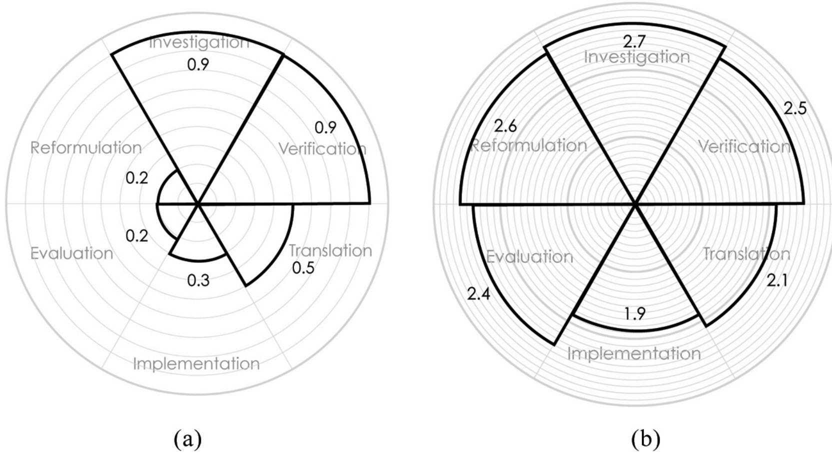

Figure 2. (a) and (b). Graphical representation of pilot project aim's average occurrence and priority rating (see Table 4).

occurrences (*i.e.*, 4 possible occurrences for reformulation). As a point of reference, the lowest average could be 0 and the highest average could be 1.

The average rating per occurrence was calculated by adding the rating for each row of occurrence (per column), then dividing that number by the total number of occurrences for that column. Based on interview questions, such an average suggests a perceived priority of the occurrence of an aim or outcome within a principal investigator's study, and according to him or her. As a point of reference, the lowest average could be 0 and the highest average could be 3. The process results in distinct sets of quantitative data, shown in table form, that provide an overall view of the average placement of an interview to the r2p2r model and the weighted rating or priority of each model area, according to the principal investigator.

This information was then applied separately to cyclical diagrams that display the information in a visual form different from the table and closer to the original diagram in Figure 1. The diagrams were separated into four types: a cyclical model displaying the average occurrence number for both (1) project aims *and* (2) project outcomes, and a cyclical model displaying the average rating of priority per occurrence for both (3) project aims *and* (4) project outcomes (Figures 2a, 2b, 3a, and 3b in the next section).

The results from the investigation remained confidential and Virginia Tech's Internal Review Board (IRB) approved all collection methods. Each Pilot Research Project was labeled as an interview, ranging from interview (1) through interview (9). Each interview's findings section included the original project aim table and outcome table, along with participants' responses.

Findings

Pilot Research Project Interview Summary

The following summary section of findings, based on the data collected and reported, mirrors the individual interview information. Information from each interview, average occurrence number, and average rating per occurrence for both project aims and project outcomes were combined and a summary average was calculated for each category. The information is presented in table and diagram form, similar to the individual cases, for comparison. A designation of "N/A" in the tables refers to omission, by interviewees, for these areas of the model.

Based on Table 4, respondents reported the highest average occurrence of project aims in the 'research' portion of the work, which is not surprising for pilot research. Some respondents reported aims within the 'translation' portion of the work, but other areas of the research model lacked significant occurrence. Table 4 also lists average ratings for priority, reported by respondents and based on project aims, of the translation model's areas. While areas within the practice side of the model were omitted more often, both sides of the model received ratings of high importance. On average, respondents seemed to regard all areas with medium-to-high priority, as no part of the model received an average rating lower than 1.9 out of 3. Of interest, while 'Reformulation and Evaluation' received lesser occurrence averages, these areas maintained high level of priority for the interviewees.

Figures 2a and 2b below provide a graphical representation of reported occurrences within the original design language of the proposed translation model. While these figures represent identical information as Table 4, the interface is proposed as a tool for translation to industry in response to criticisms of ineffective communication of research findings (Bielak *et al.*, 2008). Using such a format, the process of comparing across aims and outcomes, for a portfolio of work might become more accessible. As with Table 4, the figures are based on 9 pilot projects.

Similar in concept to Table 4, Table 5 contains a higher average of occurrences of project outcomes in the 'research' portion of the work, with a high average of reported outcomes within the 'Investigation and Verification' areas. The 'Translation' area of the projects also contained high occurrence, according to Table 5. As in Table 4, other areas of the research model lack significant occurrence.

Similar to project Aims, interviewees also reported ratings of priority, reported as averages within the translation model's focus areas. Again, respondents seemed to regard all focus areas with medium-to-high importance, as no area received an average rating lower than 2.1 out of 3, while the outcomes' priority was distributed slightly differently than the aims. Of note is the slightly higher priority overall. Also of note, 'Reformulation and Evaluation' received lesser occurrence averages while remaining a high priority for the interviewees. Variation in placement and priority seems to highlight the nature of contemporary research projects, those that are increasingly non-basic in nature (Cunningham, 1993) and diverse in aims and processes. As previously noted, applied research might contain non-traditional bearings, or beginning and ending points that reflect a dynamic environment, such as construction, that commonly changes.

Further, applied research might also require more responsive methods for targeting the world of practice. Figures 3a and 3b look similar to Figures 2a and 2b, based on responses for the portfolio of work. While these figures represent identical information as Table 5, the interface is again proposed as a tool for translation to industry in response to criticisms of ineffective communication of research findings (Bielak *et al.*, 2008).

It is finally important to note overarching themes across the pilot study research project data. *Aims* and *outcomes* seem well aligned in occurrence (including the teams' control mapping). As might be expected for pilot projects, *aims* and *outcomes*' occurrence remain mostly within the realm of the research side, with some mention

Table 5. Interview results of project outcome's occurrence and ratings, with averages

	Research			Practice		
Interview Number	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
Interview (1) Average Occurrence	0.3	0.1	0.3	0.6	0.3	0.3
Interview (1) Average Rating	3.0	3.0	3.0	3.0	3.0	2.5
Interview (2) Average Occurrence	0.7	0.8	0.7	0.7	0.3	0.7
Interview (2) Average Rating	3.0	3.0	2.8	2.8	1.5	1.5
Interview (3) Average Occurrence	0.4	0.4	0.5	0.6	0.5	0.4
Interview (3) Average Rating	2.7	2.7	2.0	2.0	2.3	2.3
Interview (4) Average Occurrence	0.6	0.8	0.8	0.0	0.0	0.0
Interview (4) Average Rating	1.3	3.0	1.8	N/a	N/a	N/a
Interview (5) Average Occurrence	0.0	1.0	1.0	0.0	0.0	0.0
Interview (5) Average Rating	N/a	3.0	2.0	N/a	N/a	N/a
Interview (6) Average Occurrence	0.3	1.0	1.0	0.6	0.3	0.0
Interview (6) Average Rating	2.0	2.0	2.0	2.0	1.0	N/a
Interview (7) Average Occurrence	0.1	1.0	1.0	0.3	0.3	0.1
Interview (7) Average Rating	3.0	2.0	2.0	2.3	2.0	3.0
Interview (8) Average Occurrence	0.2	0.2	0.2	0.8	0.0	0.0
Interview (8) Average Rating	2.0	3.0	3.0	3.0	N/a	N/a
Interview (9) Average Occurrence	0.3	0.8	0.8	0.5	0.3	0.3
Interview (9) Average Rating	3.0	2.3	1.7	3.0	3.0	3.0
Outcomes' Average Occurrence across Interviews	0.3	0.7	0.7	0.5	0.2	0.2
Outcomes' Average Rating across Interviews	2.5	2.7	2.3	2.6	2.1	2.5

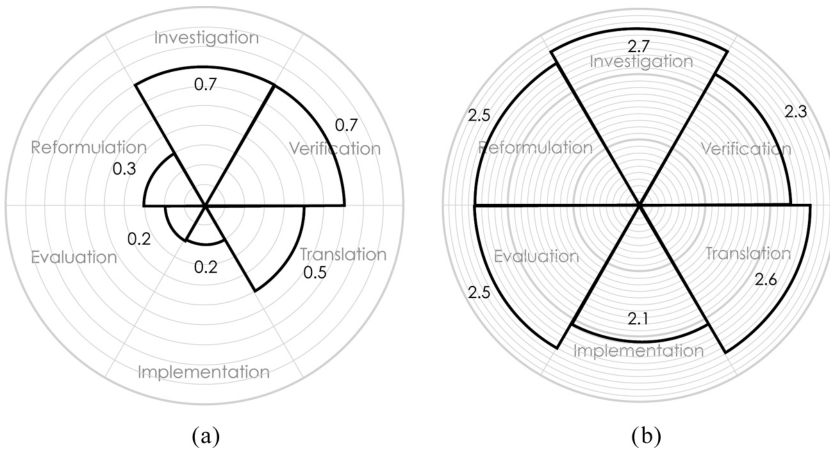

Figure 3. (a) and (b). Graphical representation of pilot project outcome's average occurrence and priority rating (see Table 5).

of the formal process of translation. All stages of the model contain an *aim* and *outcome*, as respondents did not omit entire model areas. When asked, respondents also did not suggest new areas for the model. Interestingly, all parts of the translation model seem to indicate a medium-to-high priority and, for this limited number of interviews, the amount of occurrence does not seem to lessen the level of priority and vice versa. Finally, though slight, *aims* were reported as having higher priority in research areas and *outcomes* were reported as having higher priority in practice areas.

Conclusions

This work attempted to establish a standard process for collection, application, demonstration and validation of a previous cyclical translational research model in order to be applied to a larger base of existing and future research. Included pilot projects were useful for further demonstrating the process of positioning research within the translational cycle of the r2p2r model. Previous work at RMIT superimposed their safety research projects onto the model, showing that even those projects viewed as highly translational in design, were deficient in at least 50% of the cycle.

The findings from Virginia Tech's Center for Innovation in Construction Safety and Health Research (CICSHR) Granata Pilot Research Projects, based on the survey data collected, provide a set of subjective information from primary sources, the principal investigators, and articulate that information in two main forms: 1) tables showing a quantitative representation of data collected and calculated averages within the model and 2) cyclical diagrams that articulate the information in a form that more readily communicate with the qualitative nature of the r2p2r model. The hope is that the methodology deployed in this project, along with the various forms of articulation, will be further developed and utilized in translating future applied research from the academy to industry and vice versa. In an attempt to demonstrate the use of model data towards basic forms of quantitative analysis, the next section provides an example of establishing *reliability* using interview data.

Measuring Agreement Among Respondents

In this section we provide an example of how the research model described above can be used in practice as a tool to analyze a set of research projects to determine if there are differences in the emphasis or application of different categories of the translational research model. While the low sample size makes forming statistically significant conclusions more unlikely, the data can still be analyzed to demonstrate the kind of information that can be obtained. The data collected on the priority assigned by researchers on different categories for each pilot project as well the occurrence data in the model for each project's aims and outcomes can be used to test for differences using an analysis of variance (ANOVA) procedure.

The average rating given by respondents within the research stage in the sample was 2.44, while the average rating within the practice stage was 2.25. The residuals of the ANOVA model were tested as to whether they fit a normal distribution in order to test one of the key assumptions of the ANOVA model. The p-value of the Shapiro-Wilk test was less than 0.0001, which does not support a normal distribution for the data. Thus, the data at Research/Practice level should not be tested using an ANOVA model for differences in assigned priority. Analysis was then performed using nonparametric statistics, and the resulting z-value of 0.1574 does not support that research or practice are consistently ranked ahead of the other by respondents.

An ANOVA was also performed on the six categories in the translational research model using rating as the response variable, and again the residuals did not support a normal distribution. Nonparametric analysis also again demonstrates that there is not a significant difference in the priority assigned to any of the categories in terms of ranking ahead of others. If an ANOVA would have been appropriate and had resulted in differences between the translational research model categories, then post-hoc tests such as a Tukey-Kramer could be used to determine the location of this difference. The ANOVA is used to test whether there is a difference in means of the explanatory variables in the experiment as a whole, and the post-hoc test would show which explanatory variables (categories) differ from one another. This type of analysis would be valuable in determining whether there is more emphasis placed on certain stages or categories versus others in a group of research projects over time, and could be used as a tool to examine whether a research program is placing appropriate emphasis on different segments of the model.

The analysis thus far supports that there is not a difference in the priority assigned by respondents to the six categories of the translational research model. Next the occurrence data was analyzed to determine if there are differences in the application to the categories in the set of research projects in the sample. To test whether the average occurrence of certain categories is higher than others, an ANOVA was run on the average occurrence score within each category of the translational research model for each interview with aims and outcomes not separated. The Shapiro-Wilk goodness-of-fit test for the Normal Distribution again does not support (p-value 0.0346), and thus the assumptions of the ANOVA model are not met. Analysis using nonparametric statistics does however suggest that certain categories consistently rank ahead of others. The results in Table 6 give no indication as to the size of these differences, but do demonstrate that the average occurrence of translation, implementation, and evaluation is higher than reformulation, investigation, and verification.

Table 6. Nonparametric results on differences between categories

Higher Rank Category	Lower Rank Category	p Value
Verification	Reformulation	0.0002
Translation	Reformulation	0.0006
Translation	Investigation	0.0347
Translation	Verification	0.0203
Implementation	Investigation	0.0018
Implementation	Verification	0.0008
Evaluation	Investigation	0.0001
Evaluation	Verification	<0.0001

**Note*: Analysis was performed using a Steel-Dwass method for all pairs.

Finally the data were tested to determine if the average occurrence of the categories differed within aims and outcomes. The residuals of the data does not reject a Normal Distribution for either data set, as the residuals of average occurrence for aims having a Shapiro-Wilk score of 0.1847 and residuals of the outcomes having a score of 0.1022. The F-ratio of the ANOVA test for project aims was 13.92, and the F-ration for project outcomes was 6.37. The p-values of these tests are both less than 0.0001, and this suggests that, for the data set, there is a significant difference in the average occurrence using "category of the translational research model" as the independent variable.

Post-hoc tests were then performed using the Tukey-Kramer method to determine the location of the differences in the categories. Table 7 displays these results, and can be interpreted that the same letter in the connection column does not connect categories that are significantly different. The results suggest that investigation and verification categories have a higher average occurrence than the implementation and evaluation stages. One possible conclusion for these occurrences is that, for the research program used in this sample, the investigation and verification stages contain a majority of both research aims and outcomes for the pilot projects.

Table 7. Tukey-Kramer method to determine the location of the differences in the categories

	Aims		Outcomes	
Category	Mean Average Occurrence	Connection	Mean Average Occurrence	Connection
Reformulation	0.21	B	0.32	C D
Investigation	0.88	A	0.68	C
Verification	0.9	A	0.7	C
Translation	0.48	B	0.46	C D
Implementation	0.34	B	0.22	D
Evaluation	0.2	B	0.18	D

Larger Themes

On a larger level, basic analysis of the limited sample indicates that, in practice, some parts of a research model occur more frequently than others. While previous safety research project work at RMIT showed that projects were deficient in at least 50% of the cycle, the VT pilot projects seem to suggest occurrence and importance in almost all areas of the model. The VT project aims initially trended towards the research side of the equation, and outcomes later had a higher priority in the practice side. Given these are pilot projects; this trend is to be expected. Further analytical methods reinforce a lack of agreement, by pilot project investigators, as to model areas most populated with aims or outcomes, suggesting a lack of certain areas that could be proposed as critical in nature. Only one pilot project, in fact, was in almost perfect agreement as to model areas that contained aims and outcomes for the work.

Importantly, and due to the dynamic nature of the industry, applied research might consider steps that reinforce the middle (the central, black bar of Figure 1), proposing aims and outcomes that could enable the transition from one side of the model to the other. Findings suggest similar trends in safety pilot research: when proposing projects, academics seem to set aims less in the practice side of the work, but consider it a priority; when stressing outcomes, academics place them more into a category of practice and stress their priority for the work.

The success of approaches that reinforce the middle requires different strategies for different levels, whether considering the project level versus the program level, and could be useful at the organizational level. On a project level, if research is to successfully turn aims into planned outcomes, it seems important to be linear within a dynamic model. For example, it could be strategized that pilot projects would "stay above the line" and contain goals of further research that cross the middle into translation. At the larger project or programmatic level, a dynamic model also helps to differentiate starting points—if one does not start at the same place, he or she does not have to go through the full cycle or show evidence of such aims and outcomes. Such a "middle" strategy could reduce system complexity and increase efficiency. Programmatically, a dynamic modeling strategy might further be useful for assessing program needs and projects that fill gaps in these needs. Grantors could use such a model to gauge breadth in larger bodies of research work. If the mission of an organization is at both levels, such as VT's CICSHR, a need to be linear is evident, but an emphasis of transition across the black line of the model is also needed. From the demand-side of the dynamic model, mapping exercises could align academic research projects with direct industry issues to better foster a relationship between desired research outcomes, industry adoption, and reformulation into new research.

According to these preliminary data, many areas of the translation process are being proposed and executed within the research process. These areas do not seem to be consistent across projects, though, which might suggest the differing nature of the studies within the topic of safety. One hypothesis for further study could be the inappropriateness of models, other than historical linear forms, for evaluating research into practice in the construction industry. Can we draw conclusions (even anecdotally) about why researchers might not follow a linear process?

While this limited set of pilot projects does offer a balanced portfolio, the research team also finds limitations of this research, such as:

- Self-reporting bias—survey participants for this research project were the principle investigators for the corresponding pilot project case; therefore, they were

subject to potential bias based on their personal involvement with the pilot project.
- Sample pool—the Virginia Tech OSHRC GPRP are a set of small projects that have NORA goals for NIOSH, but were not necessarily designed to require outcomes that can be implemented by industry. Rather, they were designed to address specific safety issues in the construction industry with the goal of larger R01 or R21 NIOSH-funded research projects. As well, the sample pool is a convenient data set that facilitated the development of a useful foundation for a methodology developed throughout the course of the research project that can be further developed and utilized by future research on similar topics.

The potential for great, mutually beneficial relationships and interactions between academic research and industry adoption exists. Researchers are actively seeking solutions in various forms, including models of translational research, to improve these interactions. The information in this project is designed to address and potentially support further research in these areas. The methodology developed throughout the project offers a strong foundation to formulating an effective methodology to be used in future academic research for cyclical translational research models applied to safety in the construction industry, and potentially to a wider area of industry.

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