Received: 30 November 2020 | Revised: 28 June 2021 | Accepted: 2 August 2021

DOI: 10.1002/sys.21599

WILEY

REGULAR PAPER

Academics' perception of systems engineering and applied research projects

Evelyn Honoré-Livermore[1] | Knut Robert Fossum[2] | Erik Veitch[3]

[1] Department of Electronic Systems, Norwegian University of Science and Technology, Trondheim, Norway

[2] Centre for Interdisciplinary Research in Space (CIRiS), NTNU Samfunnsforskning, Trondheim, Norway

[3] Department of Design, Norwegian University of Science and Technology, Trondheim, Norway

Correspondence
Evelyn Honoré-Livermore, Department of Electronic Systems, Norwegian University of Science and Technology, Trondheim 7491, Norway.
Email: evelyn.livermore@ntnu.no

Funding information
Norges Forskningsråd, Grant/Award Numbers: 223254, 270959

Abstract

There is an increased complexity in applied research projects that demand more researcher skills, especially in managing the research project and interdisciplinary work. Researchers receive little training in how to manage such projects, yet most manage to deliver project results. There is a tradition of project management and systems engineering which benefits complex development projects in industrial settings. Despite the apparent benefits, we found limited application of either project management or systems engineering practices in academia. Furthermore, we found barriers to applying these practices in the first place, such as a lack of clear guidance or tools for their execution. A case study based on 18 semi-structured interviews provides a perspective on academic research projects, and how the application of project management and systems engineering in an academic setting shows promise to improve the realization of concept design.

KEYWORDS
project management, projects, research, systems engineering

1 | MULTIDISCIPLINARY COMPLEX RESEARCH PROJECTS IN ACADEMIA

Universities and research institutes are increasingly asked to participate in applied research and development activities, sometimes in parallel with basic research; adding *engineering tasks* to their responsibilities in addition to research and education.[1] The motivation for conducting this analysis was to understand how a university executes projects concurrently with research, how academic staff view projects, and what opportunities exist for improving the system to support researchers in balancing the workload of performing in these different roles.

Research activities, especially in technology-related fields, sometimes need advanced infrastructure and multidisciplinary cyber-physical systems. For example, in the field of cybernetics, we observed that much of the prior research was focused on algorithm development and simulation to increase autonomy at some research institutions. Today, there is an increased focus on algorithm development, simulation *and* implementation and testing of these in a sociotechnical setting, for instance on drones or other types of multi-robot systems interacting in society.[2] This complexity creates continuity challenges to pick up the research where a colleague left off and continue pushing the research frontier. In academia, the non-tenured staff is constantly in flux, depending on the research funding structure, resulting in a dynamic research environment. Concurrently, the research activities are funded through *projects*,[1] requiring scientific personnel to act as *project managers* to manage the funding applications, financial reporting, and research tasks. However, not all universities researchers provide training in managing projects or engineering tasks, leading to cost and schedule overruns, or under-delivery. It may also lead to frustration, stress, or conflict within the research teams: challenges for which the *project managers researchers* may not have the training to recognize or remedy.

Industry, such as aerospace, defence, or pharmaceutical companies, is structured to do project work with the needed personnel, training, processes, standards, supplier chains, workshops, and other support systems in place. Naturally, the industry faces its own set of challenges, suggesting that there may be opportunities for learning between the two areas. Like Google, Tesla, or SpaceX, some companies do research and development and deliver cutting-edge products and services simultaneously, often while working together with universities to push the research frontier.[3] Distinctions between university and industrial research projects may be explained by known challenges of combining efficient resource management with high-level exploratory knowledge work[4–6] and differences in established norms, ideals and identities characteristic of the academic researchers and their scientific practice. Such distinctions support the motivation for studying the structure and systems associated with Systems Engineering (SE) and Project Management (PM) in academia and research institutions.

The importance of the coordination and integration of SE and PM tasks and roles has gained attention recently. The recognition of overlapping artifacts, tasks, processes, and responsibilities such as *risk management*, *planning*, *configuration management*, *data management*, *assessment*, *customer interaction*, and *decision analysis*[7–9] has been shown to increase the probability of success of project results for cost, technical aspects, and schedule performance.[10–13] Similarly, if tailored to the situation, for example, collaborative research projects, existing PM knowledge can reduce the time required to learn-by-doing and draw from the various benefits of a professional and targeted project manager.[14] While PM is traditionally concerned with cost, schedule, and scope aspects, and SE with the product aspect, these are not necessarily easy to separate. Studies suggest that coordinating SE and PM will benefit most types of projects and organizations.[15]

Observations gathered during action research of involving two case studies, where researchers had to balance engineering, management, education, and research tasks, without much formal training in SE or PM, suggested a research focus and the questions we sought to address were as follows:

- **RQ-1**: How can an engineering project ensure the fulfillment of academic research goals (in a university setting)?
- **RQ-2**: How can engineering goals and individual research goals be fulfilled simultaneously?
- **RQ-3**: How do researchers understand SE and PM?

To address these research questions, we examined two groups working on externally funded projects to develop space technology. The data collected is based on 18 semi-structured interviews of between 45 and 60 min.

This paper is structured as follows: In Section 2, we describe SE and the differing perspectives of hard and soft systems. Following that, we describe what a research project and process are, and an introduction to the integration of SE and PM. In Section 3, we outline the research methodology and analysis method applied. Next, we report on the results in Section 4, and discuss what this means for research projects in Section 5. Finally, this paper concludes with a set of additional questions for the organization of future research projects.

2 | BACKGROUND

A research organization is a sociotechnical system developing the *engineered* systems. This sociotechnical system needs to be analyzed and understood so that we can improve the way we develop systems. In this section, we outline SE and sociotechnical research. We then describe the integration of SE and PM, since these fields offer heuristics for managing complex projects. Finally, we introduce applied research projects and their role in academia.

2.1 | Systems engineering

SE is concerned with understanding the needs of the stakeholders and the context of the problem and determining how to meet those needs with a system or product throughout its useful life.[16] SE emerged as a discipline during the Apollo program, where it became clear that the current working practices were not adequate to manage the complexity of putting a man on the moon and returning him back safely.[17] The discipline and practices have evolved and been refined, but the essence remains the same.

SE can be viewed as a methodology; a set of methods and tools, and a process. There is also an International Standards Organization (ISO) standard 15288 documenting and describing the underlying processes that typically make up a system life cycle.[18] This paper adopts the International Council of Systems Engineering (INCOSE) definition because it is widely recognized and includes relevant keywords such as stakeholder needs, requirements, verification and validation:[16]

> A transdiciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods.

In *applied research*, the focus is often on transdisciplinary research.[1] For the projects studied in this paper, this research focused on a complex System of Systems (SoS). The definition of SoS adopted here:[19]

> A System-of-Systems is a collection of systems that maintain their operational and managerial independence.

To develop complex systems, we need people, processes, and supporting systems: also called a *sociotechnical* system or organization. A sociotechnical system can be described as a system that contains the subsystems *people* and *processes*, and the *methods*, *facilities*, and *equipment*, as shown in Figure 1. Organizational real-world systems are complex and messy[20] and cannot be analyzed in the same way as physical systems.[21–23]

Winter and Checkland[22] suggest the need for two viewpoints, *hard* and *soft*, each providing a contrasting image of managing projects. According to Crawford and Pollack,[24] there is some confusion between

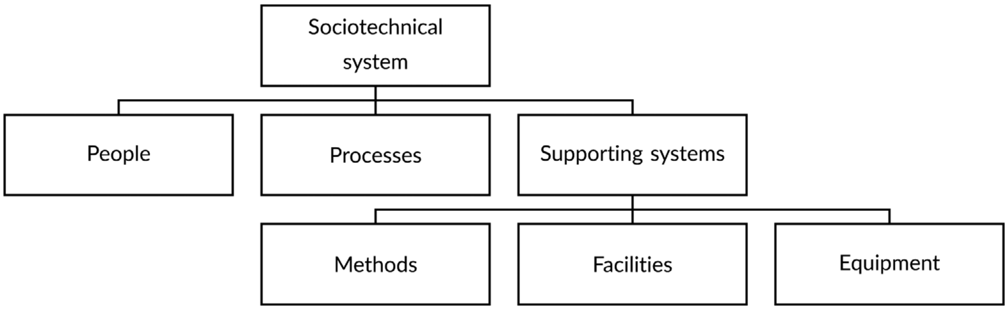

FIGURE 1 The sociotechnical system adapted from Pajarek[21]

the hard and soft paradigms in PM. The hard paradigm is philosophically grounded in positivism and realism, while the soft paradigm is grounded in interpretivism and the constructivist epistemology.[24] Furthermore, the hard paradigm is often associated with a linear approach to problem solving and management to realize the goal and manage the project life cycle. In contrast, in the soft paradigm viewpoint to project management, the manager is continuously observing and evaluating the situation, and can make a choice to take action to improve or change the project.[22] This does not mean that the hard paradigm cannot take an iterative approach to problem solving, but the goals and the approach to achieving the goals are known and planned. Hard systems thinking aspires to about "an efficient means to achieve a predefined and agreed end,[25]" while soft systems thinking methods are based on "interactive and participatory approaches to assist groups of diverse participants to alleviate a complex, problematic situation of common interest.[25]"

Some have claimed that SE employs "common sense" principles[26–28] and others suggest its value may be underestimated and its benefits underrepresented in the literature. There have been efforts,[29] most notably by Honour[12,30] and Boehm et al.[31] to quantitatively measure the benefits of SE activities in projects. Honour[12] found an optimal level of SE activities in a project of 15%–20% of the total effort. However, this was a limited study with self-reporting primarily by systems engineers and their individual perceptions. This study was continued and in Honour,[30] the aspects of technical quality and program success concerning SE activities were discussed.

Furthermore, a division of effort to the different SE activities of: *mission definition*, *requirements engineering*, *system architecting*, *system implementation*, *technical analysis*, *technical management*, *scope management* and *verification and validation* was suggested, where verification and validation clearly came out as the prime benefactors of SE activities.[30] Boehm et al.[31] looked at software projects and measured the Return on Investment of applying SE. They found a relationship between SE activities and software productivity, and that even minimal SE efforts would increase the project productivity significantly.[31] Cook and Wilson[27] describe which types of activities yield the most significant value in a project's life cycle, and how the advent of Model-Based Systems Engineering (MBSE) may bring added further value to projects and may be more easily linked to traditional engineering activities. They also touch on what is necessary to have a *good* SE environment, such as clear and shared objectives, a common model of system and worldview, an understanding of the process, and a stable environment and context in which the system is developed and deployed.[27] Even so, there are obstacles and barriers to introducing SE in any organization. Some organizations believe that using SE *processes* may hinder creativity because they associate the process with a prescriptive, detailed, flow-diagram approach which forces your work process.[32] Sheard et al.[32] continue to list other barriers such as: poor definition or understanding of SE, applying SE without a specific purpose, and lack of resources.

2.2 | Integration of project management and systems engineering

The systems developed in the past decades are more complex and require a higher level of coordinated engineering and management.[33] INCOSE, the Project Management Institute (PMI) and the Massachusetts Institute of Technology (MIT) established an alliance team in 2011 to analyze the integration of SE and PM, based on the recognition that these roles have overlapping and complementary responsibilities. Both are concerned with running a project and delivering a system that satisfies the needs of their stakeholders. Separately, INCOSE produces the SE Handbook which includes processes and guidelines for managing a system life cycle, and the PM Body of Knowledge (PMBOK) does the same for project management processes. We apply the PMBOK definition for Project Management:[34]

> Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.

An early study from industry recognized that through their shared concern of meeting a customer's needs, SE and PM should be integrated both by functional decomposition and by practical integration[35] and suggests that teamwork is the key to making it successful. Roe[36] discusses the integration of PM and SE in an Integrated Product Development setting. Smith and van Gaasbeek[37] use the analogy of the DNA double helix to represent an inherent need for integration of the two for project success. Johnson[38] discusses the history of, and similarities and differences between, PM, SE, and Operations Research. Other research suggests that sharing a common language and understanding of responsibilities is necessary to make the integration work.[39–41] Xue et al.[42,43] describe a practical case of applying integrated SE and PM to a student engineering project. They introduced a framework to support the tailoring and application of such activities and showed its utility. Traditional PM has been criticized for restricting innovation and creativity[44,45] because of its strict processes require detailed planning and scoping before starting the project. For innovation and product development, it may not be possible to plan to the level of detail needed by these guidelines, and, may restrict the solution space alternatives. The terms *research* and *innovation* may be used interchangeably in product development, but the terms may have different implications depending on how the end goals are framed or expressed. The *agile* project management approach is grounded in enabling the ability to respond to changing circumstances and new discoveries. It also means empowering the whole project organization to participate in making decisions, instead of relying on the project manager to decide the scope and team activities. There will still be project management activities, but the top-down hierarchical chain-of-command is replaced, reducing some of the asymmetry between power and influence over work. Simultaneously, agile project management is not equal to the absence of management,[46] but rather a shared team leadership and management.[44]

However, it is rare to receive training in both SE and PM, as they are typically separated in academic or training environments. Cohen et al.[47] piloted a training simulator for systems engineers to learn PM in their graduate studies. They concluded that simulations help build the practical understanding[35] needed, and that further scenarios should be developed for training as well as comparing with real-life situations.[47] Baron and Daniel-Allegro[48] provide the results from an online course for improving systems thinking through embedded systems projects. This proved helpful for the students participating. The authors highlighted the outreach potential of online courses and the possibility for distance learning. Furthermore, training in PM relevant to research projects is lacking.[6] There is also a need for hands-on training and a good understanding of the field in which the projects are executed.

2.3 | Applied research projects

Academic research activities are increasingly project-based and applied.[1,6] Applied research projects are linked to *Mode 2* research which includes "collaborative and transdisciplinary research, greater heterogeneity in the sites of knowledge production, deeper social accountability and broader forms of quality control."[1, p. 690]

In comparison, basic research is focused on "advancing knowledge for its own sake."[1, p. 690]

An observation that motivated the research questions was of doctoral researchers who balance researching remote sensing and engineering tasks. When building a satellite, there are many engineering tasks such as circuit board layout, mechanical design, physical integration, vibration and shock testing — all of which are everyday in the industry. They do not necessarily yield research data for publication in remote sensing journals. However, since the satellite is the foundation for the remote sensing system, it needs to be engineered and built to deliver data. In this situation, the doctoral researcher must manage their tight schedule to deliver both engineering product and research results. At the same time, one can argue that the problem with this example is poor project planning, and that the university should have taken engineering tasks into account from the start of this research project. A more informed assessment during the application phase could anticipate these needs and plan for them. This suggests the importance of involving the broadest set of disciplines in the proposal writing and work-package definition phases.

Fowler, Lindahl and Skjöld[6] discuss the application of PM in universities based on an empirical study. Traditional PM was developed for the linear execution of pre-defined tasks/goals, countering the iterative research and knowledge-building trajectory. They found that with the projectification of research projects through funding mechanisms, researchers "indeed feel compelled to appropriate and use PM to become viable for funding.".[6, p. 11]

In the article, the interviewees discussed the concept of project start and end in the context of research. It is essentially a continuous effort that does not have a clear start and end, except within the context of individually funded projects or assignments. The authors also found that there is a separation between the project leader and the project manager, where PhD and post-doc candidates are often given the more practical and administrative tasks in a research project. Finally, they list barriers to implementing PM: (1) PM requirements in projects "have little relevance for how the research should in fact be carried out,"[6, p. 25] (2) projectifying the administration separately from the research work, and (3), division of labor between researchers and project administrators (who technically have the role of researcher but end up being responsible for the PM tasks.)

2.4 | SE and PM for applied research projects

The role of SE and PM in applied research projects is not well-defined. SE and PM practices are documented through their processes, such as in ISO standards, and these are commonly authored by industry practitioners. Research processes may not be communicated in the same way. Still, most researchers follow a simple workflow, as shown in Figure 2, and scholars can find guidelines[49,50] on how to run a research project and suggestions for qualitative or quantitative methods.[51]

However, given the definitions provided in the earlier sections and the description of SE and PM roles in the SEBoK[16] and PMBOK,[34] there are qualities that researchers could aspire to apply to managing their projects. For example, using data-driven decision-making; applying holistic thinking; defining lifecycle processes; project planning, monitoring, and controlling; demonstrate end-user awareness and stakeholder analysis; continuous development; teamwork; managing technical and project risk.

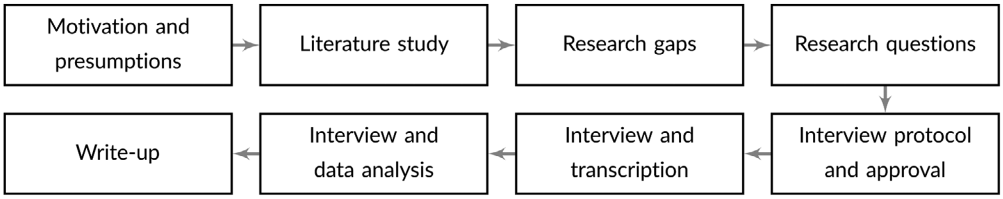

FIGURE 2 The research method applied

3 | RESEARCH METHODOLOGY

3.1 | Study method

The research is based on a qualitative case study, and follows a workflow shown in Figure 2. The data sources include a literature review to substantiate the knowledge gap and semi-structured interviews of between 45–60 minutes of 18 participants. The participants were selected based on their involvement in space projects in two university-based institutions: using a *key informant sampling* method.[52] The key informant sampling method was chosen to collect in-depth information relevant to the research questions, with a mix of people representing different roles within their respective projects. The informants perform research based on space knowledge and are also responsible for technology development, and practice applied research.[1] Half of the informants (9) are employed by a research institute, and the other half are members of various departments within the faculty of engineering at a public university. The informants all have a MSc degree, and most have PhD degrees. The organizations are in the same city and can be considered to be influenced by Scandinavian socio-cultural norms.

In the academic organization, there was an effort to introduce more SE both into the curriculum (by introducing systems engineering classes in 1st, 4th, and 5th year courses), and in faculty membership (hiring of one adjunct professor and one associate professor in SE). The results of these efforts were not clear at the time of the study, except that more people knew of the SE concept and had heard the term previously.

3.2 | Interview and data analysis

The interview protocol was based on the research question developed through an iterative process using relevant literature. A semi-structured interview format was chosen for a natural flow of a dialogue and allowed the interviewer to ask additional questions, if needed.[53] Introductory questions such as "Tell me a little about your background." or "What educational background do you have?" started each interview to help the informant relax and build rapport. The questions were posed in a combination of descriptive, ("How would you describe the research process?") and reflexive, ("What would you say are the benefits and challenges of systems engineering?") questions. All interviews were carried out face-to-face and recorded, and the interviewer took notes in case the recording was lost. A single researcher acted as the primary interviewer for all informants, while the second researcher listened and asked additional questions if needed at the end. The third researcher did not participate in the interviews, and only analyzed the transcriptions. The questions were available in two languages, and interviews were transcribed in their original language, either English or Norwegian. The informants were anonymized prior to analysis, and only the interviewer had the key to match the informant to a transcript.

An interview analysis protocol was based on Likert-scales of 1–5 (1 = to a low degree; 5 = to a high degree), with different statements the researcher would evaluate, given in Table 5. The interviews were analyzed independently by three researchers to provide triangulation on the results. The statements were based on the research questions, in addition to an evaluation of to which degree the informant had an engineering, educational, or research stance. The assessment of stance was based on how the informants identified themselves (for example if they said they were engineers, or if they said their primary role was as a lecturer), and what types of tasks they said they did in their jobs. The first round of analysis took place over the course of ten weeks, where the researchers independently evaluated the statements based on the interpretation of the transcripts. After that, the researchers met and discussed the results and explored the differences in rating where applicable. Finally, a score, S_x, was assigned to each statement based on the median of the researchers' scores. A median was chosen because it gives a measure of central tendency based on the rank of the score, appropriate for the non-continuous nature of Likert scales data. The Likert scale was further compacted to three levels: *low* for levels 1–2, *neutral* for level 3, and *positive* for levels 4–5 to enable more accessible discussion of results.

Spearman's ρ correlation coefficient was used to measure the relationships between Likert scale scores assigned to the fourteen protocol categories. The equation is given in Equation 1.

$$\rho = 1 - \frac{6\sum d^2}{n(n^2-1)} \tag{1}$$

where d is the difference between the ranks of the median Likert scores, and n is the number of questions. We also calculated the *p-value* for each ρ-value to signify statistical significance at the $\alpha = 0.05$ level. The coefficient measures the tendency for ranked values to change together. A so-called monotone relationship has a value between -1 and $+1$, where -1 is perfect negative monotonic, 0 is no monotone, and $+1$ is perfect positive monotonic. A perfect positive monotonic means that all data points in X increase as Y increases, and a perfect negative monotonic means X decreases as Y increases.

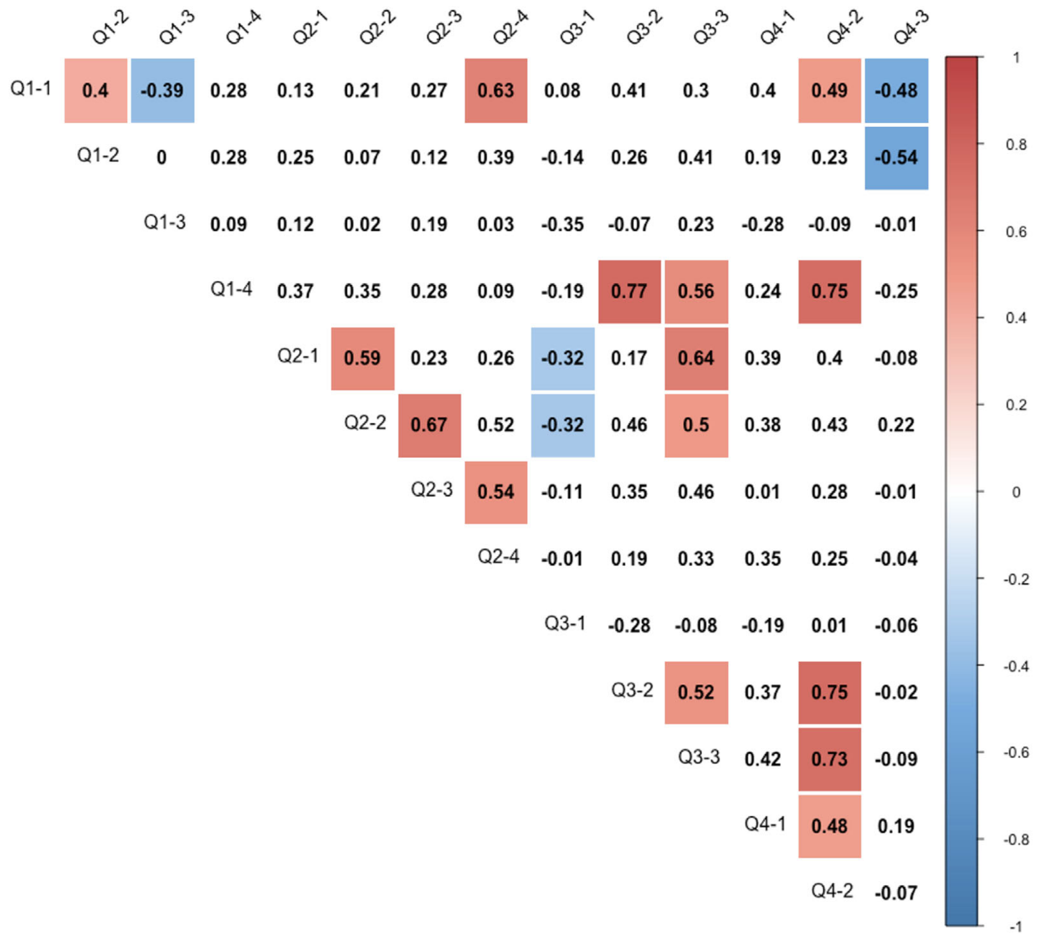

FIGURE 3 Correlation matrix of statements. The colored elements have a p-value larger than 0.05 (significant correlation)

3.3 | Validity and reliability

Lincoln and Guba[54,55] introduced four criteria for research trustworthiness commonly applied among social science researchers to sensitize reliability and validity to the specific nature of qualitative research: dependability, credibility, transferability and confirmability. The terms reliability and validity have by some been considered unsuitable for qualitative research[56,57] while others[58] use these terms but include several recommendations, including triangulation for enhancing quality. Triangulation is defined as "The use of more than one method or source of data in the study of a social phenomenon so that findings may be cross-checked."[57, p. 392]

The term also applies when multiple observers are employed to overcome the weakness or intrinsic biases and the problems that arise from a single observer, as done in this study.

The trustworthiness of the research presented here is ensured by addressing both the dependability (reliability), credibility (internal validity), transferability (external validity), and confirmability (construct validity) in the research design and data collection.[56] The triangulation strategy implemented improves the credibility and dependability of the case study research, i.e. data source (literature and a case study), data type (interviews and interview analysis), theory (PM and SE perspectives) and researcher triangulation of both theory and in the interview analysis. By addressing transferability similar to generalization, the study considers the extent to which the findings can be analytically generalized to other institutions or situations.

Confirmability refers to the extent to which others can confirm the findings, i.e. the reproducibility of the research. The confirmability of the study is obtained employing accurate and objective account of the concept under study, the research problem, case studies, research approach and the construct under investigation. However, given the inherent weaknesses of qualitative research methods and that most social settings are contextually unique, the authors acknowledge some limitations regarding construct validity. The impact of these limitations on the interpretation of results and conclusions are discussed in Section 5.

4 | RESEARCH FINDINGS

In this section we present the main findings from the interview analysis and quotes from the interviews that address the research questions.

TABLE 1 Statements used to guide the researcher assessment of interviews. Q1-Q4 were evaluated on a Likert scale

ID	Topic	Relevant to RQ no.
Q1	Understand the academic stance of the Informant	
Q1-1	To what extent does the Informant hold a research stance?	
Q1-2	To what extent does the Informant hold an educational stance?	
Q1-3	To what extent does the Informant hold an engineering stance?	
Q1-4	To what extent does the Informant understand systems engineering?	RQ3
Q2	Understand the stance/definition/explanations of project, process, task, and goals. Understand how the Informant balances between processes and goals	
Q2-1	To what extent does the Informant distinguish between engineering project and research project?	RQ1,RQ2
Q2-2	To what extent does the Informant distinguish between the engineering process and research process?	RQ1,RQ2
Q2-3	To what extent does the Informant distinguish between engineering tasks and research tasks?	RQ1,RQ2
Q2-4	To what extent does the Informant distinguish between research goals and engineering goals?	RQ1,RQ2
Q3	Understand if systems engineering could contribute towards research processes and goals	
Q3-1	To what extent does the Informant believe that SE is integrated in academia?	RQ3
Q3-2	To what extent does the Informant believe that SE should be integrated in academia?	RQ3
Q3-3	To what extent does the Informant believe that SE could be integrated in academia?	RQ3
Q4	Understand the stance on different types of management	
Q4-1	To what extent does the Informant distinguish between research and engineering management?	RQ2
Q4-2	To what extent does the Informant distinguish between research and project management?	RQ2
Q4-3	To what extent does the Informant distinguish between project and engineering management?	RQ2
Open-answer questions for the analysis		
Q5	What are the greatest benefits of systems engineering?	RQ3
Q6	What are the most challenging aspects of systems engineering?	RQ3
Q7	What, if anything, separates an engineering project from a research project?	RQ1,RQ2
Q8	What, if anything, would be the benefits of more knowledge/support to project and engineering processes in academia?	RQ1
Q9	To what degree did the SE course influence the Informant? What thoughts does the Informant have about the course?	

Notes: Q5-Q9 were open-ended questions that were evaluated based on overall impression and direct quotes from the interview transcripts.

The quotes have been translated from Norwegian to English by the authors. The correlation coefficient results of the interview analysis are given in Figure 3. The relationships which have a lower *p*-value than 0.05 are highlighted in the matrix with a background color. Some correlate with the literature but were not directly analyzed by the statements in Table 1. The main statistical correlations were: (1) Opinion on the integration of SE in academia is linked to the understanding of SE; (2) There is a perceived distinction between research and project management; and (3) The variety in goals and tasks distinguish research and engineering.

4.1 | Tabulated results

Tables 2, 3, and 4 list the data from the interview analysis on Table 1 questions, the counted informants per Likert level (1–5), and compacted counted informants per categorized (low–neutral–positive) Likert level.

Infromants may have a combination of stances (Q1-1 to Q1-3), and 13 of 18 had a research stance, 5 of 18 had an educational stance, 11 of 18 had an engineering stance, see Figure 4 for a mapping of stances.

4.2 | Main findings

4.2.1 | Opinion on integration of SE in academia is linked to understanding of SE

All informants were asked to state their understanding of systems engineering and were encouraged to reflect on what it meant for them and whether it had a place in research and academia. A typical answer that resulted in a high score is when many of the keywords given in Section 2 are included.

> "SE is everything related to systems. From you have an idea until you have an existing technology and you need

TABLE 2 Median score results of interview analysis based on Likert scale of 1–5

Informant no.	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Q1-1	1	5	4	4	4	3	2	4	2	4	5	5	5	5	4	1	5	5
Q1-2	2	3	4	1	1	1	1	1	3	3	5	3	2	4	4	3	5	2
Q1-3	5	2	5	2	2	5	4	2	4	4	1	4	3	4	2	4	4	4
Q1-4	3	2	4	4	4	4	2	1	3	4	4	2	4	5	4	4	4	5
Q2-1	4	4	4	4	2	4	4	3	3	4	5	2	4	4	3	4	4	5
Q2-2	4	4	4	5	3	4	4	3	3	5	4	3	4	4	4	2	4	4
Q2-3	4	4	4	4	3	3	4	3	3	4	2	3	4	5	4	2	4	4
Q2-4	4	5	4	4	3	3	4	3	3	5	4	5	4	4	4	3	5	5
Q3-1	2	2	1	2	2	1	2	3	3	2	2	2	2	2	2	2	2	3
Q3-2	3	3	4	4	5	4	3	3	3	5	4	3	4	5	4	3	5	4
Q3-3	4	3	4	3	3	3	3	3	3	4	4	2	4	4	3	3	4	4
Q4-1	3	4	5	4	4	3	3	3	3	4	5	3	4	2	3	3	4	4
Q4-2	3	2	4	4	4	3	3	3	3	5	5	3	5	5	3	3	4	5
Q4-3	5	3	3	4	5	3	4	3	3	4	3	3	3	1	3	3	3	3

TABLE 3 Counted tabulated results of interview analysis based on Likert scale

Likert score	Q1-1	Q1-2	Q1-3	Q1-4	Q2-1	Q2-2	Q2-3	Q2-4	Q3-1	Q3-2	Q3-3	Q4-1	Q4-2	Q4-3
1	2	5	1	1	0	0	0	0	2	0	0	0	0	1
2	2	3	5	3	2	1	2	0	13	0	1	1	1	0
3	1	5	1	2	3	4	5	5	3	7	9	8	8	12
4	6	3	8	10	12	11	10	8	0	7	8	7	4	3
5	7	2	3	2	1	2	1	5	0	4	0	2	5	2

> to connect to it. You need to write and specify this system. You need to write requirements' definitions. (…) And you have different types of diagrams, context diagrams, class diagrams…that you use to describe your system. And then you need to be able to document it. And plan how to test and verify and validate it. And you need to understand the regulations. And quality systems. You need to have an understanding of electronics, mechanics, how things are linked together. (…) You need to understand the context of what you're working on [Informant 15]."

Understanding of SE (Q1-4) was positively correlated with (Q3-2) believing that SE should be integrated in academia ($\rho = 0.77$, $p = 0.00021$), and with (Q3-3) believing it could be integrated ($\rho = 0.56$, $p = 0.015$). Having an understanding of SE (Q1-4) also correlated positively with (Q4-2) differentiating between research and project management ($\rho = 0.74$, $p = 0.00037$). According to Table 3, only four informants were scored low or neutral on the understanding of SE (Q1-4), shown in Figure 5. We found no relationship between stance (Q1-1, Q1-2, Q1-3) and understanding of SE (Q1-4).

The informants noted that to them, SE was common sense and recognized the SE processes from how they already worked. Furthermore, that having implicit knowledge and applying "common sense" processes and principles may be challenging when there is a personnel turnover.

> "I feel like we have it already. We do not talk about it in the formal way, we just do as we always have done. At a certain level I feel like we have those processes

TABLE 4 Compacted counted tabulated results of interview analysis based on categorized Likert scale

Likert score	Q1-1	Q1-2	Q1-3	Q1-4	Q2-1	Q2-2	Q2-3	Q2-4	Q3-1	Q3-2	Q3-3	Q4-1	Q4-2	Q4-3
1–2 (not)	4	8	6	4	2	1	2	0	15	0	1	1	1	1
3 (neutral)	1	5	1	2	3	4	5	5	3	7	9	8	8	12
4–5 (positive)	13	5	11	12	13	13	11	13	0	11	8	9	9	5

TABLE 5 Comparison of the linear, agile, and research development environment

	From Paluch et al.[62]		Research findings	
Characteristics	**Linear development**	**Agile development**	**Applied research**	**Engineering**
Solution space	Solution space defined.	Solution space undefined.	Solution space undefined. Theoretical grounding.	Solution space and boundary conditions defined.
Customer	Stable and known customer preferences. Limited customer willingness to interact. Customer in need of fully specified product.	Changing and/or unknown customer preferences. High customer willingness to interact. Customer open to engage with interim products.	Changing research community interests. High willingness to review. Research community open to contribute to products.	End-users are typically known. Stable and known preferences.
Task	Low task modularity.	High task modularity.	High individual research modularity. Managing researchers and research projects. Applying for research funding. Explore deep into the topic and develop knowledge.	Implementing the details. Integrating systems. Make a product quickly.
Goal	Well-defined and agreed-upon goals.	Open and agreed upon goals.	Open goals, not well-defined. Creating knowledge for a better world. Answering research questions.	Known, defined goals. Solving a problem. Product delivery.
Process	Well-defined and standardized process.	Adaptive process models. Continuous integration, test-driven.	Weakly defined, but highly adaptive process. Highly learning-focused process. Known and declared methods in some fields.	Strict processes with higher maturity projects. Less strict with low-maturity projects.
Organizational	Low tolerance for interim failure. Strong need for managerial control.	High tolerance for interim failure. Weak need for managerial control. Shared ownership.	Weak need for managerial control. High tolerance for interim failure. High acceptance for individuality.	Need control in large companies, not necessary for smaller.

Notes: The linear and agile development columns are from Paluch et al.[62] while the Applied research and engineering columns are based on the findings of the case studies.

already. Without thinking over what it means or explicitly describing them. (…) That might be the challenge today, to onboard (…) and transfer the knowledge. We who have worked a couple of years have lots of implicit knowledge, which we don't think about in the daily work, but just do. New people need to be trained in the routines and the way of working. They may have similar experience from other employers, so they are probably not strangers to the way of working. But maybe not with the same vocabulary [Informant 17]."

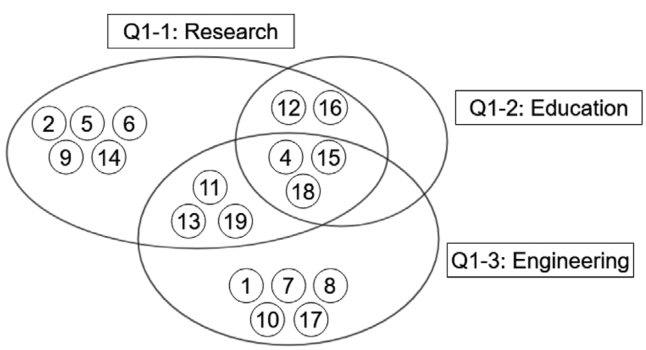

FIGURE 4 Venn diagram of informants and stances

4.2.2 | Distinction between research and project management

There was a significant positive correlation between the informants (Q1-1) holding a research stance and (Q4-2) differentiating between research and project management ($\rho = 0.49$, $p = 0.0040$). However, there was a significant negative correlation between the informants (Q1-1) holding a research stance and (Q4-3) differentiating between project and engineering management ($\rho = -0.48$, $p = 0.0043$). Similarly, there was a significant negative correlation between the informants (Q1-2) holding an educational

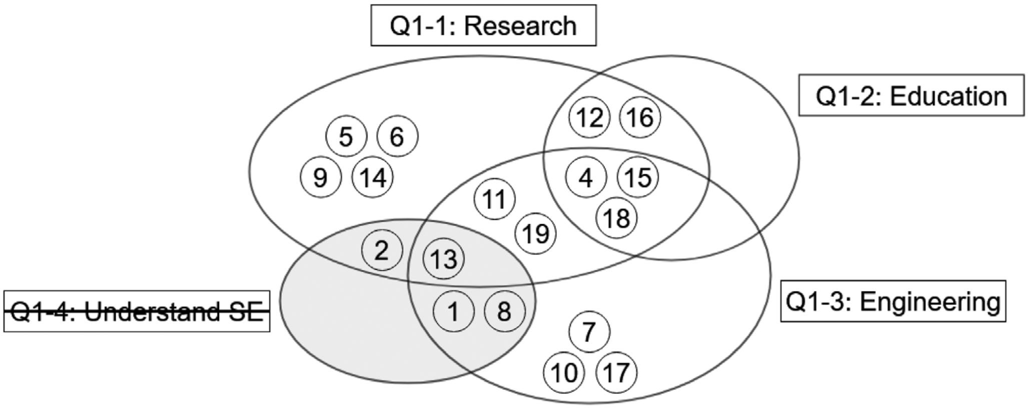

FIGURE 5 Venn diagram of informants' stances, and indicating which were perceived to not understand SE (gray circle)

stance and (Q4-3) differentiating between project and engineering management ($\rho = -0.54$, $p = 0.0022$). Some informants explained engineering management in the same way they described project management, with a clear end-goal and schedules and boundary conditions. The informants' stated that in practice, in academia, engineering projects are run more like projects traditionally are run, where the scope and requirements are agreed upon beforehand.

Three types of projects in academia were described by some of the informants: the education of doctoral students, the actual research projects from when funding arrives until the end of funding, and the continuous project of determining how to push and contribute to the research front. These projects have different time scales and needs, and should be managed differently. Additionally, each instance of these projects needs tailoring to support the specific project objectives. For example, two doctoral students may have very different plans in terms of laboratory equipment and experiments, or active supervision needs. However, both doctoral students have to complete coursework, submit research articles, and defend their thesis on time, and as such the project follows a pattern with known objectives.

4.2.3 | The goals and tasks distinguish research and engineering

The informants were asked to compare research and engineering in terms of tasks, projects, goals, and processes. There were positive correlations between the informants who differentiated between (Q2-4) research and (Q2-2) engineering goals with engineering and research processes ($\rho = 0.52$, $p = 0.027$), and with (Q2-3) engineering and research tasks ($\rho = 0.54$, $p = 0.022$). There was a positive correlation between the informants holding a (Q1-1) research stance and (Q2-4) differentiating between research and engineering goals ($\rho = 0.63$, $p = 0.005348$).

The informants were asked to describe the engineering and research process. Many of the informants related the process to the end goal and end product, and did not elaborate on the procedure or process used. Most of the informants stated that there were not clear guidelines for processes or methods for managing projects at the university.

Researchers have been asked to do engineering tasks, which may or may not contribute to publishable research results. There were different opinions on whether or not researchers should do these in order to produce answers to the research questions. On the one hand, to fully understand the measurements you are producing, you should fully understand the instruments that provide the measurements. On the other hand, if all researchers should understand their instruments or infrastructure fully, it would take too long to push the research frontier.

> "When you say research project I think basic research. While when you say engineering I think something needs to be developed because there is a specific task, you are developing equipment for a function. Both use a scientific approach. You have a hypothesis which needs testing, and you evaluate the results in the end [Informant 17]."

> "If you as a physicist are doing an experiment where you need electronics. You are doing the research. While the person making the electronics is just making the electronics. Pushing the boundaries for electronics for making an instrument, I don't view that as research. (…) Incremental development, which instruments exist or what they measure or which measurement electronics are incremental research. I am hesitant to say that it's research [Informant 1]."

> "To me, if you cannot build your infrastructure you cannot use it. I don't consider it engineering. It is a natural part of being a researcher. (…) For maximum performance you have to know everything about your lab and you can only do that by being hands-on. (…) Standard maintenance is a part of the social research context. I actually consider that all doctoral researchers shall contribute with some sort of technology for the lab [Informant 12]."

4.3 | Other findings

4.3.1 | Perceptions on management

In terms of what constitutes good management, although not asked explicitly, some of the informants discussed positive experiences of management and their experiences with management at the university. Informants also described how "too stiff" or "too strict" management could hinder the progress.

> "Iterative discussions. Have short and frequent meetings, try not to plan too large increments between the milestones — make them smaller to give people a chance to come up with ideas and concepts. Evaluate them strictly but keep the ideas coming and in the knowledge base. (…) So I think you could call it lean. That you try to develop things as time moves ahead, and that you're not too rigid with the specification [Informant 4]."

> "I believe in the cooperation between the technical system manager with the project manager. (…) If you can get a good symbiosis between those who can run and manage the project, and those who works with and understand the architecture well. (…) Good people chemistry and workflow. You need dynamic people in both roles who don't care too much about rigidity and hierarchy. (…) You need to be relaxed and with the mindset of helping each other. Of course you need specific role definitions as you move up in the organization, but I think if it gets too stiff it stops working. I also think it has a lot to do with personalities. [Informant 4]"

There was an agreement that universities were not structured for running projects as viewed from an engineering perspective. However, there are administrative support functions, and guidelines and support for preparing funding applications.

> "There has been little support from the university for the execution of the project. We have gotten rooms and areas, and the scientific employees are available to answer questions. But you have to figure things out yourself. (…) There is no template for how you run a project. But you might not want one to exist either [Informant 1]."

4.3.2 | Processes can hinder creativity and require resources

The informants were asked to discuss what they saw as challenges or negative sides of having SE or PM processes in research. Some of the informants mentioned how strict processes might hinder creativity. Another challenge was that implementing processes and training people is costly and may be challenging to show the Return on Investment of such efforts.

> "It [SE] should not be a straitjacket that limits the craziness in your ideas. But some understanding of how the world works is good [Informant 15]."

> "For small companies and small projects it is not possible to apply the full systems engineering process. The question is how to find the right balance. How do we develop or find the tools that suit our processes and capabilities. I think that is the work that needs to be done. (…) We would definitely benefit from the systems engineering way of thinking in the Research & Development and European Space Agency (ESA) projects [Informant 6]."

4.3.3 | SE gives a holistic overview and structure to applied research projects

In the interviews, the informants were asked to reflect upon what they saw as benefits to having more SE in their research environment. A repeating theme revolved around having enough people and resources to do the activities and enough knowledgeable people to do them. For the projects with explicit resources allocated to either PM or SE, informants saw clear benefits. For the projects with no explicit resources, but with thoughts of using the practices, it was difficult to see a clear connection between resource use and utility. Finally, sometimes the projects have just the right people with the knowledge to introduce and use the practices in the right way.

> "Everyone working in research that is to be applied, infrastructure, platforms, can benefit from [SE] [Informant 15]."

> "Holistic thinking puts things in perspective. Within signal processing, we try to make something *epsilon better*. In a communication system we have many algorithms in a pipeline, each epsilon better — but the system may not be better as a whole because the epsilons cancel each other out. And then you've written 5 articles about something that doesn't help anything, except feeding academics [Informant 18]."

> "I feel like systems engineering is a good tool to get a holistic picture and ensure that things flow together and that everyone contributes, or at least that they can

contribute. In the right order. Piece together the good puzzle it should be in the end [Informant 17]."

5 | DISCUSSION

During the course of this case study it became clear that with the increased challenges of complex systems, there is a need to enable researchers to manage applied research projects concurrently with other university duties. There is not a clear distinction between research and engineering tasks, and it is challenging for researchers to have the resources and time needed to manage the complex technical infrastructure requiring to perform research activities. The perception of academics on SE and PM for applied research projects, and the distinction between research and engineering, are the key contributions of this paper.

5.1 | Implications

The goals of the work performed in many cases may be used to distinguish between engineering and applied research,[59] while keeping in mind that the source of the goals (individual scientist? Society? End-user?) matters. According to Niiniluoto,[59] "the knowledge provided by applied science is expected to have *instrumental value* for the associated human activity."[59, p. 6]

However, Niiniluoto also argues that a practitioner of applied science (or research) using knowledge gained to solve a problem, is not doing science. Stuart[60] suggests several methods for different areas of applied research to provide the needed end product, from the viewpoint of engineering design, and comments on how research in applied science can contribute to satisfying societal needs. In the field of artificial intelligence, early work was published through application studies, which "could uncover deficiencies in the current body of scientific knowledge."[61, p. 128]

However, as the field has matured, topics published 20 years ago could be considered engineering today, and not research because it is practiced in industrial settings.

Some of the informants' impressions support taking a soft and sociotechnical viewpoint to management analysis in academia.[21,22] Supervising researchers (such as PhD or PostDoc) requires interpersonal skills, and needs tailoring depending on the specific research project. The informants highlighted flexibility, and agility, confirming some of the literature on good management.[8,22,46] Managing applied research projects also requires a soft approach,[22] based on the complexity of the project that includes multidisciplinary people and components. The research process can be considered a "messy real-life situation," which cannot be planned and detailed ahead of time, and the goals (apart from contributing to the knowledge frontier) keep changing.

The study presented in this paper contributes to the discourse on the demarcation between engineering and applied research, by offering different perspectives from academics mainly in engineering fields, who largely do applied research projects[1] that need engineering support. Furthermore, this study can inform on the application of systems engineering and project management practices in applied research projects. The results confirm some of the findings from Malik et al.[44] as the informants were hesitant to apply too much process because it could hinder the creative flow of research. Furthermore, there is a strong agreement that much of SE is "common sense," but that it helps sharing a common language to enable collaboration.[26–28]

There is a difference between the formalization of projects and executing project activities. The increased complexity drives the need for planning and management of research projects, and if the researchers are not trained they will choose their methods and tools arbitrarily. Researchers will execute their research projects and deliver research results even without formalized project activities, as they have been doing until now.

In some cases, there will be little distinction between the planning of and execution of research projects. The process of writing research funding applications may include some high-level planning, but in practice does not include *how* the project can be implemented. It is not surprising that a good understanding of SE correlated with informants' belief that SE should be integrated in academia, because most peoples' understanding of SE is based on their personal interest in SE as it is not explicitly taught in general courses. A possibility would be for the university to offer short courses or training in systems thinking and short introductions to relevant SE and PM skills. This could be done in collaboration with other universities, to lower the cost for setting it up. Baron and Daniel-Allegro[48] give an example of a successful MOOC (massive open online course) and its success in developing systems thinking skills.

Research findings are usually the output of a research project, analogous to the "product" that the industry delivers, where the research community is comparable to paying customers. Researchers are continuously asked to publish their results (product), during which they go through a peer-review process (analogous to prototype feedback from end-users and managing risk), are asked to make improvements (analogous to iterating on design), and publish (analogous to introducing a product in the market place). Once the research is published, other researchers may build on that knowledge to create new knowledge. The original research group may continue developing additional knowledge, circling with an iterative product delivery where the product delivery responds to the customer feedback.[46] Another feature of research observes that while individual researchers focus on a specific small part of the field, together researchers form a community that encourages feedback and where "failures [are] not considered as defeats but as valuable opportunities for learning."[62, p. 499]

Many of the informants commented that it had become more challenging to do research without being supported by engineered infrastructure. Furthermore, that engineering support alone was not sufficient for the researchers, but that the community needed research engineers — typically people with higher-level research experience and engineering know-how, to maintain and innovate the infrastructure and labs. However, the way research projects are funded does not always allow for this, or the departments do not have adequate resources.

Furthermore, it is not clear what role SE and PM have in academic research projects. The data shows agreement that holistic thinking is valuable, and this suggests that researchers should have this skill. It could also be helpful for managing stakeholder expectations, and to plan and monitor research projects to help departments manage their engineering infrastructure better. SE and PM offer project performance measurements,[63] and these could support the management of applied research projects and engineering infrastructure. None of the informants mentioned applying analytics or measurements to their research projects, nor were they specifically questioned about this. There are promising opportunities for including AI and ML for PM activities and performance measurements,[64] which could be applied for research institutions. Still, there is a need for training of personnel and adoption of new techniques and systems.

This study supports the theory of the research organization as a sociotechnical system, as shown in Figure 1. There are different perceptions of the meaning of a research project, process, task, and systems engineering. Furthermore, there are different approaches to leadership, and the interviews highlighted that a tailored approach is needed for different research projects and at different levels. A challenge for researchers today is how to separate and balance their time between research, engineering, education, and project management. Although challenging, a practical implication from this study is that projects to a greater degree separate the engineering and research tasks assigned to researchers, to enable the researcher to focus on value-adding activities. This could also, over time, allow for better allocation of engineering resources in the department.

5.2 | Addressing the research questions

This paper laid the results of a study on how systems engineering and project management could benefit academic research projects by analyzing through the analysis of two case studies based on project data, participatory action research, and 18 semi-structured interviews. The findings from this study can improve the way research projects are managed in academia, by addressing the research questions:

- **RQ-1**: How can an engineering project ensure the fulfillment of academic research goals (in a university setting)?
- **RQ-2**: How can engineering goals and individual research goals be fulfilled simultaneously?
- **RQ-3**: How do researchers understand PM and SE?

For RQ-1, there were different opinions on what constitutes research and engineering. Most research topics today involving technology need engineering to push the research boundaries. Either because one needs engineering work to build scientific equipment, or the scientific research in developing technology needs to be integrated and tested. Engineering and research are more and more intrinsically linked in the applied research domain.

In addressing RQ-2, the concern is balancing the workload for research and engineering. There was agreement that in applied research the projects today are so complex that the traditional PM heuristics fail to support the process. Engineering tries to plan all activities and all requirements to meet specific goals, while research by nature is more iterative while moving towards a desired end-state. Perhaps what is needed is a more robust and systemic approach to research, and guidelines to enable researchers to distinguish between engineering and research. If one acknowledges incremental engineering as a part of the research, the gap between engineering and research engineering narrows.

For RQ-3, we found no clear data on how well researchers understand either SE or PM. However, people with a research stance do not distinguish between project and engineering management. People with a research stance differentiate between research and project management. Table 5 summarizes the distinction between engineering and applied research tasks, processes, projects, and goals based on the interview analysis and the literature in which the linear life cycle development and agile development were compared.[62]

5.3 | Limitations

The disadvantages of using interviews as a data source include sampling bias, interviewer bias, and interviewee bias. A potential challenge was that the interviewer could be considered an expert in the field compared to the interviewee. While this, on the one hand, allows for more straightforward exploration of topics and knowledge to carry informed conversations, on the other hand, this can also make the interviewees insecure, such that they try to "perform" to prove that they also know the topic because they feel the interviewer is testing them.[53] Because this study is interested in understanding how researchers view PM and SE, it was considered a strength that the interviewer was knowledgeable in the field to be able to follow up interesting topics in the semi-structured interview, which a less familiar interviewer may overlook. One researcher carried out all the interviews, while the second researcher listened and contributed with additional questions at the end of an interview. Both interviewers had knowledge and experience in PM and SE. The third researcher asked to analyze the transcriptions did not have strong knowledge of SE, but was given the definition from the INCOSE to compare against as a reference. The interviewer mentioned that it took some time to get accustomed to performing interviews, and that the quality could have been improved by training. If interviews are chosen as a data source for future studies, the authors recommend applying a pilot interviewing phase to improve the interview guide and "train" the interviewer. The key informant sampling method applied is helpful at the beginning of a study such as this, but is limited and cannot support generalizations.

6 | CONCLUSION

Autonomy of the researcher is a principle that "goes against" conventional PM. In traditional PM, the manager, be it the systems engineering manager or project manager, decides the scope of work and how and when it should be performed and completed.[44] For some researchers, they may feel that these restrictions hinder creativity and limit the research process of exploring new avenues and theories that were not pre-defined in the project.

Future work and research ideas:

- *Are research funds managed efficiently?* Research projects have goals for publications, for graduating PhDs, dissemination, and impacts. They often include a set schedule and limited funding. A future study could investigate which indicators are relevant to track for applied research projects, the historical track record for meeting goals, schedule, and budget constraints. The new study could categorize the findings according to type of project, and fill a gap in the literature by expanding on the relevance of this study.
- *Should research projects include funding for engineering tasks?* We found that for applied research, there is a need for resources for engineering tasks and infrastructure. A broader study into which types of research projects need this additional support would enable departments to prioritize resources during the proposal writing phase and researchers to be assured of this support so they may focus their time on research.
- *How do you measure the effectiveness of a research project?* Finally, what are the metrics or methods to measure the effectiveness of an applied research project to determine if it has been effective or not. There may be effects that will not materialize in the short run, but the project will still be effective.

ACKNOWLEDGEMENTS

This work was supported by the Research Council of Norway, Statoil, DNV GL and Sintef through the Centers of Excellence funding scheme, Grant 223254 - Center for Autonomous Marine Operations and Systems (AMOS) and the Research Council of Norway through the IKT-PLUSS programme grant 270959 (MASSIVE). It has been approved by the Norwegian Centre for Research Data (project no. 560218).

DATA AVAILABILITY STATEMENT

The data are not publicly available due to privacy or ethical restrictions.

ORCID

Evelyn Honoré-Livermore https://orcid.org/0000-0002-5664-330X
Knut Robert Fossum https://orcid.org/0000-0002-1020-730X
Erik Veitch https://orcid.org/0000-0001-6049-8136

REFERENCES

1. Bentley PJ, Gulbrandsen M, Kyvik S. The relationship between basic and applied research in universities. *Higher Education*. 2015;70(4):689–709. http://dx.doi.org/10.1007/s10734-015-9861-2
2. Tunstel E, Cobo MJ, Herrera-Viedma E, Rudas IJ, Filev D, Trajkovic L, Chen CLP, Pedrycz W, Smith MH, Kozma R. Systems Science and Engineering Research in the Context of Systems, Man, and Cybernetics: Recollection, Trends, and Future Directions. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*. 2021;51(1):5–21. http://dx.doi.org/10.1109/tsmc.2020.3043192
3. Google. Outreach – Google Research https://research.google/outreach/ 2020 Accessed on September 04 2020.
4. Lenfle S, Loch C. Lost Roots: How Project Management Came to Emphasize Control over Flexibility and Novelty. *California Management Review*. 2010;53(1):32–55. http://dx.doi.org/10.1525/cmr.2010.53.1.32
5. Lenfle S. Floating in Space? On the Strangeness of Exploratory Projects. *Project Management Journal*. 2016;47(2):47–61. http://dx.doi.org/10.1002/pmj.21584
6. Fowler N, Lindahl M, Sköld D. The projectification of university research. *International Journal of Managing Projects in Business*. 2015;8(1):9–32. http://dx.doi.org/10.1108/ijmpb-10-2013-0059
7. Sharon A, de Weck OL, Dori D. Project management vs. systems engineering management: A practitioners' view on integrating the project and product domains. *Systems Engineering*. 2011;14(4):427–440. http://dx.doi.org/10.1002/sys.20187
8. Conforto E, Rossi M, Rebentisch E, Oehmen J & Pacenza M Survey Report Improving Integration of Program Management and Systems Engineering: Results of a Joint Survey by PMI and INCOSE tech. rep. 2013.
9. Kordova S, Katz E, Frank M. Managing development projects. –The partnership between project managers and systems engineers. *Syst Eng*. 2019;22:227–242.
10. Hamann RJ, Zandbergen BTC, Zijdemans PJ. Does Systems engineering in space projects pay? *INCOSE Int Symp*. 2009;19:1349–1361.
11. Honour E, Mar B. 9.2.8 Value of Systems Engineering - SECOE Research Project Progress Report. *INCOSE International Symposium*. 2002;12(1):450–455. http://dx.doi.org/10.1002/j.2334-5837.2002.tb02495.x
12. Honour EC. 6.2.3 Understanding the Value of Systems Engineering. *INCOSE International Symposium*. 2004;14(1):1207–1222. http://dx.doi.org/10.1002/j.2334-5837.2004.tb00567.x
13. Department of Defense Systems Engineering Management College. *Systems Engineering Fundamentals*. Fort Belvoir, VA: Defense Acquisition University Press; 2001.
14. Lippe S, Brocke J. Situational project management for collaborative research projects. *Proj Manage J*. 2016;47:76–96.
15. Rebentisch E, Prusak L. *Integrating Program Management and Systems Engineering: Methods, Tools, and Organizational Systems for Improving Performance*. John Wiley and Sons; 2017.
16. SEBoK (Editorial Board), RJ Cloutier (Editor in Chief). Overview of the Systems Engineering Body of Knowledge (SEBoK). https://www.sebokwiki.org/w/index.php?title=Systems_Engineering_Overview&oldid=61847 Retrieved 2020-09-21 from https://www.sebokwiki.org/w/index.php?title=Systems_Engineering_Overview&oldid=61847.
17. Johnson SB. *The Secret of Apollo: Systems Management in American and European Space Programs*. Johns Hopkins University Press; 2006.
18. International Organization for Standardization. ISO15288:2015(E): Systems and Software Engineering - System Life Cycle Processes Standard. Geneva, Switzerland; 2015.
19. Maier MW. Architecting principles for systems-of-systems. *Syst Eng*. 1998;1:267–284.
20. Yeo KT. Systems thinking and project management – time to reunite. *Int J Proj*. 1993;11:111–117.
21. Pajarek L. Processes and organizations as systems: when the processors are people, not pentiums. *Syst Eng*. 2000;3:103–111.
22. Winter M, Checkland P. Soft systems: a fresh perspective for project management. *Proc Inst Civ Eng*. 2003;156:187–192.
23. Donaldson W. In Praise of the "Ologies" A discussion of and framework for using soft skills to sense and influence emergent behaviors in sociotechnical systems. *Syst Eng*. 2017;20:467–478.
24. Crawford L, Pollack J. Hard and soft projects: a framework for analysis. *Int J Proj*. 2004;22:645–653.

25. SEBoK (Authors), RJ Cloutier (Editor in Chief). System Approaches, https://www.sebokwiki.org/w/index.php?title=Systems_Approaches&oldid=58931
26. Brill JH. Systems engineering– A retrospective view. *Syst Eng.* 1998;1:258–266.
27. Cook SC, Wilson SA. The enduring path to system success: investment in quality early-phase systems engineering. *INCOSE Int Symp.* 2019;29:817–835.
28. Vanek F, Jackson P, Grzybowski R. Systems engineering metrics and applications in product development: a critical literature review and agenda for further research. *Syst Eng.* 2008;11:107–124.
29. Carnegie-Mellon Univ. Pittsburgh PA Software Engineering Inst., Elm JP, Goldenson DR. The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey Tech. Rep. ADA610517 2012.
30. Honour E. 11.4.2 Systems engineering return on investment. *INCOSE Int Symp.* 2010;20:1422–1439.
31. Boehm B, Valerdi R, Honour E. The ROI of systems engineering: some quantitative results for software-intensive systems. *Syst Eng.* 2008;11:221–234.
32. Sheard SA, Lykins H, Armstrong JR. Overcoming barriers to systems engineering process improvement. *Syst Eng.* 2000;3:59–67.
33. Sauser B, Boardman J, Gorod A. System of systems management. In: Jamshidi M. Dr. ed. *System of Systems Engineering: Innovations for the 21st Century*. John Wiley and Sons, Inc.; 2008.
34. Project Management Institute. *A Guide to the Project Management Body of Knowledge*. 5th ed. PA, USA: Project Management Institute; 2013.
35. Lilburn Bert. Integrating Systems Engineering and Program Management. *INCOSE International Symposium.* 1996;6(1):689–696. http://dx.doi.org/10.1002/j.2334-5837.1996.tb02071.x
36. Roe Charles L.. Project management and systems engineering in an IPD environment. *INCOSE International Symposium.* 1996;6(1):1063–1068. http://dx.doi.org/10.1002/j.2334-5837.1996.tb02123.x
37. Smith Byron, van Gaasbeek Jim. Project Management, Systems Engineering and the Amazing DNA Double Helix. *INCOSE International Symposium.* 1996;6(1):882–886. http://dx.doi.org/10.1002/j.2334-5837.1996.tb02098.x
38. Johnson SB. Three approaches to big technology: operations research, systems engineering, and project management. *Technol Cult.* 1997;38:891–919.
39. Mooz H, Forsberg K. Visualizing system engineering and project management as an integrated process. In: *INCOSE International Symposium.* Vol. 7. Los Angeles, CA; 1997:573–580.
40. Emes M, Smith A, Cowper D. Confronting an identity crisis–How to "brand" systems engineering. *Syst Eng.* 2005;8:164–186.
41. Sharon A, Perelman V, Dori D. A project-product lifecycle management approach for improved systems engineering practices. *INCOSE Int Symp.* 2008:18.
42. Xue R, Baron C, Esteban P, Yang JB, Zheng L. Toward an improved monitoring of engineering projects. *IEEE Trans Syst Man Cybern Syst.* 2018;50:3541–3553.
43. Xue R, Baron C, Vingerhoeds R, Esteban P. Enhancing engineering project management through process alignment. *Eng Manag J.* 2021:1–19.
44. Malik M, Sarwar S, Orr S. Agile practices and performance: examining the role of psychological empowerment. *Int J Proj Manag.* 2020.
45. Bianchi M, Marzi G, Guerini M. Agile, Stage-gate and their combination: exploring how they relate to performance in software development. *J Bus Res.* 2020;110:538–553.
46. Rother M, Rosenthal M. An Approach to Becoming Agile in a Dynamic World. Helping employees develop scientific thinking empowers them to solve problems and make decisions. *AME: TARGET.* 2018:34.
47. Cohen I, Iluz M, Shtub A. A Simulation-based approach in support of project management training for systems engineers. *Syst Eng.* 2014;17:26–36.
48. Baron C, Daniel-Allegro B. About adopting a systemic approach to design connected embedded systems: a MOOC promoting systems thinking and systems engineering. *Syst Eng.* 2020;23:261–280.
49. Verschuren P, Doorewaard H, Mellion M. *Designing a Research Project; 2*. The Hague: Eleven International Publishing; 2010.
50. O'leary Z. *The Essential Guide to Doing Your Research Project*. Sage; 2017.
51. Yin RK. *Case Study Research and Applications: Design and Methods*. 6th ed. SAGE Publications Inc; 2017.
52. Lavrakas PJ. *Encyclopedia of Survey Research Methods; 1*. Sage Publications Inc; 2008.
53. Hove SE, Anda B. Experiences from conducting semi-structured interviews in empirical software engineering research. In: *11th IEEE International Software Metrics Symposium (METRICS'05)*. 2005:10–23.
54. Guba EG, Lincoln YS. *Fourth Generation Evaluation*. Newbury Park, CA: Sage Publications Inc.; 1989.
55. Lincoln YS, Guba EG. *Naturalistic Inquiry*. Newbury Park, CA: Sage Publications Inc.; 1985.
56. Wahyuni D. The research design maze: understanding paradigms, cases, methods and methodologies. *J Appl Manage Account Res.* 2012;10:69–80.
57. Bryman A. *Social Research Methods*. 4th ed. New York: Oxford University Press; 2012.
58. Yin RK. *Application of Case Study Research*. 3rd ed. Thousand Oaks, CA: Sage; 2012.
59. Niiniluoto I. The aim and structure of applied research. *Erkenntnis.* 1993;38:1–21.
60. Pugh S. Engineering design–unscrambling the research issues. *J Eng Des.* 1990;1:65–72.
61. Provost F, Kohavi R. Guest editors' introduction: on applied research in machine learning. *Mach Learn.* 1998;30:127–132.
62. Paluch S, Antons D, Brettel M, et al. Stage-gate and agile development in the digital age: promises, perils, and boundary conditions. *J Bus Res.* 2020;110:495–501.
63. Rhodes DH, Valerdi R, Roedler GJ. Systems engineering leading indicators for assessing program and technical effectiveness. *Syst Eng.* 2008;12:21–35.
64. Niederman F. Project management: openings for disruption from AI and advanced analytics. *Inf Technol People.* 2021. https://doi.org/10.1108/ITP-09-2020-0639

AUTHOR BIOGRAPHIES

EVELYN HONORÉ-LIVERMORE is a Phd candidate at the Department of Electronic Systems at the Norwegian University of Science and Technology (NTNU). She received her MSc in Electronics Engineering in 2012 from NTNU, and a Master of Business Administration from Yonsei University in Seoul in 2017. Evelyn has experience as a project manager and systems engineer from the industrial space sector (2012–2017). She is researching systems engineering and project management methods for academic research projects. She is also the project manager of the small satellite HYPSO (www.hypso.space).

KNUT ROBERT FOSSUM works as a research manager at Centre for Interdisciplinary Research in Space - CIRiS, NTNU Samfunnsforskning AS. He holds a MSc in biotechnology and PhD in Production and Quality Engineering. Fossum has worked with European space sector since 1997, mainly related to integration and operation of ISS payloads. He has 15 years' experience with space project management and 7 years with research- and human resources management responsibilities. He was responsible manager for the definition and establishment of N-USOC (www.n-usoc.no) and CIRiS (www.ciris.no). From 2010–2017 he served as senior advisor and national delegate to the European Space Agency (ESA). Resent work and field of interest is related to the integral role of human dependability for the safe, reliable and efficient organization and management of complex sociotechnical projects, in specific the application of System Engineering methodology for development and operation of autonomous systems.

ERIK VEITCH is a PhD candidate at the Department of Design at the Norwegian University of Science and Technology (NTNU). He is responsible for applied research in the field of human-system integration for autonomous marine systems. His research focus is on understanding operators' situation awareness needs during remote intervention operations of autonomous surface vessels. Erik has a Master's in Ocean and Naval Architectural Engineering from Memorial University of Newfoundland (2018, Fellow of School of Graduate Studies) and industry experience as a marine hydrodynamics engineer at a private consulting company (2013–2016).

How to cite this article: Honoré-Livermore E, Fossum KR, Veitch E. Academics' perception of systems engineering and applied research projects. *Systems Engineering*. 2022;25:19–34. https://doi.org/10.1002/sys.21599