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Decolonizing Stakeholder Analysis for Engineered Systems

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Abstract

In systems engineering (SE), requirements dictate the manifested system. If requirements are incomplete or inaccurate, the engineered system manifests those flawed requirements. From smart cities to AI decision making, a flawed system can have significant impact on human lives. The stakes are high in systems engineering. "Flawed" requirements can mean many things. They can emerge from human error, incomplete data collection, or a misperception of stakeholder needs and cultural context. Requirements are based on stakeholder and market analysis focused on quantitative data capture and tend to overlook the nuances and context of the underlying stakeholder population. The problematic construct that emerges is the absence of a framework and related education for engineers to consider and design with ethical, equity, and social justice implications in mind. Further, there is still a general lack of diversity of stakeholder parameters in early engineering design classes. Introduction to systems engineering courses lack integration of current thinking on community engagement ethics and that absence can be seen across the systems engineering curriculum, as well. We ask: How do we create learning opportunities/engineering interventions that are technically sound, and also prioritize community voice, cultural appropriateness, and contextual efficacy? In this paper, we review three methods of stakeholder analysis taught in system engineering courses and identify where and how one can integrate community voices through a decolonial lens. We then propose a framework that encourages a more holistic understanding of the stakeholders and the positive and negative impacts on those stakeholders.

Introduction

All Systems engineering introductory courses include stakeholder analysis in either concept design phase or problem definition phase. While most SE educators go through the general guidelines of who a stake holder is and what is their relationship with the system of interest, there is not enough space in the curriculum to identify subtle nuances that can make or break the concept design. This lack of time and effort and or ignorance sometimes results in engineers trained poorly in examination of human diversity, political systems and their role in civic society. Author Bhada teaches both an introduction to systems engineering course and Engineering and Public Policy course. The former is heavy on engineering design with a blind eye to the reality of the civic society and the latter heavy on policy with overview of engineering design. There is room for cross pollination and in this paper, we identify stakeholder analysis as the first SE process or tool and examine it with a decolonization lens. The goal of this paper is examination and recommendation and not definitive statement. We also apply our examination to a systems engineering project and student stakeholder artifact commonly used and developed and demonstrate a simple exercise of decolonization.

Additionally, there is a significant and growing trend of engineering education encouraging students to have an experiential learning component in community, whereby they practice engineering design in communities. Yet, this happens rarely with the appropriate training and with no partnership with community-based scientists. For example, in this case from the

American Society of Agricultural and Biological Engineers [1] , the team identified the challenges of distribution of aid in agricultural development projects and, using stakeholder analysis, outlined the essential voices as the engineer, funder, government, and the international NGO. While this is a strong team of voices, they were missing important insight from stakeholder who were immediately impacted by the design of these engineering solutions. This oversight, in turn, created a technically viable product but not usable by the community [1]

Literature Review

Stakeholder analysis, a cross-cutting tool for all systems engineers [2]. Stakeholder needs and requirements definition process shown in Figure 1 is something that all systems engineers must know in order to be certified by INCOSE as Associate in Systems Engineering Professional (ASEP). While the standards and conduct of stakeholder analysis are emphasized, the INCOSE handbook does not prescribe any particular methodology to complete stakeholder analysis but is part of the technical process.

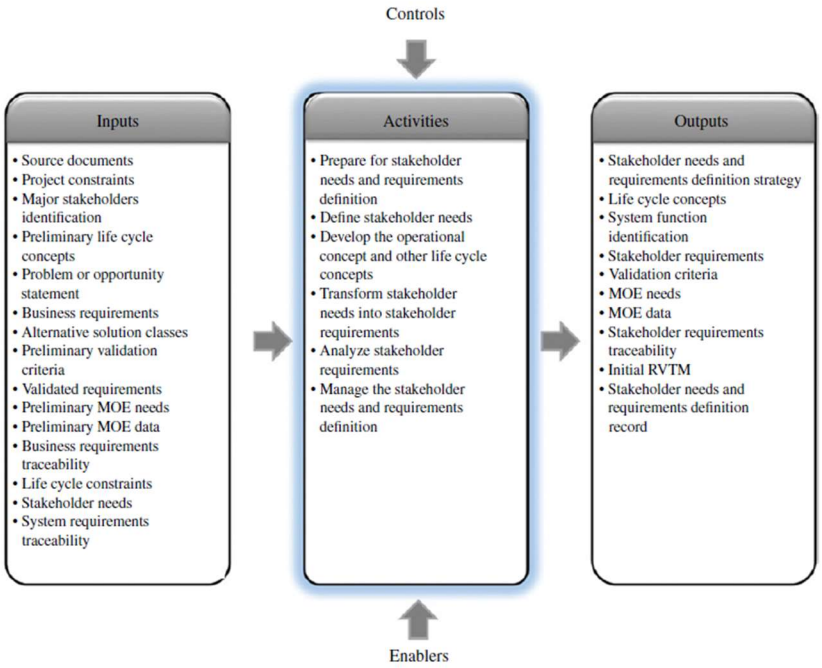


FIGURE 4.4 IPO diagram for stakeholder needs and requirements definition process. INCOSE SEH original figure created by Shortell and Walden. Usage per the INCOSE Notices page. All other rights reserved.

Figure 1: Technical process for stakeholder needs and requirements [2]

Most curricula then recommend their set of stakeholder analysis that they think are appropriate to their domains. In Author Bhada's case she uses these three to help students withs some examples of stakeholder analysis and its application to systems engineering projects [3], [4], [5]. All the stakeholder analysis methods help students understand role of stakeholder in problem definition, need identification and concept design along with some capture of the voice of the customer and

therefore prioritizing the requirements. In order to examine these three from a decolonization lens, we had to first understand what decolonization is and how it applies to these three tools.

Decoloniality is a process by which scholars, educators, and thinkers can evaluate the impact of colonialism on our current understandings of the world. Decolonialism addresses the cultural and intellectual domination of the Europeans [6]. This historical has implications for how science, technological, and engineering knowledge has been created and the voices that have been left out of the creation of that knowledge [7]. Additionally, criticism of surface-level, performative decoloniality (e.g. official statements) shows that there is room to create more practical, meaningful tools for moving from statements to action [8]. Little has been done in STEM fields to connect disciplines with decoloniality, thus the opportunity to focus tools for decoloniality in systems engineering is fruitful.

Most curricula then recommend their set of stakeholder analysis that they think are appropriate to their domains. Additionally, there is a significant and growing trend of engineering education encouraging students to have an experiential learning component in community, whereby they practice engineering design in communities. Yet, this happens rarely with the appropriate training and with no partnership with community-based scientists. For example, in the case mentioned above [1], the team identified the challenges of distribution of aid in agricultural development projects and, using stakeholder analysis, outlined the essential voices as the engineer, funder, government, and the international NGO. While this is a strong team of voices, they were missing important insight from stakeholder who were immediately impacted by the design of these engineering solutions. This oversight, in turn, can create a technically solid but contextually and culturally inappropriate solution. The impact ethical tools and training for more just stakeholder analysis has the potential to lead to both better trained STEM professionals – as they have a more rounded view of the process by which to gather critical information – and more ethical STEM professionals who can attend to injustices often realized through incomplete contextual understanding of real-world problems [9]

Methodology

The purpose of this paper is to survey the literature and current curricular materials to better understand the depth and diversity of community voice in the stakeholder analysis process, and to provide a usable tool for engineering faculty and students for deepening their practice in incorporating community voice.

We recognize that not all engineering faculty are not supported by social scientist and folks educated with community engagement and research methods. To better serve the engineering students diving into an experiential learning experience with community driven project. We propose a set of introspective questions to help guide engineering faculty build a meaningful, holistic educational experience for engineers.

In order to make meaning of this evaluation, we propose the following research questions:

1. What does the literature reveal about the role of community voice in stakeholder analysis?

2. What evidence of bias or coloniality do we see in the approaches to stakeholder analysis?
3. What opportunities exist decolonize stakeholder analysis?

In the following section, we will establish what the engineering challenge is, the societal and technical importance, and provide some recommendations for engineering education. While some of this work is highly contextual, we will suggest modifications to existing stakeholder analysis tools that will serve as prompts and guidance for more robust, holistic capture of stakeholder voice and choice. In the absence of a how, can we create some baseline "how" for all engineers to incorporate into their stakeholder analysis: multiple ways of knowing, culture and language, environment and ecology, and non-human-centric impacts. While there is an assumption of fairness in a stakeholder analysis being community-blind, it paints an incomplete picture of the design opportunity and misses key information to help ensure its success. We believe that engineering educators have a role in developing the skills for seeing beyond incomplete stakeholder analysis and can help transform our approach to working in community.

Decolonizing the 3 Tools

The three tools selected for one-on-one comparison were Sharp et.al, Alexander, and the INCOSE handbook's definition. Each tool defines and offers categorizes of stakeholders. Each has different approaches to the process and completeness of definition, with some leaving more room for interpretation and subjectivity. In reviewing the tools, we considered the opportunities that emerged in the literature and the challenges posed to communities due to colonialism. In the table below, we compared the three tools, understanding of community, consideration of non-human elements, impact of the tool (e.g. reach and/or educational value), and any concerns we noted as unique to the tool.

Table 1. Comparing the three traditional models of stakeholder analysis

	Sharp[5]	Alexander [3]	**INCOSE**[2]
Definition	Defining "relevant stakeholders"; organization is the stakeholder and it is comprised individuals and groups	Anything influencing/influenced by the firm	People and organizations; Defining "relevant stakeholders"; organization is the stakeholder and it is comprised individuals and groups
Understanding of Community	Monolithic understanding of organizations/communities	Semantics of "influencers"	Vague and subjective
Consideration of Ecology/Animals	N	N	N
Impact Factor	Cited by 521 in Google Scholar	Taught at WPI	Taught as text to all burgeoning systems engineers
Unique Concern	Organizational identity and assumption of "official" status; All the stakeholders that do not have an "official" voice are not represented	Too Broad / Vague Influencers without a stake/ stake without influence	Anthropocentric-focus

After reading and evaluating these three approaches to stakeholder analysis, we were left with some questions: do these analyses address the need of all of the larger community that is impacted by it? How would we know? Is there a way to build in a consideration for those not at the table in the stakeholder analysis?

There were commonalities that could lead to some areas for improvement:

- There was a lack of concrete steps for stakeholder identification
- Vague language around stakeholders and influencers left a lot of room for subjectivity in the process
- All were anthropocentric and did not consider ecological concerns or impact on non-human animal life

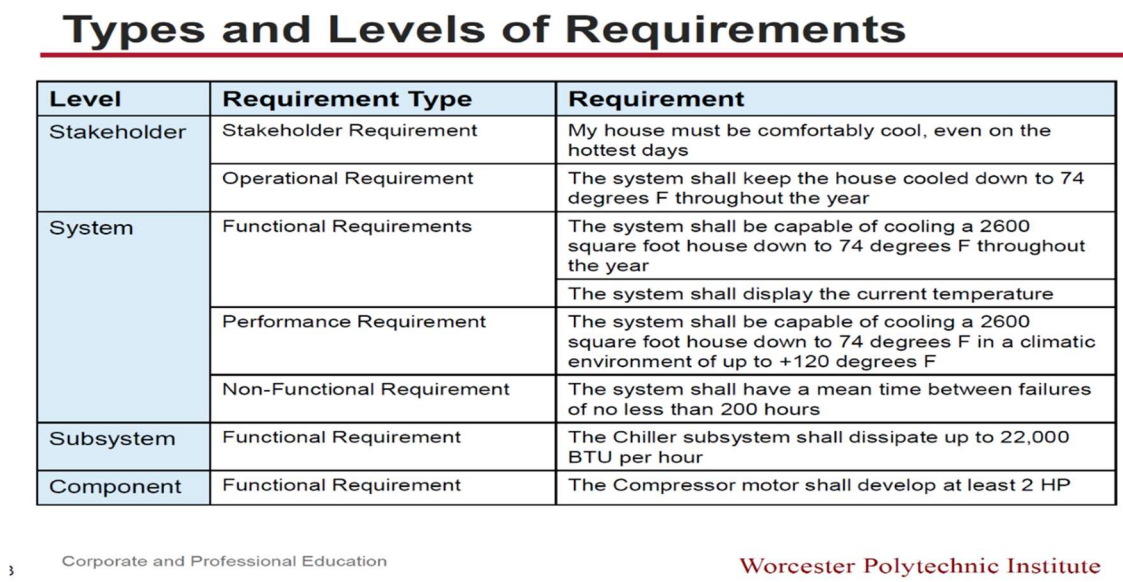
After this cursory review of the tools, we then considered issues of power, privilege, and history that might also influence the process of implementing these tools in education and professional contexts. What we found in that first review was an absence of tools to help evaluate those colonial factors. Sharp (Needs citation #) does emphasize the ethical aspects of decision-making in systems design but does not have discrete steps to critical review the process. We propose a set of questions that can be posed to processes – any of the stakeholder analysis tools – to support more community voice and just, effective outcomes for the system design. These questions that we post intend to be keep it generalizable enough to apply across many contexts, through a lens of inquiry and discovery, and responsive to new learnings through additional research. The questions to pose to the tools in action are as follows:

1. Who is driving this process?
2. Who has power in this process?
3. What societal/ historical / identity considerations?
4. Who is missing in the process?
5. What are the ethical challenges that might be posed?
6. How might we get to full participation in the process?

While table one shows us the impact of decolonization on the stakeholder analysis tools, it does not show decolonization in action or in application as feedback to our students to help them develop broader engineering perspective. In the next section we demonstrate its application of a student project.

In Author Bhada's course Introduction to systems engineering, a student project was developing AI for reducing car theft by co-relating the facial recognition with the number plate of the car. For stake holder analysis he used Figure 2 as the educational aid, along with the papers [3], [4], [5] as additional reading to help articulate the stake holders for his project. Figure 2 is typical needs and stake holder analysis slides used in most systems engineering courses along with its application on some classroom example and Table 2 is its application to a systems engineering student project on Vehicle–reidentification.

Figure 2: Typical slide for stakeholder requirements



Types and Levels of Requirements

Level	Requirement Type	Requirement
Stakeholder	Stakeholder Requirement	My house must be comfortably cool, even on the hottest days
	Operational Requirement	The system shall keep the house cooled down to 74 degrees F throughout the year
System	Functional Requirements	The system shall be capable of cooling a 2600 square foot house down to 74 degrees F throughout the year
		The system shall display the current temperature
	Performance Requirement	The system shall be capable of cooling a 2600 square foot house down to 74 degrees F in a climatic environment of up to +120 degrees F
	Non-Functional Requirement	The system shall have a mean time between failures of no less than 200 hours
Subsystem	Functional Requirement	The Chiller subsystem shall dissipate up to 22,000 BTU per hour
Component	Functional Requirement	The Compressor motor shall develop at least 2 HP

Table 2: Example of a a stakeholder analysis for vehicle re-identification project

Stakeholders	**Requirements**
Users (Traffic Police, Security, Investigators, Traffic Control Center, Department of Transportation, Law Enforcement)	The system should: • Be easy to use • Be easy to install • Consume less space in the device • Should be compatible to hardware devices like mobile, laptops, other screens, etc. • Run fast (Give fast output) • Give correct output (accuracy)
Decolonizing Questions for Users: Does the system add any inequitable burdens or benefits to a population? How and how might you design to avoid that inequity?	
Dataset Owners and Maintainers	The dataset owners and maintainers ensure that the system is not misusing the dataset provided by them. The system should only use the dataset for the defined and agreed purpose. (In deep learning world, to use the dataset of any kind an agreement is required to be signed with the dataset owner, only then access is given to the deep learning engineer)
Decolonizing Question for Dataset Owners and Maintainers: How is the data protected? Is there a history of misuse of data against the community/population? Are there concerns or considerations to build into your process to ensure the data you have collected will be used appropriately and to the benefit of those who are directly impacted by the system design?	
Software Developer and Updater	The software developers will handle the updates and changes in the existing system. Therefore, it is necessary for the system to be updatable and not fixed.
Decolonizing Question for Software Developer and Updater: Who is designing the software and what biases, lenses, or assumptions might they bring to the project? How might the developer reflect upon and address those biases? How can we check our assumptions?	
Competitors	The competitors would always come up with a better deep learning model for the system.

Decolonizing Question for Competitors: How does the ethical conduct of your entity or project influence the accepted norms of how others in the field conduct their own systems design and implementation? Can your work set a standard for ethics and justice in the design process that influences the field?	

As you can see the decolonization questions help emphasize a critical view of power dynamics and community engagement to ensure that a more full, accurate understanding of influences on the design process. In each phase, we can ask a probing question that helps the design team make more ethical, just decisions across the process.

Implications

We see implications from this ethical approach to stakeholder engagement making two immediate impacts: 1) the opportunity to develop future STEM practitioners into more ethical, effective systems designers and researchers and 2) influencing more community-engaged engineering interventions that have higher adoption and success rates in the communities they intend to influence.

For future STEM professionals, there are a number of benefits to adding ethical, inquiry-based skills to their practice of stakeholder analysis. For the engineer in the field, the ability to understand deeply the many variables and characteristics helps to make more complete and thoughtful designs with a higher potential for success. Those who will be in leadership positions – as decision-makers, designers, and team leaders – need to be able to work with diverse stakeholder groups and anticipate areas of opportunity and challenge beyond surface-level understandings. Finally, the emerging generation of engineers that we are educating are increasingly attuned to issues of ethics, justice, and community. As they

For the field of systems engineering, we see an opportunity to engage further in convergence research that has real world impact. By developing tools to better incorporate community voice, there is an opportunity to further the impact of work done in partnership with communities and build longer partnership that could lead to more innovation. Socially-literate and engaged engineers can better translate community concerns into practical action. When trust is built between practitioners and community stakeholders, it can lead to unexpected pathways for intellectual and practical exploration.

Finally, a vector that we can plan for but not control fully is the implications on communities. However, we obviously see benefits as were articulated above – more culturally and contextually-appropriate interventions, better system design – as well as the capacity to develop more asset-based approaches to work in communities. So often community engagement is framed as a way of repairing deficits. By leveraging community voice in full participation with all stakeholders, it translates to narratives about the community that are more accurate and wherein the community has and feels more agency in the process.

Future Directions

The authors intend to build from this concept paper into a research exploration of engineering educator's experiences with stakeholder analysis. We seek to collect data from gatherings of engineering educators (e.g. at the ASEE convening), as well as some surveys and interviews of engineering educators about curriculum and training for stakeholder analysis. We seek to solicit feedback on our examples and rubric above, as well as learning from educators on their experience with ethics and stakeholder analysis. We will further develop the work by elaborating the rubric into more nuanced steps and using cognitive interviewing to test the framework with engineering educators.

Conclusion

Stakeholder analysis is the foundation upon which so many engineering designs and innovations are based, yet there is much left out of the picture. We affirm the need for an ethical framework for stakeholder analysis used by engineers as a professional commitment to safety, adherence to standards, regulations and policies, and as a responsibility to the end users and those impacted by these engineering interventions. By developing tools and new approaches to stakeholder analysis that question inequities and fully engage community stakeholders, we can create more appropriate innovations for the future, ensure the ethical implementation of new technologies, develop the next generation of ethical engineers, and honor the community the dignity, respect, and justice it deserves.

References

[1] K. L. Schreiber, L. F. Rodríguez, A. P. Witmer, and B. Dill, "Understanding and incorporating stakeholder perspectives in international engineering: A phrase mining analysis," in *2019 ASABE Annual International Meeting*, American Society of Agricultural and Biological Engineers, 2019. doi: 10.13031/AIM.201901425.

[2] "INCOSE Systems Engineering Handbook 4e 2015 07".

[3] I. F. Alexander, "A Better Fit-Characterising the Stakeholders.," in *CAiSE Workshops (2)*, 2004, pp. 215–223.

[4] P. A. Laplante, "Stakeholder analysis for smart grid systems," *Penn State*, 2010.

[5] H. Sharp, A. Finkelstein, and G. Galal, "Stakeholder identification in the requirements engineering process," in *Proceedings. Tenth International Workshop on Database and Expert Systems Applications. DEXA 99*, 1999, pp. 387–391. doi: 10.1109/DEXA.1999.795198.

[6] A. Quijano, "COLONIALITY AND MODERNITY/RATIONALITY ," *Cultural Studies*, vol. 21, no. 2–3, pp. 168–178, 2007, doi: 10.1080/09502380601164353.

[7] M. A. Takeuchi, S. Kayumova, Z. de Araujo, and T. C. Madkins, “Going beyond# RetireELL: A call for anti-colonial approaches to languages in STEM education,” *J Res Sci Teach*, vol. 59, no. 5, pp. 876–879, 2022.

[8] E. Tuck and K. W. Yang, “Decolonization is not a metaphor,” *Education & Society*, vol. 1, no. 1, pp. 1–40, 2012.

[9] S. E. Stanlick and N. P. Reynolds, “Reframing professional practice, technical competency, and good intentions: Assessment and reflection tools for ethical engagement in student STEM training,” *Science, Engineering, and Sustainable Development: Cases in Planning, Health, Agriculture, and the Environment*, pp. 53–67, Dec. 2023, doi: 10.1515/9783110757507-004/MACHINEREADABLECITATION/RIS.