(RESEARCH ARTICLE)

Segmenting stakeholders for critical minerals projects: A cross-cultural risk-communication model that improves permit outcomes

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Abstract

This paper proposes and evaluates a practical, cross cultural segmentation framework for communications in critical minerals projects across the United States. We define five core cohorts—workers, residents, Tribal Nations, NGOs/advocacy groups, and regulators—and develop message frames tailored to each segment's values, risk perceptions, and information channels. The study uses mixed methods: baseline audience surveys to surface knowledge gaps and trust drivers; social listening and sentiment analysis to identify recurrent narratives; and controlled A/B tests comparing plain language versus technical frames, with and without visual aids. We measure outcomes along three dimensions: (1) comprehension and perceived credibility, (2) participation quality in public hearings, and (3) permitting milestones (e.g., comment volumes, objection categories, and timeline variance). Results are used to construct a replicable segmentation matrix and message template library that agencies and operators can adapt to local contexts. By aligning content and cadence to audience needs, the framework aims to reduce conflict, improve procedural justice, and shorten permitting timelines without compromising environmental safeguards.

Keywords: Risk communication; Stakeholder segmentation; Critical minerals; Permit outcomes; Cross-cultural engagement; Procedural justice

1. Introduction

Critical mineral extraction and processing is a strategic necessity to the United States to aid in the renewable energy infrastructure, defense systems, and technological advancement (Kaiyo et al., 2024). Several challenges are however posed by projects associated with critical minerals which include public resistance, regulatory oversight and the delays associated with the process of permitting such projects. The permitting process is an important point of a juncture where communication failure by stakeholders could trigger conflict, project approval staling, and reduced trust in institutions of decision-making (Netshifhefhe et al., 2024).

The already available studies indicate that general communication strategies are not effective in dealing with the diverse values, knowledge levels, and information preferences of large groups of stakeholders (Lee et al., 2025). Employment security and workplace safety is important to workers and the impacts on the environment and health are important to local residents, policy objectives are promoted by advocacy organizations and scientific evidence is essential explaining why certain permits should be approved by regulators (Adebiyi et al., 2025). When the differences are not taken into consideration in communications, miscommunications multiply, confidence is lost, and the procedural legitimacy is affected.

As the paper develops the hypothesis, it is the audience-specific methods of communication based on the empirical data on the stakeholder values, perception of risk, and communication preferences that can be expected to positively

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influence the outcomes of the permits and positively affect the procedural justice. The study constructs and implements a segmentation model that operationalizes this methodology to five groups of stakeholders in critical minerals projects. The model integrates audience research, message testing and outcome measurement to develop an implementable tool to practitioners.

2. Literature Review and Conceptual Framework

2.1. Stakeholder Communication and Risk Perception

The literature on risk communication shows clearly that the societal awareness of technical projects arises due to complicated interplay between scientific knowledge, societal trust, and cultural ideals and perceptions of procedural justice (Wing et al., 2024). Stakeholders do not receive the information as it is, but they make sense of technical information using cognitive frameworks mediated by their previous experience, social identity, and institutional relations (Callaway and Tsyawo, 2023). As a result, there is a significant difference between perceived risks and professional risk evaluation especially where there is an absence of communication where stakeholder concerns are viewed as rational and legitimate as opposed to irrational.

The clash between the version of risk perception held by experts and that held by the populace is not an expression of a public irrationality but rather is more of a reflection of radically different sets of risk assessment frameworks. The assessment of expert risks is generally aimed at probabilistic forecasts of the negative consequences based on scientific information and technical analysis (Aror & Mupa, 2025). Public risk perception combines these probability estimates with other factors such as personal agency (are individuals capable of controlling exposure), catastrophic potential (are worst-case scenarios existential threats), and distributional fairness (are risks disproportionately distributed among populations or concentrated among at risk groups). An assessment of technical risk that proves that a project has one-in-a-million potential risky outcome may be rationally valid but may fall on deaf ears when it comes to the residents who are exposed to concentrated risk, have minimal personal control, and whose community has historically been the victim of environmental injustices.

Projects of critical minerals are associated with complex risks of an environmental, occupational, economic, and cultural nature. Occupational health and safety frameworks enable workers to report on hazards that are encountered by the workers, and this should value both short term physical safety and long-term occupational health. Physical injury due to working with equipment, respiratory illness due to the exposure to dust, hearing loss due to noise exposure, and musculoskeletal injury due to repetitive tasks are some of the risks mine workers are exposed to (Matsebula et al., 2025). The conceptualization of the risk by local residents is in terms of possible effects on the water quality, air quality, and community stability and is based on the ecosystem services such as the supply of potable water and agricultural productivity. Tribal Nations combine environmental issues with lawful demands on sovereignty and cultural resources of protection and consider projects as the possible risks to sacred locations, harvesting land and inter-generational cultural inheritance. The advocacy groups usually construct risks within larger policy discourse about industrial regulation and environmental justice where individual projects are connected to larger patterns of environmental racism and regulatory ineffectiveness. Assessments of risks undertaken by regulators are carried out in a procedure of structured scientific and legal procedures and in evaluating the consistency with the environmental standards and legal provisions applicable. Perceived credibility goes down and resistance increases when communications favor technical risk measures and do not favor stakeholder-based risk measures. By unwittingly broadcasting the message that they lack the knowledge of the concerns of the stakeholders, proponents of the project prompt an increased level of opposition that will go far beyond the technical value of certain risk reduction strategies.

2.2. Message Framing and Audience Segmentation

Empirical studies on the topic of message framing testify that the same information can generate different reactions based on the presentation of the risks and advantages (Arkhangelsky et al., 2024). Frames that focus more on loss aversion (highlighting what the stakeholders will lose without approving the project) and frames that focus more on gain potential (highlighting economic benefits and national security benefits when domestic mineral production takes place) attract different responses. Impersonal statistical data is less convincing as compared to stories and real-life examples that can relate statistical trends to concrete lived experience (Mishra et al., 2022). Particularly, descriptions of the rates of injuries at 2.1 to every 200,000 worker hours are less convincing compared with accounted descriptions of near-misss averted by safety measures or equipment adjustments. Visual aids help in grasping of technical information with complex numbers by converting abstract numerical associations into the spatial representations that the human cognition can easily process.

Risk communication should be successful, which presupposes segmentation of the audiences, i.e. the systematic division of heterogeneous populations into comparatively homogeneous groups that share similar values, information needs, and communication preferences (Zayed et al., 2022). Instead of designing single communication messages that are aimed at serving all groups of stakeholders, the process of segmentation acknowledges the fact that different stakeholders' groups are more interested in various issues, process information differently, and react to various communication techniques. Organizations that employ segmentation strategies are able to create specifically targeted messages that are relevant to the interests of the different stakeholders, they are able to make efficient resource allocation by directing intensive communication efforts on stakeholder populations where communication investments yield the highest returns, and they are also able to select the right communication channels to reach the different stakeholders. Studies prove that segmented strategies lead to better results in the form of understanding, change of attitude, and behavioral alteration in contrast to undifferentiated mass communication (Kalu-Mba et al., 2025). Segmented communication also facilitates the more effective allocation of resources, in which communication resources are focused on stakeholder groups that have either an impactful power to impact project results, either through the ability to make a formal decision, through a community or through the power to litigate.

2.3. Procedural Justice and Institutional Legitimacy

In addition to the content of what is said, the manner in which stakeholders are approached is a basic concept of their sense of legitimacy in decision making (Mupa et al., 2025). Procedural justice theory is an assumption that the involved parties assess institutional decisions on the basis of whether decision-making procedures give them any meaningful voice, clear decision criteria, unbiased decision makers, and disrespect (Tina and Mupa, 2025). In procedural injustice, the stakeholders challenge decisions despite the substance merits, and this extends the length of time to permit and destroys institutional trust. Procedural justice has several mechanisms in that stakeholders who feel part of the process are more content with the decisions made even at times when the decisions made are not in accordance with the preferences of such stakeholders, stakeholders perceive process as legitimacy when the rules that guide the decision-making processes are clear and consistently applied, and stakeholders get a sense of being treated with respect as decision-makers may address concerns raised by the stakeholders and provide a clear explanation as to how the concerns influenced the decisions made. These processes underlie the fact that the granting of stakeholder voice opportunities has a significant positive effect on outcome satisfaction compared to the outcome satisfaction should one expect gains in solely decision substantive content.

Critical minerals projects are often faced with contestation of stakeholders based on perceived procedural illegitimacy, especially where the people disproportionately affected by the environmental impact are concerned, and it is true that the disproportionate impact may be seen when the process of consultation is conducted after the basic decisions have been made, as in the case of the Tribal Nations whose sovereignty is implicitly challenged (Netshifhefhe et al., 2024). Rebel Alliance Patterns of tribal consultation processes start after decisions on project design have crystallized i.e. the tribal input to fundamental project parameters cannot actually be influenced. This time of consultation conveys the message that the sovereignty of the tribe is upheld only to the limited areas, which weakens the legitimacy of the institutions and provokes an augmentation of competition. Correspondingly, procedural legitimacy will be lost when local communities feel that environmental impact assessments are biased on what they can approve or not, (as opposed to a genuine assessment of alternatives). Personalized communication strategies that are in line with the values of the stakeholders can be used to enhance procedural justice by showing that their issues have been taken into account, listened to, and integrated into procedures. Communications must clearly describe the contribution of the stakeholder input to the project changes giving a rationality of the decisions made to the stakeholders and showing them that the decision processes did take proper consideration of the stakeholder's concerns.

3. Methodology

3.1. Research Design

The research design of this study was mixed-method research based on the collection and analysis of quantitative and qualitative data. The study was carried out in four successive stages, which were (1) baseline audience evaluation, (2) development and testing of the message, (3) field implementation and (4) measuring and analysis of the final outcomes. This incremental style allowed systematic optimization of the communication strategies through empirical findings at every phase, so that field implementation tested extensively developed strategies as opposed to theoretical various constructs that might not be well-grounded in stakeholder reality.

3.2. Audience Assessment Phase

Baseline audience measurement consisted of the survey of representative groups of workers (n=287), local residents (n=403), representatives of the Tribal Nation (n=68), members of the advocacy groups (n=142), and the staff of the regulatory agencies (n=94). Knowledge of critical minerals projects, perceptions of risk in various areas, confidence in the project operators and regulatory agencies, favorite sources of information, and demographics were the measures used in surveys (Biswas & Dutta, 2020). The survey tools were also created via iterative processes including input of stakeholders to make sure that the questions adequately communicated the concerns of the stakeholders as opposed to making the researcher assumptions concerning the relevant issues. The analysis of social listening involved the study of communications on social media sites, during the open comments, and in the news media reports and identified shared themes, pattern of sentiments, and frames applied by the interested parties. This discussion showed the aspects of the project that the stakeholders were naturally interested in when discussing the project in unconstrained discussions, which serves as a balance to the survey results that might have been subject to biases like question framing or social desirability bias. Surveys and social listening analysis, combined, produced in-depth knowledge about stakeholder values, issues and communication preferences used to shape future message development.

3.3. Message Development and Testing Phase

Based on the data obtained through baseline assessment, the research team created audience-specific message frames that would respond to the major concerns of the cohort. The messages were subjected to a controlled A/B testing whereby a participant would have been exposed to a technical version or a plain-language version, with or without visual aids. Testing involved comprehension measured using multiple choice questions of whether participants have correctly comprehended the relevant information, perceived credibility through validated scales of trust in information source and attitudes towards the hypothetic project through Likert scale items of support, opposition and uncertainty. Difference-in-differences estimation methods of statistical analysis were used to adjust the baseline differences between the treatment groups and estimate the causal impact of the message characteristics (Wing et al., 2024; Lee et al., 2025). Such methodology allowed them to identify message attributes that yielded quantifiable understanding and attitude changes, and the field application made use of message packages that were empirically tested to create changes.

3.4. Outcome Measurement

Field implementation Field implementation continued with critical minerals projects pursuing segmented communications strategies in their permitting procedures. Comparison was made between projects that used segmented strategies and matched control projects that went on with undifferentiated communication strategies which allowed attribution of the differences in outcomes to changes in communication strategies. Three dimensions were measured through outcome measurement, including comprehension and credibility (assessed using post-engagement surveys given to stakeholders after communication events), quality of participation in the public hearings (coded with content analysis protocols that assessed whether the comments were about the substantive project issues or a reflection of uninformed opposition), and whether the milestones were permitted to be achieved (timeline to decision, quantity of comments, categories of objections). Survival analysis methods were used in the statistical analysis of time-to-permit results in various communication strategies (Li et al., 2023). Such strategies allowed strict quantification of whether segmented communication strategies in fact led to any improvements in permitting outcomes or were merely due to selection effects and confounding factors.

4. The Segmentation Framework: Five Core Stakeholder Cohorts

4.1. Workers

The employees in the critical minerals projects are concerned with employment security, occupational health and skills. The issues raised by this cohort were related to the workplace risks, job stability during the project period, and a possibility to develop a career with the help of training. It was discovered that communications that highlight safety measures, job opportunities, and development of skills work best with the workers. Employees prefer the face-to-face communication channels such as tool box talks, union meetings, and horizontal communication (Adebiyi et al., 2025). Framing on safety information based on occupational hazards was more convincing compared to abstract statistical risk information. Visual safety helps to depict the recognition of hazard and the use of personal protective equipment increased understanding and remembrance.

4.2. Local Residents

The local citizens imagine the impacts of the project in terms of their impact on their immediate surrounding, property value, and character of their community. The issues that were raised by this cohort included water pollution, poor

quality of air, noise, and traffic. The studies revealed that the most effective communications involving the presentation of clear environmental monitoring information, illustration of mitigation measures taken, and recognition of valid concerns are appropriate among the local residents. The local residents have favored the community-based information such as the town halls, the local media, and the community group meetings. The use of communication based on accumulative effects and long-term environmental sustainability were more convincing as compared to single-issue technical communications.

4.3. Tribal Nations

Tribal Nations claim their sovereignty rights, protection of their cultural resources and have the right to consult. According to this cohort, the standard environmental impact assessment procedures do not deal with cultural impacts, protection of sacred sites and treaty rights satisfactorily. It was found that the best way to engage the Tribal Nations is through communications that illustrate meaningful consultation prior to the essential decisions, direct assistance of Tribal environmental expertise, and respect of tribal authority on decisions impacting tribal lands and resources. Direct nation-to-nation communication and consultation procedures were necessary; general public engagement strategies were even seen as disrespectful and procedurally invalid.

4.4. Non-Governmental Organizations and Advocacy Groups

Non-governmental organizations and advocacy groups promote the policy-based missions, acting as strategic players in permitting the processes. This group also indicated that their main issues are regulatory sufficiency, compliance in the industry and the precedents in policies. It was discovered through research that this cohort is very responsive to messages that are scientifically backed with details, have comparative approaches to regulation, and policy implications. This group also employs advanced information seeking techniques such as technical reports, peer-reviewed documents and regulatory filings. Communications need to accept a reasonable policy disagreement and be scientifically rigorous and engage in good-faith discussions.

4.5. Regulatory Agency Personnel

The regulatory agencies need scientifically defensible information, evidence to the permit conditions, and records of compliance in procedures. In this cohort, there were statements that the communications should show how the project design will meet the regulatory requirements and the way the stakeholder concerns have been reflected in the project changes. Regulators like more elaborate documentation of the technical details, peer-reviewed facts and explicit connections between the nature of the project and the terms of the permit. Project information should be framed by communications that show that it is consistent with regulatory precedent, and is framed within the existing regulatory frameworks.

5. Message Templates and Communication Strategies

5.1. Safety and Employment (Workers)

Untechnical messages will be focused on: This project develops [X] construction jobs with an average yearly wage of [Y], and all employees will be offered thorough safety training before employees are hired. Personal protective equipment is provided to all workers and they are allowed to take part in daily safety briefings. Past analogous ventures have recorded [X] days of injury-free safety measures by adhering to constant safety procedures.

The visual aids will be hazard identification posters and personal protective equipment demonstrations and flowcharts of workplace safety. Messengers must consist of the representatives of unions, veteran workers who have been on similar projects and professionals in occupational safety. The channels of information are the toolbox talks, union meetings and worker orientation programmes.

5.2. Environmental Protection (Local Residents)

Direct messages are used to highlight: The project will use [X] environmental safeguards on water quality, which will also include [specific measure]. External monitoring of the quality of water will be done [frequency] and the result will be made available on [website]. When the change in water quality surpasses [threshold], the remedial action will take place immediately.

Examples of visual aids would be maps that display monitoring locations, baseline water quality and comparison before and after similar projects. Examples of messengers are environmental scientists, community members who have

benefited by the similar projects and independent environmental consultants. Community meetings, local media, and project websites, where information is updated regularly, are used as information channels.

5.3. Tribal Consultation and Cultural Protection (Tribal Nations)

Communications should focus on the nation-to-nation consultation, open up prior to the basic decisions are made and offer direct assistance to Tribal environmental expertise. Messages highlight: This project area is overlapping with [Tribe] treaty areas and cultural resources. The [Tribe] reserves the decision-making power on the effects of tribal lands and cultural resources. [Project proponent] agrees to [specific protections] that have been created by consulting with [Tribe], and conflicts will be settled by [agreed dispute resolution process].

Some of the means of information flow would include official government-to-government consultation, meetings of the Tribal council, and direct contact with Tribal leadership. The messengers should be official representatives of the project that have the real power of making decisions. It should be documented that there is an incorporation of the Tribal input in project modifications.

5.4. Policy and Regulatory Compliance (NGOs and Advocacy Groups)

Detailed communications address: "This project complies with [specific regulations] as demonstrated in [comprehensive documentation]. The Environmental Impact Statement addresses [key concerns] and incorporates [specific mitigation measures]. This project aligns with [regulatory precedent] and exceeds [comparative performance standards] observed in [similar projects]."

Information channels include regulatory filings, detailed technical reports, peer-reviewed publications, and direct engagement with organizational leadership. Messengers should be technical experts and regulatory specialists. Communications should acknowledge policy disagreements whilst demonstrating scientific rigor.

5.5. Regulatory Compliance Documentation (Agencies)

Structured communications give: Authorization of the project is made subject to conditions of a particular permit. This will be monitored and reported [frequency] and results put forward to [agency] within [timeframe]. The applicant undertakes to obey [certain compliance measures], and will be punished in the event of not doing so by [enforcement consequences]. This strategy responds to the requirements of regulations via [certain mechanisms]."

The channels of information involve filings of regulations, permit applications and agency consultation meetings (Efe, 2024). Messengers should be applicants to the project who can promise terms of the project legally.

6. Findings and Implementation Results

Application of the six critical mineral projects of segmented communication strategies meant quantifiable gains in outcome dimensions. The workers who were given specific safety communications had 34 per cent more understanding of occupational hazards information than workers who were provided with generic safety communications ($p < 0.05$). Living neighbors who were provided with clear information on the environmental monitoring had 52 per cent more confidence in environmental protection measures than living neighbors who were provided with regulatory compliance reports only ($p < 0.01$). Tribal Nations which had material nation-to-nation consultation prior to the making of basic decisions also scored much higher on procedural legitimacy perception ($p < 0.001$).

Allowing results enhanced significantly. Time-to-permit average decision time in control projects was 18 months and that of segmented communication projects was 14 months. There was an increase in the number of commentaries made by the public, that is, an implication of a greater level of stakeholder engagement, but a reduction in the volume of substantive objections as the stakeholder interests are resolved in the process of communication and project modification. The opposition among the community reduced to 34 per cent on segmental communication projects compared to 68 per cent in baseline projects.

7. Discussion

The study evidences that individual, audience-based communication plans that are based on empirical research on stakeholders can create quantifiable changes in understanding, trust, procedural legitimacy, and permitting outcomes. The results are consistent with the greater risk communication literature that supports the greater efficacy of end-engineered reporting over more indistinct methods (Kalu-Mba et al., 2025; Mupa et al., 2025). More to the point, the

study provides evidence that communication excellence yields tangible business results, which include faster permitting schedules, decreased litigation risk, and increased operational legitimacy, and recommends organizational investments in advanced stakeholder communication strategies.

These findings are attributed to several mechanisms. First, audience-specific messages discuss issues that the stakeholders have determined as salient and this means that their issues have been addressed and taken into account. This deals with procedural justice issues despite the underlying substantive differences. Stakeholders who feel that decision-makers have known all about their interests and taken them seriously achieve greater procedural legitimacy satisfaction whether decisions end up as being consistent with the preferences of the stakeholders or not. Second, it is essential to employ the proper means of communication and messengers which increase credibility- the workers believe peer communication and experts in occupational safety more than generic communications in the corporation. Tribal Nations focus on direct nation-to-nation consultation no matter how bad the information in other channels is because it is an underlying principle of sovereignty. Local citizens put a value on independence of information sources, and want to use community-based channels over the corporate-controlled information. Third, messages written in a specific way lessen the barriers to understanding owing to the use of proper technical language and the presentation of real examples instead of abstract statistics. Occupational hazards are understood by the workers in a better grasp when a certain reference is made to the workplace situation they face and not the statistical risks that are presented to them. Regulatory compliance documentation does not work as well as concrete monitoring data and before/after comparisons in helping local residents to understand environmental impacts better. Fourth, the implicit communication of respect towards stakeholder values through segmented communication strategies conveys to the audience that the proponents of the project are aware of stakeholder issues, and they have accordingly tailored their communications to those issues. This respect increases credibility of the institutions, and desires of the stakeholders to deal positively.

The framework helps in guiding practitioners on the application of evidence-based stakeholder engagement. The segmentation strategy shifts away to generic engagement of the people to systematic analysis of the heterogeneity of the stakeholders and intentional development of strategies. The message templates give us the initial points on which project teams customize to the local realities instead of pre-programmed formulas to be used in all projects. The outcome measurement framework allows organizations to evaluate the effectiveness of communication and improve approaches through evidenced-based approaches (Wahyuandari et al., 2025). Such a learning orientation, evaluating the best results of the communication strategies and improving it on a regular basis and evidence-based, is a big step towards the conventional method of communication that focused on the amount of communication but not its effectiveness.

8. Limitations and Future Research

The study analyzed six key mineral projects and this might not be broadly applicable to the other type of project or geographical context. Future studies would be needed to test the framework on a wide range of projects, geographical areas, and stakeholder make up to determine the external validity of the results and find out possible contextual moderators that may affect the effectiveness of the framework. Also, this study assessed permit outcomes over comparatively short periods; more extended periods of monitoring project implementation and community outcomes would enhance causal conclusions and allow evaluating whether enhanced permitting procedures result in long-term stakeholder satisfaction and positive project outcomes in operation periods. A study on the effectiveness of communication strategy in the project operation phases, and not necessarily only as a permitting event, would be a way of treating communication as a dynamic process and not as a permitting event, and communication stakeholder engagement will not only be limited to initial permit award but to the implementation activities, monitoring and closure activities. The next set of research must be done on how communication strategies change in response to changes in project situations, changes in the composition of the stakeholders and new issues that emerge in the process of project implementation. Also, the study that included linear outcome measurement would help understand whether the initial communication investments yield sustainable trust relationships or the trust may be broken once the reality of the project and the communication representations do not align. Cross-regulatory and cross-jurisdictional comparison would help elucidate the role of institutional structures and legal demands in communication strategy effectiveness. Lastly, the costs of implementation of communication strategies and the payoff would enable the economic rationale of organizations spending heavily in audience research and customized messaging strategies.

9. Conclusion

Communication with stakeholders has a significant impact on the results of critical minerals projects, and most organizations adopt generic communication strategies that do not sufficiently accommodate the needs of

heterogeneous stakeholders in terms of values and information. The paper offers empirical evidence that an audience-specific communication strategy that involves segmentation will work better in terms of comprehension, trust, procedural legitimacy and permitting milestones. The framework of segmentation with five main groups of stakeholders, message formats specific to the values and concerns of each group, and protocols to measure outcomes will offer practitioners with the evidence-based approach to the execution of the successful stakeholder engagement. Stakeholder heterogeneity may be addressed by identifying diverse communication strategies, based on the dissimilarity between different stakeholders, which is achieved through acknowledging the issues that the stakeholders have identified, and tailoring communication strategies appropriately, to achieve reduced conflict, enhanced procedural justice and permitting processes that do not undermine environmental or community protection.

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