Foundations of Spatial Data Infrastructure for Underground Mining Decision-Making in Namibia

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SUMMARY

Underground mining is among the most spatially complex industrial activities, where decisions on exploration targeting, resource evaluation, mine design, operational control, safety, environmental protection, and mine closure rely heavily on accurate and integrated spatial information. Unlike surface mining, underground operations occur in environments with limited direct observation, high geological uncertainty, and continuously evolving conditions, which increases decision-making risk, especially when spatial data is fragmented across disciplines, institutions, or technology platforms. Spatial Data Infrastructure (SDI) provides a comprehensive framework to address these challenges by enabling coordinated management, integration, and use of spatial data. SDI goes beyond GIS and digital mapping to encompass institutional arrangements, legal frameworks, technical standards, data-sharing mechanisms, and human capacity. When effectively implemented, SDI transforms isolated datasets into a strategic decision-support asset, reducing uncertainty, improving operational efficiency, enhancing safety, and strengthening governance. This study presents a multi-commodity analysis of SDI as

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decision-support framework for underground mining in Namibia. The research adopts a systems-based approach, integrating geospatial science, spatial decision theory and subsurface governance. It evaluates SDI's role across the full mining lifecycle, from exploration to post-closure land management, highlighting the interaction between corporate mining SDI systems and Namibia's National Spatial Data Infrastructure (NSDI), including both synergies and gaps. Findings indicate that SDI is essential for three-dimensional geological modeling, mine planning optimization, real-time operational monitoring, spatially informed safety management, and transparent environmental and regulatory reporting. However, its effectiveness in Namibia is constrained by fragmented data governance, inconsistent spatial standards, limited institutional interoperability, and a shortage of specialized geospatial skills, challenges that are primarily organizational rather than technological. The study argues that SDI should be viewed as a strategic national and corporate asset, important for improving mining performance, responsible subsurface governance, environmental sustainability, and long-term socio-economic benefits. SDI is positioned as a foundational pillar for the future of underground mining in Namibia and similar resource-rich contexts.