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## Sustainable territorial development strategy for the impact of mining megaprojects: a study of four intermediate cities in Chile, Latin America

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The Chilean economy draws its strength from the robust foundation laid by the mining sector, a cornerstone that significantly shapes the nation's economic landscape. This sector doesn't merely play a role but stands as a pivotal force, contributing a substantial 9.4% to the national Gross Domestic Product (GDP). Beyond its domestic impact, the Chilean mining industry exercises a commanding influence on the international stage, attracting an 33.3% of the total foreign investment directed into the country.

In the web of global industries, the Chilean mining sector emerges as a frontrunner, taking the lead in the production of indispensable minerals. Among these key minerals are copper, a vital component in various industrial applications and a crucial player in the global economic scene. Rhenium, known for its unique properties that enhance the performance of various alloys, also features prominently in Chile's mining portfolio. Additionally, the nation contributes significantly to the global supply of natural nitrates, essential for agricultural fertilizers, and lithium, a linchpin in the burgeoning electric vehicle industry. The mining of iodine further solidifies Chile's position as a major player in the global mineral market.

This economic reliance on the mining sector not only underscores Chile's strategic importance in the world economy but also highlights the responsibility to navigate the associated challenges and opportunities wisely. The fortunes of Chile's economic prosperity are intricately woven with the success and sustainability of its mining industry, emphasizing the need for strategic planning, innovative practices, and a forward-looking approach.

In the 21st century, the mining industry in northern Chile has undergone continuous expansion, sparking noteworthy socio-spatial transformations in cities and surrounding territories. This growth has given rise to fresh demands for industrial urban expansion, prompting urban development planning to become a recognized priority for the state (Devenin, 2021).

However, there exists a notable gap in studies regarding the transformation experienced by so-called "intermediate cities" at the regional level. This gap stems from the fact that productive mining industries have significantly altered the local reality. Throughout this process, urban development patterns have been predominantly shaped by an economic logic focused on the supply of services and products, occasionally neglecting the well-being standards of the inhabitants.

Understanding the effects of the mining industry on these urban centers is crucial for comprehending the economic logics in the region. The objective is to generate a model of urban planning capable of mitigating negative socio-spatial consequences by introducing environmental factors typical of sustainable cities. This approach envisions mining urban centers beyond finite production cycles (Bithas & Christofakis,



2006), activating social, environmental, and cultural resources for sustainable development that ensures the well-being of residents (Van Kessel, 2003).

Addressing the adverse impacts of mining necessitates active planning and the adoption of development strategies that not only stimulate the growth of the productive industry but also alleviate its effects on the natural environment and social dynamics of cities (Bithas & Christofakis, 2006). These crucial issues have been understudied until now.

The historical roots of mining activity in the region trace back to the extractive industrial occupation of the late 19th century. The exploitation of resources such as nitrate and copper spurred significant investments in northern Chile, leading to the formation of small settlements linked to mines. However, this planning model collapsed with the closure of mining operations in the mid-20th century. Originally designed for productivity (Venegas & Morales, 2015), mining cities were abandoned due to neglect of human needs and the well-being of their inhabitants.

In the contemporary urban landscape, models are being promoted to enhance citizens' quality of life. Social movements are advocating for a more ethical consideration of the past, present, and future, taking into account the needs of future generations. This evolution signifies a more holistic approach in urban planning, recognizing the importance of balancing economic development with improving the quality of life and environmental sustainability (Poudyal et al., 2019).

From this perspective, the research zeroes in on the impacts of the mining industry on urban areas directly affected by economic development patterns in Chile's administrative regions. Four mining cities are scrutinized as case studies, where environmental emergencies stemming from environmental degradation have significantly impacted urban life. These impacts manifest through legal issues related to water scarcity and deterioration, as well as the lack of planning in the cities' growth.

The analysis delves into the local scale, studying the impact of mega mining projects on Chilean cities. In the face of uncontrolled expansion, a development model based on sustainability principles is proposed to strategically manage cities' basic resources and ensure their future without compromising it.

The effects of urban transformations, derived from the influence of the mining industry, are presented conclusively. The primary objective is to develop a strategy of urban planning that mitigates negative socio-spatial consequences and incorporates environmental factors aligned with contemporary models of sustainable cities. This approach aims to project the future of four mining-related urban centers beyond production cycles, activating their human, environmental, and economic structures to ensure residents' quality of life without compromising it.

In light of these considerations, the proposal suggests integrating social issues and human structure as elements equivalent to economic factors in territorial management. This seeks to address the following postulates:

- Can a methodological model integrate the human component in the territorial planning of mining cities and consider that development criteria should be based on sustainability principles?
- Can the territorial development of mining cities be prioritized in a balanced way to avoid compromising environmental, social, and cultural resources?

These postulates form the basis of the present investigation, which integrates environmental responsibility and well-being into territorial planning, treating it as an applicable indicator for cities linked to the mining industry—a productive sector that, due to its extractive nature, is a major cause of environmental deterioration.

A vision of territorial development based on environmental responsibility is proposed, integrating indicators aligned with the Sustainable Development Goals proposed by the United Nations in 2015. While these goals are subscribed to by member countries for improvements in social, environmental, and equity areas, they lack a defined standard, remaining as statements rooted in good intentions. Given this premise, a territorial development model based on qualitative indicators is proposed, originating from studies of the social realities of each city to balance environmental, social, and cultural factors against the economic factors governing public policies.



The proposed methodology serves as a prospecting tool for territorial planning based on sustainability standards obtained from the global development goals proposed by the United Nations (2015). A comparative analysis is conducted using the methodology on three cases of mining localities affected by environmental pollution in Chile— emblematic cases of lack of planning and its consequences on the local community. These Chilean cities—Tierra Amarilla, Quinteros, and Puchuncaví—are all intermediate cities that had the mining industry as their primary support.

These Chilean cases are particularly pertinent because Chile is a middle-income country with neoliberal economic development, permitting economic activities that have caused pollution. Consequently, numerous geographical areas with high industrial concentration prioritize establishing industrial centers over people's well-being and environmental protection.

Strategic planning is presented as an essential opportunity to address urban land demands according to the projected demographic growth. This strategic planning is active, prioritizing environmental damage and seeking to safeguard, organize, and enhance the resources available in cities to achieve comprehensive and sustainable growth that promotes equity in access to the economic, environmental, and social needs of its inhabitants without jeopardizing their permanence in the city.

The proposed model's objective is prospective, quantifying demographic growth, the new urban land required by the city, the water consumption needed for its inhabitants, and the recreational areas required for the optimal functioning of the human structure. Armed with this information, it is possible to make an initial proposal of how cities will grow, based on the recognition of the endogenous dynamics of each settlement for the implementation of public policies in critical areas identified. References include the results achieved by the municipal environmental certification system evaluated by Rungruangsakorn in 2020, which has successfully implemented strategies for each commune focused on environmental education and awareness.

Given this premise, territorial planning stands out as a process of vital importance, aiming to address these challenges from a quantified perspective, analyzing multiple scales and interconnected aspects within urban ecosystems. For this planning to be effective, it is crucial to adopt a holistic approach that considers the interdependence of various factors. Overvaluing a single aspect can have negative consequences on citizens' quality of life and the sustainability of the urban environment. In the context of our study, we have observed a constant deterioration in urban settlements due to a lack of proper planning. This has led to the proliferation of informal settlements, the placement of harmful industrial activities in residential areas, and a scarcity of recreational areas for residents.

A sustainable territorial development model should focus on optimizing the use of urban land, taking into account the economic, social, and environmental resources available without compromising the productive activities of the region in question. This approach promotes the governance of territories and seeks to establish strategies from a perspective that spans from neighborhoods to state administration.