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Mode Selection of the Implementation and Construction of Projects on the Comprehensive Utilization of Mineral Resources: A Feasibility Study for Higher Education

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ABSTRACT

Projects for the comprehensive utilization of mineral resources involve multi-disciplinary technology and management knowledge. However, enterprises often do not have relevant technical reserves and construction experience, thus posing difficulties in balancing the cost, progress, quality, and other indicators of construction while considering the team building of enterprises If not resolved, these problems may lead to resource wastage and low rates of comprehensive resource utilization. This paper introduces the advantages and disadvantages of Outsourcing, Self-management, Consultant, and Joint Management Modes in handling such projects. Taking a mining company in Guangxi as an example, the pros and cons of the above modes are analysed from different perspectives according to the actual situation of the enterprise being studied. The study's findings have some guiding significance and can provide a comprehensively practical view from an educational significance perspective for enterprises who are planning to implement project construction.

Keywords: comprehensive utilization of resources; selection of project management mode; project construction

INTRODUCTION

The comprehensive utilization of mineral resources generally refers to the process of complete development and rational utilization of the symbiotic and associated minerals in the mining process as well as the recovery and rational utilization of the waste residue, wastewater (liquid), waste gas, waste heat, and pressure produced during production (Yongzhia et al., 2019; Zhikun et al., 2020). For example, in the processing of coal, ferrous metal mines, non-ferrous metal mines, crude oil, and nonmetal mines, the solid waste generated from the recovery of valuable elements or harmless treatment comprises the aggregate of the building materials industry (Li et al., 2011).

At present, there is still an evident gap between China's mining technology and that of industrialized countries. Specifically, the gross recovery rate of mineral resources is 20% lower than that of industrialized countries, and the recovered co-associated metals are less than 1/3 (Wang & Yu, 2009; Gong, 2006).The resource utilization of waste is low in China. In fact, even the utilization rate of secondary metal mineral resources is also very low—less than 5% of the total annual increase compared to over 30% in developed countries (Cai & Yang, 2000). This indicates that China has great potential for comprehensive utilization of resources.

Maximizing mineral resources means tapping their potential to transform waste into treasure and turn harm into benefits while reducing environmental pollution.

Enterprises dealing with the comprehensive utilization of mineral resources can be divided into three types according to the source of raw materials for a project. The first type consists of enterprises that process primary mineral resources, such as mining, metallurgy, chemical, and petroleum; produce main products and wastes in the technological production process; and sell the wastes at reduced or discount prices. The second type includes enterprises dealing with professional resource comprehensive utilization. They do not produce wastes but take local or industry-specific wastes as raw materials and dispose of them to obtain processing fees and facilitate the recovery of valuable elements or preparation materials. The third type consists of enterprises that not only produces waste but also have the qualification to perform waste treatment and undertake the waste processing of external units. For example, cement manufacturers use cement kilns to co-process hazardous waste or household garbage, whilst smelteries use rotary kilns to dispose of metallurgical slag.

The construction, renovation, and expansion of comprehensive projects for the utilization of mineral resources often involve the disciplines of mineralogy, metallurgy, and material science, as well as the related cross and edge. However, project sponsors typically lack technical reserves and engineering experience. Therefore, choosing appropriate methods of project implementation and construction can effectively avoid risks, improve the quality of the final deliverables, and help manage the schedule and project cost.

OPTIONAL MODES FOR PROJECT IMPLEMENTATION AND CONSTRUCTION MANAGEMENT

The main business of most of the abovementioned enterprises or investors is not the comprehensive utilization of resources. They also do not have the technical ability to achieve comprehensive utilization and processing of waste. The modes of project implementation and construction, which help obtain the best technical scheme and construction, can be divided into four types, as discussed in the sub-sections below. From these, a construction unit can select the most suitable mode for the needs of an enterprise according to its operation situation, industry characteristics, technology, and management personnel reserve.

OUTSOURCING MODE OF THE GENERAL CONTRACT FOR DESIGN AND CONSTRUCTION (DB), GENERAL CONTRACT FOR ENGINEERING PROCUREMENT CONSTRUCTION (EPC), AND TURNKEY PROJECTS

In the above three types, the general contractor is fully responsible for the work contracted and may allocate some of the work to sub-contractors as required. There are three types of contract; Design and Construction Contract (DB), Engineering Procurement Construction (EPC) and Turnkey project (Turnkey). They differ in terms of the scope of the business to undertake and the level of contractor risk involved, in which case the owner has to pay more risk costs (contract cost). The owner must also make decisions on some major issues that are closely related to the final effect of the project and cooperate with the contractor to complete the matters agreed upon in the contract according to the requirements of the contractor, such as the purchase of equipment, the provision of basic information and data, etc. Under the contract, the contractor shall undertake specific work, such as project approval, feasibility research, economic evaluation, survey, design, procurement, construction, installation, equipment debugging, and pilot production service of the project. The contractor shall also be fully responsible for the quality, safety, construction period, and cost of the contracted project; hence, the owner need not employ relevant professionals.

A comprehensive mineral resources utilization project usually covers a wide area. The construction area is often large with high-rise buildings or facilities, such as chimneys. The mining or factory area where the project is located may also be affected by complex geological conditions and difficult construction issues, which involve many safety factors. Therefore, it is generally required that the contractor has certain design and general contracting qualifications. The contractor is usually a large-scale architectural design institute or a professional engineering consulting company, has case experience in related industries and fields, and has undertaken projects of the same scale and above.

This outsourcing mode is suitable for new large-scale projects or the owners who are new entrants across industries.

SELF-MANAGEMENT MODE

In this management mode, the enterprise does not hire any project consulting or consulting units, and all the project management is completed by the enterprise employees themselves. Large state-owned enterprises with relatively complete organizational design and staffing often adopt this mode (Luo & Ji, 2012).

Under this mode, the enterprise establishes the project team with its own team of professionals as the main team members through internal selection and external recruitment in accordance with the needs of project development and implementation. Owners generally do not hire consulting companies and do not entrust technical and management affairs to outside units. Instead, the enterprise independently carries out the project approval and business case, the owner formulates a technical route and scheme, and then organizes the construction bidding of the survey and design, civil construction, the production of large equipment, special equipment installation work, etc. The owner is not only responsible for land auction, planning permits, and construction permits but also entrusts other units to complete the environmental impact assessment (EIA), energy-saving assessment, occupational safety, and health pre-assessment. Upon completion of the construction preparation for the project, the supervision unit shall be hired to supervise the construction, purchase and handle equipment installation, and debug the production line to achieve the desired production standard.

This mode is suitable for the same or similar medium and small projects with the owner's existing business. The owner shall have certain resource reserves and experience for the new projects. However, it is also necessary to entrust qualified survey and design units to complete the drawing design, select the appropriate construction companies to carry out civil construction, and purchase non-standard equipment from professional equipment manufacturers.

CONSULTANT MODE OF OUTSOURCING CONSULTING SERVICE

Under this mode, the owner shall employ an expert team composed of relevant members (including professionals in related fields) or entrust a professional consulting company or an expert team to provide consulting services and feasibility study reports to guide the owner to complete the project approval. Once the relevant examination and approval procedures are completed, the expert team or consulting company shall formulate a technical route and construction plan and make a plan of the management process and system. Then, in accordance with the owner's construction plan, the expert team or the consulting service company will create the Gantt chart and appoint project managers and other professionals to form a joint management team together with the enterprise's personnel. As required in the cooperation agreement, the expert team or consulting company usually leads the overall operation of the project and provides the process package and the overall technology of the project construction, along with the services for the entire project approval process, feasibility study, design,

construction, procurement, installation, commissioning, and the assessment of relevant project indicators.

Although consulting services will be outsourced to a team of industry experts or consulting services companies under this mode, the construction unit will still undertake the commercial part of civil engineering, utilities, and equipment procurement (Luo & Ji, 2012). The expert team or consulting company will then provide civil engineering materials and basic information on the required utilities to qualified design institutes, cooperate with construction unit to create the related technical specifications in accordance with the equipment procurement, and supply consulting services in the market research, selection, and technical negotiations of them equipment procurement.

This mode is suitable for construction units aiming to enter a new industry or field with some experience in project management but also lack the relevant technical personnel to proceed with the project. This mode is typically adopted to control the cost or when there is no available contractor with general contracting capability in the market.

JOINT MANAGEMENT MODE OF OWNER-LED CONSULTING SERVICE COMPANIES

Under this mode, the owner shall appoint the project manager to lead the construction and management of the project team. This project manager has the authority to review and approve the technical, design scheme, and construction schemes on behalf of the owner; distribute consulting tasks to the consulting service company; coordinate with a third party in evaluating and appraising the consulting result; and establish the business process of project operation. Usually, apart from the project manager, the owner establishes a procurement team and recruits other project managers to collectively complete the project examination and approval, bulk engineering, and equipment procurement, and other works. Meanwhile, the role of the consulting company is similar to that of an adviser, who proposes solutions for the assigned consulting tasks to the project managers.

For the management mode of an owner-led consulting service company, the success or failure of the project depends not only on the choice of the project manager and consulting service company but also on the effect of the entire project management organization and coordination. At the same time, aside from possessing rich project experience and management knowledge, a project manager should be familiar with professional technology, and the procurement personnel should also have a certain understanding of proprietary equipment and non-standard customized equipment. Based on the above analysis, the comparison of the above four modes is listed in Table 1.

TABLE 1.Comparison table of Project Implementation and Construction Management Mode

Mode	Outsourcing Mode (DB\EPC\Turnkey)	Self-management Mode	Consultant Mode of Outsourcing Consulting Service	Joint Management Mode Led by the Owner
Owner's Workload	According to the contract, the owner's workload should be minimal.	The owner has the largest workload and is responsible for the entire project completion process.	The workload is small, and the owner mainly works with expert teams or consulting service companies.	Owners are responsible for a huge chunk of the workload.

Cost	The highest	With good operation, project cost is expected to be the lowest.	Lower than outsourcing	Depends on the effect
Construction Period	The shortest	It depends on several factors.		
Quality	The most guaranteed	There is a certain guarantee.	It depends on several factors.	
Personnel Requirements	As long as the necessary docking personnel is employed, the number of personnel required is minimal.	Most people needed	It has to be staffed by a certain number of people.	With a good project manager, the number is second only to self-management mode.
Contractor's Responsibility	Responsible for the final results of the project	Delivery in accordance with the contract, but no responsibility for the final results	Develop a technical plan and provide a process package to ensure an advanced and reasonable production line.	
Risk	The minimum	The biggest	Smaller	Bigger
Scope of Application	Mature product line, suitable for new enterprises	Leading enterprises in the industry with a strong technical force	Enterprises with certain project management experience and similar industry background	

There is no absolute optimal mode among the abovementioned modes. For any comprehensive project on the utilization of mineral resources, it may be difficult to find contractors with general contracting experience and consulting service companies with actual case experience in the market. Design and research institutes as well as consulting service companies must also analyse specific materials and conditions and pass the required tests before conceiving and proposing technical solutions. Compared to other types of projects, the comprehensive utilization of mineral resources has more rigid requirements, including a longer process flow, more strict formalities for examination and approval, larger investments, higher requirements for environmental protection and safety, longer construction period, and so on. Therefore, choosing the management mode of the implementation and construction of the project should be based on the environmental factors and other specific situations, including the owner's management level, human resource reserves, project budget, and target, to name a few.

CASE STUDY

This paper analyses how a mining company in Hechi City located in the Guangxi Zhuang Autonomous Region chose its project implementation and construction mode for the comprehensive utilization of resources. The aim of this work is to provide a decision-making reference for the construction process of the same type of projects.

The mining company in this case has vast zinc sulphide mineral resources rich in high germanium in Guizhou and Guangxi. On the basis of the characteristics of zinc sulphide concentrate, the enterprise has chosen the international advanced oxygen pressure leaching process to produce electrolytic zinc. Currently, it has built a production line with an annual

output of 50,000 tons of electrolytic zinc. Conventional associated elements, such as sulphur, lead, silver, and cadmium, are recovered in different forms. However, germanium, which has the highest value, cannot be enriched and utilized effectively for various reasons. In view of the above situation, the mining company has decided to launch a new project for the comprehensive utilization of germanium metal resources. Its main goal is to recycle 50 tons of germanium of metallic volume annually to produce high purity germanium dioxide and zone-refined germanium ingots, which in turn, will generate sales income of 325 million yuan. The total investment is 120 million yuan, and the project land covers a total area of about 20000 square meters. The main unit consists of two production buildings, one affiliated workshop, one R&D centre, one sewage treatment station, one transformer and distribution station, one storage tank area, a raw and auxiliary materials warehouse, and a finished products storage facility. The construction period is projected to be 2 years.

The enterprise has been established within a short period of time, and the main engineering and technical personnel and management personnel are allocated according to the labour quota of a zinc smelter. The enterprise temporarily arranges three part-time personnel for this comprehensive germanium utilization project.

FEASIBILITY ANALYSIS OF OUTSOURCING MODE OF THE GENERAL CONTRACT FOR DB, GENERAL CONTRACT FOR EPC, AND TURNKEY PROJECTS

Several large-scale germanium industry companies in China have already mastered the technology required for the comprehensive recovery and deep processing of germanium. The core processing equipment, which is non-standard and customized, is difficult to purchase directly on the market. Even large metallurgical research and design institutes with strong technical capabilities usually do not have the ability to execute general contracting of design, construction, and operation. Furthermore, the management fees of outsourcing mode are charged according to the proportion of the total investment. Taking EPC as an example, contractors charge project management fees at a rate of 5%–15%. If the mining company in the case adopts the outsourcing mode for the construction project, the management fees will be 6–18 million yuan.

The outsourcing mode can effectively avoid the disadvantage of the lack of knowledge and experience in this field. For the mining company's comprehensive utilization of germanium metal resources, the main risks lie in selecting qualified contractors; agreeing on important terms, such as contract scope, construction period, quality, and cost; and choosing the design scheme. The advantages of outsourcing mode are its low risk, professional design and construction, and reliable quality, while its main disadvantages are high cost, low participation, and weak control of owners.

FEASIBILITY ANALYSIS OF THE SELF-MANAGEMENT MODE

In this mode, the owner should hire external professional technical personnel and management personnel from all aspects. Additionally, a set of efficient management systems is needed for all professional personnel to cooperate effectively and successfully complete the construction task. The project manager must be able to master the technology and understand the project construction process in order to coordinate effectively. Combined with the previous experience and the specific circumstances of the current project, if the project uses the self-management mode, the personnel quota should be 12 people, and the per capita labour costs should be 280,000 yuan/year (including salary, bonus, welfare, insurance, tax, etc.).Therefore, the annual labour cost will be 3.36 million yuan, and the total labour cost of the entire construction period is expected to be RMB 6.72 million.

On the one hand, the main risks of the self-management construction project come from the external staff, such as their failure to meet the requirements of professional knowledge and ability, the team fit-in failure, and the midway resignation. On the other hand, the advantage of the self-management mode is that it can make full use of internal technical personnel; thus, the cost is often relatively lower. However, its main disadvantages are that it requires a large number of personnel and professional categories, imposes a heavy workload for the organization and coordination efforts, and has a high risk of failure.

FEASIBILITY ANALYSIS OF THE CONSULTANT MODE OF OUTSOURCING CONSULTING SERVICE

Although the existing company personnel may have some experience in engineering project management and professional reserve in the field of zinc metallurgy, they may be unfamiliar with the direction of germanium comprehensive utilization and deep processing, especially in the purification of high-purity materials and semiconductor physical testing. From market research, we learned that a large germanium plant, established for half a century in China, has a complete range of products and production technology covering the entire process of enrichment, purification, and deep processing, while also possessing strong research and development capabilities. This year, due to the restructuring and transformation of the enterprise and other factors, some technical personnel have set up a team to establish a consulting service outsourcing company that can provide technical services for new renovation projects of germanium resources comprehensive utilization and deep processing industry in the domestic market.

Therefore, the consultant-type mode of consulting service outsourcing can solve the problem that enterprises are difficult to independently undertake construction projects. After contact and negotiation, it is estimated that the consultant mode of technical service outsourcing has to pay about 3 million yuan for technical service fees.

On the one hand, the consulting service outsourcing mode has two advantages: the owner can fully play the role of external forces with the help of external management and technical personnel, and the cost is lower than the outsourcing mode. On the other hand, the main risk comes from the selection of the consulting team or consulting service company, as well as the signing and fulfilment of the contract.

FEASIBILITY ANALYSIS OF JOINT MANAGEMENT MODE OF OWNER-LED CONSULTING SERVICE COMPANIES

The most critical aspect of the joint management mode of owner-led consulting service companies is the selection of project managers. This is because the project managers selected by the owner should not only have professional skills in the non-ferrous metal metallurgy and semiconductor materials field but also possess the ability in technical project management, leadership, strategy, and business management (Project Management Institute, 2017). In addition, the services of a technical expert who is familiar with the comprehensive utilization of germanium resources and deep processing technology and equipment are required.

Currently, the mining company has no personnel reserve that meets the above conditions; thus, it needs to entrust the task of directional recruitment to a head-hunting company.Based on *liepin.com*salary statistics for high-end talents, the salary of project managers and technical experts should range from 500,000 yuan and 400,000 yuan per year. Hence, in accordance with the two-year construction period, the additional cost of human resources will be 1.8 million yuan, and the consulting company will pay about 1 million yuan, thus reaching the total amount of 2.8 million yuan.

This mode requires the project manager to connect the comprehensive utilization of germanium resources and the construction of the deep processing project withthe mining

company's various functional departments and the construction of a zinc production line. Therefore, the technical experts can solve the connection between the zinc line and the germanium line, that is, how to separate both lines in an efficient and environment-friendly manner.

On the one hand, the advantages of the joint management mode of the owner-led consulting company are that the owner can comprehensively control the cost, quality, safety, and schedule of the project construction. On the other hand, the main risks lie in whether qualified project managers can be selected, whether the outsourcing consulting company clearly understands the project intention and is able to provide professional consulting services, and whether the project manager can connect the germanium production and construction with other departments and zinc production lines.

SELECTION OF THE MANAGEMENT MODE

After conducting site investigation and data collection, it is now clear that the mining company has engaged in the mining and beneficiation of zinc sulphide ore and has some experience in the construction of nonferrous metal metallurgical plants. However, it lacks talents in the comprehensive utilization of germanium resources and has a limited understanding of the process, equipment, installation, and debugging of germanium recovery and processing.

As the germanium of a mining company is associated with zinc sulphide concentrate, the most important aspect of the comprehensive utilization of germanium resources is to "not only make the recovery rate of the main metal zinc rise to more than 95% but also ensure the recovery of associated silver and germanium" (Wang & He, 2005). Consequently, it is essential to select a highly efficient, green, and environment-friendly key technology to separate germanium from the solution, dust, and slag of the zinc system in accordance with the characteristics of raw materials and the main process flow of zinc. Inthe future, on the one hand, germanium extraction work should further optimize the existing technology. On the other hand, it should focus on the exploration and development of green, efficient, and environment-friendly new technology (Zhang et al., 2020). At present, the existing technology in the industry still has many disadvantages and is not yet suitable for the specific situation of the owner.
After further conducting the diagnosis analysis ofthe mining company in terms of enterprise environmental factors, organizational process assets, and organizational structure, the relevant conclusions are as follows:

1. The company has sufficient funds and reserves for the proposed project, and the project construction mainly relies on its own funds.
2. The project of comprehensive utilization and deep processing of germanium resources lacks technical reserves. In particular, the mining company has unique raw materials. However, the current process that prevails in the industry is not efficient, low-cost, and green when it comes to the comprehensive utilization of germanium resources. Thus, the enterprise urgently needs the most appropriate technology to recover germanium efficiently.
3. The comprehensive utilization of germanium resources is an open circuit from oxygen pressure leaching and zinc hydrometallurgy. The selection of technical scheme and process flow should not only consider low cost and efficient recovery but also the influence of the oxygen pressure leaching of zinc hydrometallurgy and the avoidance of the introduction of iron, copper, lead, cadmium, cobalt, fluorine, chlorine, and other inorganic elements and high water-soluble organic matter into the zinc sulphate solution.
4. The zinc smelting project of the enterprise has required the training of some project managers and engineering technical personnel in various fields, such as metallurgical technology, construction, structure, water supply and drainage, HVAC systems, electrical,

mechanical, along with other human resources, especially management personnel who are familiar with the site management, approval, and construction business.

5. The mining company has established a relatively complete set of enterprise management systems, including the decision-making mechanism of major concerns, the organizational structure, the procurement management system, and the use of foreign technology.
6. Many aspects of the comprehensive utilization of germanium resources must dock with oxygen pressure leaching hydrometallurgy zinc, such as the project land, water and electricity supply, public works, road greening, fire protection, and drainage, to name a few.

In view of this case, the possibility analysis, cost calculation and advantages and disadvantages analysis of four implementation and construction modes are carried out above. This combined with the situation of a mining company further SWOT analysis as shown in Table 2.

TABLE 2. SWOT Analysis Table

Internal ability **External factors**	**Strength**	**Weakness**
	a) Well-funded b) Resource advantages c) Perfect management system d) Some professionals have been reserved	a) Complex ingredients b) No similar project experiences c) New project should connect with zinc line d) Lack of core technical personnel
Opportunities	**SO**	**WO**
a) **The market has an optional advisory team** b) **Project managers and technical experts are available** c) **Perfect management system** d) **Professionals are partially stocked**	Adopt "owner-led joint management mode" a) Recruit project managers and technical experts b) Choose a consulting service c) Improve management process	Adopt an "advisory model" a) Select a team of consultants b) Signing a service contract c) The client collaborates with the consultant to implement the project
Threats	**ST**	**WT**
a) **External contractors have no case experience** b) **Higher fees for outsourcing** c) **External personnel do not meet the requirements** d) **The consultant team cannot fulfil the contract**	Adopt "Autonomous management Mode" a) Recruit all kinds of people b) Determine technical solutions and construction plans c) Promoting projects	Adopt the "outsourcing model" a) Performance contractor b) Sign general contract c) Client monitors contract execution

Along with the SWOT analysis of the respective advantages and disadvantages of the construction mode and the diagnosis analysis of the mining company, market research shows that there is no suitable general contractor in the market and that the self-management mode has high costs and high risks. A further comparison between the consultant mode of consulting service outsourcing and the joint management mode of owner-led consulting service company shows that the cost difference between the two is not significant. Furthermore, the owner retains the right to make purchasing decisions and make the final confirmation of technical solutions and processes. However, in terms of more specific aspects, such as the selection of equipment, general layout, workshop layout, architectural planning and design, the two modes of owner role and participation in the degree of control are different. If the owner is willing to undertake greater responsibility and fully control the construction process, he/she should choose the joint management mode of owner-led consultancy services. On the contrary, the consultant mode of consulting service outsourcing should be chosen.

CONCLUSION

The implementation and construction modes of a project on the comprehensive utilization of mineral resources are divided into four types according to the construction party's chosen level of engagement. Each mode has its own advantages and disadvantages. This paper compares and analyses the four modes from the aspects of the construction party's workload and level of involvement, as well as other factors, including cost, construction period, quality, personnel quota, contractor's responsibility, and risk. The results show that the implementation and construction mode of the new or rebuilt/expanded projection the comprehensive utilization of mineral resources should consider the construction scale, technical level, the characteristics of raw materials, and degree of difficulty, as well as the enterprise's conditions. Furthermore, different modes have a different scope of application. Only in this way can the owner ensure the premise of investment, progress, quality, and obtain better economic and social benefits.

Will the rapid development of the economy in China, numerous enterprises have ignored the common problems that have been highlighted in this paper. In the case study of the comprehensive utilization project of germanium resources in a mining company in Hechi City, Guangxi Zhuang Autonomous Region, this work combined the theories mentioned above in analysing the activities of the mining company within a domestic market in analysing the activities of the SWOT analysis of the enterprise.

This work is concluded by providing suggestions on the mode selection of project implementation and construction. The chosen case could be a typical selected sample that can be used as reference by studies on the comprehensive utilization of resources and mode selection. Finally, the results can also provide feasible guidance—from the perspective of educational significance—for companies who are facing to the same situation.

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