Senior Capstone Projects: Student Success from an Impossible Design

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Abstract

The senior capstone design project in Mining Engineering consists of a mining operation pre-feasibility study adhering to the Security and Exchange Commission's SK 1300 guidelines. Students begin with a drill hole and topology dataset and must complete the feasibility report to the best of their ability. This includes geostatistical analysis of the drill holes, pit optimization, mine scheduling, equipment selection, mineral processing, reclamation, and market/economic analysis. Like in industry, students strive to create the most economical mine design. However, like in industry, not every deposit is guaranteed to be a financial success. Students whose projects fail to break even in the economic analysis reexamine the design choices for the project. This leads to an iterative design process, novel approaches requiring research, and raises ethical challenges of estimating and reporting. This will improve students' ability to transition to an industry where tough decisions must be made, and bidding for projects must be realistic.

Keywords

Capstone Design, Industry Project, Mining Engineering, Iterative Design

Introduction

The senior capstone design class for the Missouri University of Science and Technology's Mining Engineering program consists of two semesters of coursework. The fall semester students form groups and can obtain data from their industry contacts or be provided data from the instructor. The spring semester is focused on designing a mine and writing a professional report based on the SEC's SK 1300 requirements for publicly traded mining companies [1], [2]. The list of required chapters is provided below. The specific details for each chapter can be found in the SK1300 information guide [2].

1. Executive Summary
2. Introduction.
3. Property description.
4. Accessibility, climate, local resources, infrastructure, and physiography.
5. History.
6. Geological setting, mineralization, and deposit.
7. Exploration
8. Sample preparation, analyses, and security.
9. Data verification.
10. Mineral processing and metallurgical testing
11. Mineral resource estimates.
12. Mineral reserve estimates
13. Mining methods.
14. Processing and recovery methods
15. Infrastructure.
16. Market studies.
17. Environmental studies (etc.)
18. Capital and operating costs.
19. Economic analysis
20. Adjacent properties.
21. Other relevant data and information
22. Interpretation and conclusions
23. Recommendations.
24. References
25. Reliance on the information provided by the registrant.

The minimum data required to start a capstone project is geologic data such as drill holes, a surface topology map, and a property location. This project starts from a minimal initial data set but through the design process incorporates the entire mining curriculum into a final capstone design. Mine design is a complicated, iterative process, and there is not always a clear starting point.

When writing the SK1300 report for the capstone design course, many sections can stand alone without the need for iteration. For example, climate information, property history, and geological setting can be considered research chapters. The research chapters are where many assumptions and constraints are determined. Hydrology data is not directly provided, but students are expected to research local hydrology information based on the location of the mining property. Chapters 11 through 19 are considered design chapters. These require significant design, calculation, and engineering decision-making to complete. The designs and decisions must be reexamined at each step to ensure previous assumptions still hold.

Students often create designs that must be discarded once other aspects of the project make them obsolete. An extreme example would be discovering a local ordinance that limits water draw. This could cause a change in the processing plant from a water-based method to a dry process. This will generally be accompanied by an increase in the required feed grade, limiting the tonnage that can be mined. Mining equipment selection and optimization must be recalculated with the lower capacity. One small change can cause a complete redesign from the beginning. This example is visualized in Figure 1, using the chapters of the pre-feasibility report as the nodes. Due to the numerous interactions between design components and the various independent decisions, there is no single software that can optimize the entire pre-feasibility process. This manual redesign and iteration the students must endeavor will be the focus of this paper.

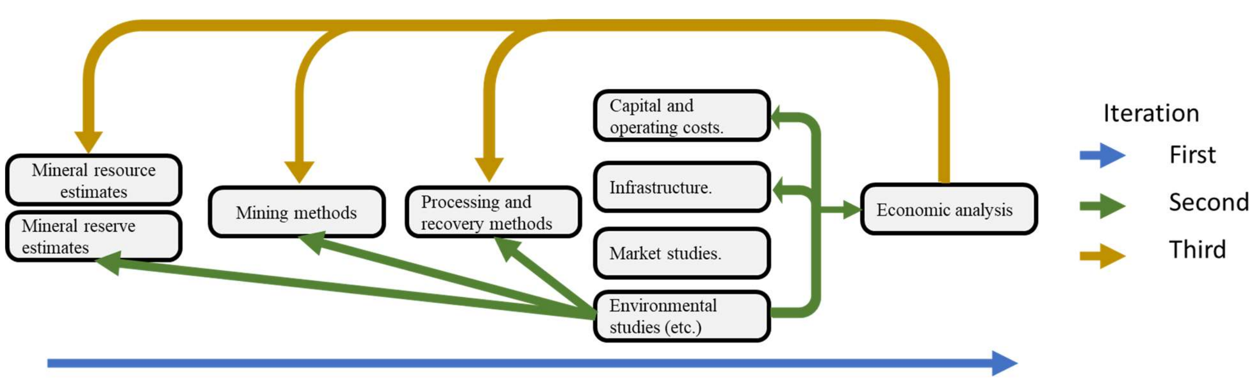

Figure 1. Example Iteration Process

Methods

The Mining and Explosives Engineering department recently hired a new teaching professor who is taking over the capstone design class. For the first two years, the professor only taught the final semester of the senior capstone design. The previous instructor still taught the first semester, where the data was provided and the initial designs started. While other professors serve as judges for trial presentations and provide assistance in their speciality when needed, the capstone design course is managed by the single professor.

This year, nineteen students formed six groups. Groups 1 and 2 received anonymized data from an industry society data set, Groups 3 and 4 were provided data from operating mines, and Groups 5 and 6 were provided data from mining companies not currently mining the deposit. The groups were provided, at a minimum, the drill holes, topology, and location of the property. A summary of the data sources are shown in Table 1.

Table 1. Data Sources

Group Number	Direct Source	Indirect Source
1	Industry Society	Anonymous
2	Industry Society	Anonymous
3	Professor	Operational Mine
4	Internship	Operational Mine
5	Professor	Pre-Mining Property
6	Professor	Pre-Mining Property

Throughout the second semester, Groups 5 and 6, who received data from the inactive properties struggled to develop designs. Both mines had restrictions due to nearby waterways that limited the options for traditional mining. Group 5 decided to use a dredge, which is not a method taught in the curriculum. Group 6 chose to mine in phases, using an aggressive pumping strategy to the previous phase as a dewatering pit.

Results

Groups 1 and 2 participated in an international, industry-run, design competition with several design constraints geared at challenging their design skills. At specific points, additional information was revealed that needed to be incorporated into the design. This allowed some iteration in the design, but with the very short time to work due to competition deadlines, fewer iterations on the design could be conducted in much detail. Since the design competition runs concurrently with the capstone design, use of the data has been allowed for the academic class. However, each mining school can only enter one team to the competition, so this is not a viable option for all groups in the class.

Group 3 chose to challenge themselves with a type of mining they had no experience. This led to an intense research focus for their design. They taught themselves a new modeling method for stratigraphic seams. The seam type deposit did not allow many options for iteration on mine design as only one is logically possible, but the group tried several iterations of equipment selection.

Group 4 selected data from a mine one of the group members interned with. The mine wanted a second opinion on the design they have been using. The group was able to confirm that the design was economically feasible. However, the group followed the existing plan very closely and pushed back when asked to investigate other methods as they had a feasible design.

Group 5 focused much effort on alternative mining methods. The high water table made it immediately apparent that traditional truck and shovel operations would be complicated. The students knew of dredges but had no previous design work with them. They researched pipe sizes and pump characteristics required for the mining operation. They designed an onboard primary sizing circuit to reduce material handling costs and a discharge into the pit to eliminate fine recirculation. The initial box cut to float the dredge was another opportunity for novel ideas. The group researched underwater dozers and slack drag lines but settled on a traditional backhoe and truck operation performed by a contracting company to reduce capital expenditures.

Group 6 encountered the water table at a depth of 30 ft in their 60 ft deposit. The bearing capacity of unconsolidated sand and gravel is severely reduced when saturated with water. They ran designs staying above the water table and dewatering the entire pit. Dewatering the whole pit provided additional challenges in researching the local geology for the permeability of gravel. In this region, the high clay content creates a barrier to groundwater flow but is highly dependent on the immediate grade. The group included contingencies in case the clay barrier is breached during mining.

Neither Group 5 nor 6 could design a profitable mine by the semester's end. Looking at the mines the data was sourced from, Group 5's source was never attempted to mine, and Group 6's source has gone through multiple companies and multiple bankruptcies in the last 20 years. While these groups were unsuccessful in designing a profitable mine, they were successful in demonstrating how to conduct a pre-feasibility study and designing mines that met safety, environmental, and engineering standards. The successful analysis of a mining property fulfills the capstone design requirements, regardless of the economic success of the property.

Summary

Six groups were given data for the senior capstone design project to perform a pre-feasibility report based on the SEC's SK 1300 reporting requirement. Two groups were provided data from real mines that were not profitable, and neither student group could design a profitable mine from the data.

The students in groups with unprofitable mines performed more iterations of mine designs than the other groups and conducted more research into uncommon or novel mining methods. Even with the mine not being feasible, the students demonstrated competency in designing and analyzing mining projects.

The increased research and iterative design processes could better prepare students for industry. The Capstone Design class will continue to provide challenging data that is not guaranteed to be a profitable mine. The professor can perform data manipulations to ensure challenging projects. This could include deeper deposits, changing water tables, introducing faults, or creating environmental/regulatory barriers. Other engineering disciplines may also benefit from creating impossible challenges and be surprised by the ingenuity and novel ideas it can create.

References

[1] *Modernization of Property Disclosures for Mining Registrants, 17 CFR §229.1300-1305*.
[2] *Standard Instructions for Filing Forms Under Securities Act of 1933, Securities Exchange Act of 1934 and Energy Policy and Conservation Act of 1975—Regulation S-K, 17 CFR 229.601(b)(96)*.

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Dr. Alexander Douglas, is an Assistant Teaching Professor at Missouri University of Science and Technology (Missouri S&T). He previously worked as the Lead Service and Support Engineer for Hexagon Mining's Safety product line in North America before returning to school to obtain his Ph.D. from Missouri S&T in 2021. Dr. Douglas's research interests encompass a wide range of topics, including vehicle automation, operational safety and road maintenance. He teaches classes in mine power and drainage, mine safety, senior design and materials handling. Additionally, he holds a professional engineering license and is a certified mine safety instructor.