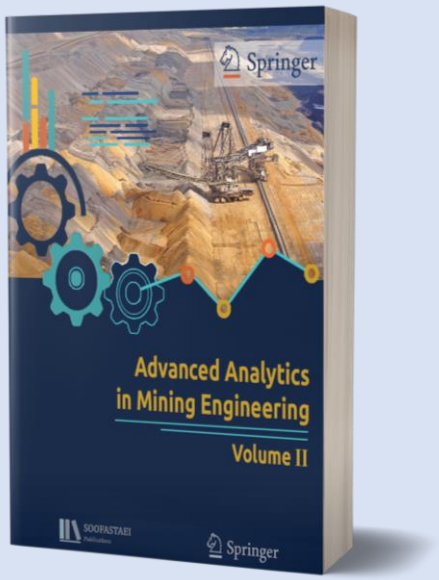
Advanced Analytics in Mining Engineering
Volume II



Aim

The book aims to provide practical help for executives, managers, and research and development teams to identify where and how to apply advanced data analytics in their enterprises. The use of advanced data analytics can support Their goals of improving energy efficiency, productivity, and reducing the associated costs of maintaining their mining operations.

The book is aimed at providing mining executives with an understanding of the business value and applicability of different analytic approaches and helping data analytics leads by giving them a business framework in which to assess the value, cost, and risk of potential analytic solutions. In addition, the book will provide the next generation of miners - undergraduate and graduate students of IT and mining engineering - with an understanding of data analytics applied to the mining industry. By providing a book with chapters structured in line with the mining value chain, we will provide a clear, enterprise-level view of where and how Advanced Data Analytics (ADA) can best be applied. In particular, we highlight the potential to interconnect activities in the mining enterprise better. We explore the opportunities for optimization and increased productivity offered by better interoperability along the mining value chain – in line with the emerging vision of a creating a Digital Mine with much-enhanced capabilities for modeling, simulation and the use of digital twins – in line with leading “digital” industries like automotive and aerospace.

Objectives

The Objective of the book is to provide a concise overview of the state of the art of advanced data analytics for mining executives and managers. They will value a book that helps them position the emerging capabilities of advanced data analytics in their businesses and provide an assessment of where and how these new capabilities can help to optimize the end to end operations of their mining enterprises.

For data analysts, geologists, mining engineers, operators, and specialists along the mining value chain, the book will explain how to implement advanced data analytics, using case studies and worked examples, and will help prepare students and graduate engineers to apply new advanced analytics in practice. For critical supporting functions like the IT and OT teams, the book will provide guidelines on how data needs to be collected, stored, and managed and what supporting architectures and infrastructures are needed to enable different advanced data analytics methods to be applied effectively in practice.

Mining companies are transforming how they mine, seeking to take advantage of operating a digital mine in which decisions are guided by analysis of operational data and decision support tools can present minute by minute advice to guide and trade-off risk, value, and cost. Increasingly a “whole of mining enterprise” view is being taken, driven by the need to optimize the business at an enterprise rather than a functional level.

This book is a timely reference source that mining enterprises can use to guide their digital mining journey and, at the same time, create some immediate value as part of their wider business transformation.

Scope

The book describes the key challenges facing the mining sector as it transforms into a digital industry able to fully exploit process automation, remote operation centers, autonomous equipment, and the opportunities offered by the “Industrial Internet of Things.

The book will guide the application of advanced data analytics by considering each of the major activities undertaken along the mining value chain of typical, operating surface and underground mines.

Each of the first eleven chapters focuses on one of these major activities, starting with exploration and ending with material transportation. The final two chapters are devoted to two specific, increasingly important dimensions of mining: Health and Safety followed by Environmental aspects – each an essential aspect of a mine’s social license to operate.

Each chapter describes one of the major mining value chain processes, the inputs required, and the deliverables created. The overall process dependencies and the upstream and downstream connectivity are highlighted, with particular reference to the levels and types of interoperability required so that advanced data analytics techniques can be applied to improve functional performance while driving wider, enterprise-level optimization.

A key objective of this book is to help readers understand where advanced data analytics (ADA) can be applied most successfully along the mining value chain, how to build practical ADA applications and, most importantly, how to develop optimization capabilities along the mining value chain, using ADA tools that link multiple Level 1 mining activities to create value chain optimization – a step towards the digital mine vision of Enterprise Level Optimisation.

The book provides an analysis of ADA Exploration techniques with a study of ADA in Deposit Assessment, Mine Management, and Mining Methods Selection – all areas in which traditional high-performance computing (HPC) and large data sets (Big Data) have been the norm for T1 miners, and areas in which ADA is making inroads. This is followed by ADA studies of mining methods: Rock Breaking, Ground Mechanics, and Infrastructure Services. The latter includes aspects like power and water usage, asset management, and mine communications – high-cost drivers with significant environmental impacts.

Chapters 8 and 9 consider the use of ADA in surface and underground mining development and extraction, respectively. These activities involve the use of complex, high value, high recurring cost assets, many of which are the target for automation or full autonomy and are therefore essential candidates for the application of ADA technologies. Significant progress has been made in this area in mining, and adjacent sectors (e.g., agri-business) and increased use of ADA will take place to squeeze increased returns from the high-value assets deployed.

Chapter 10 considers mineral processing – an area in which sophisticated levels of process control have been deployed for many years. The capability to better connect mineral processing operations to upstream and downstream activities, enabled by improved communications and IIoT developments, is explored and ADA opportunities described and detailed through case studies.

In Chapter 11, the opportunities for using ADA to improve material transportation – at mine site as well as from pit-to-port and beyond, is presented, with applications in road, rail and shipping areas considered. The connectivity of material logistics to product blending and marketplace “pull” systems is considered, and role ADA will play in optimizing these activities, along with the potential for Blockchain to manage extended, connected supply chains is assessed.

Chapters 12 and 13 exclusively will explain the role of ADA in health, safety, and environment. All of these subjects are interesting topics for mining companies globally.

Each chapter includes a high-level summary and provides case studies for executives and managers as well as technical details for ADA technologists.

Chapters

Chapter Description:

Due to the decrease in commodity prices in a constantly dynamic environment, there has been a constant urge to maximize benefits and attain value from limited resources. Traditional empirical and numerical simulation techniques have failed to provide comprehensive, optimized solutions in little time. Coupled with the immense volumes of data generated on a daily basis, a solution to tackle industry challenges became imminent. Various expert opinion fraught with bias has posed extra challenges to obtain timely, cost-effective solutions. Data Analytics has provided substantial contributions to several sectors. This chapter presents a review of various advanced data analytics and Machine Learning applications in mining exploration.

Chapter Contents:

- Introduction to Exploration
- Geological Features and Genetic Models of Mineral Deposits
- Minerals Prospecting and Exploration
- Geophysics Prospecting
- Geochemical Prospecting
- Summary

Chapter Description:

The application of advanced data analytics, machine learning, and artificial intelligence in the mining industry is growing fast. One of the essential subjects in the mining value chain is the deposit assessment. This chapter aims to present an introduction of deposit assessment in mining, a summary of geological data collection, geologic interpretation, modeling, and representation. Moreover, this chapter discusses the sample preparation and assaying process and ore-body sampling and metallurgical testing. Furthermore, other subjects, including mineral resource estimation, valuation of mineral properties, mineral property feasibility studies, and cost estimation for underground and surface mines, are discussed in this chapter.

Chapter Contents:

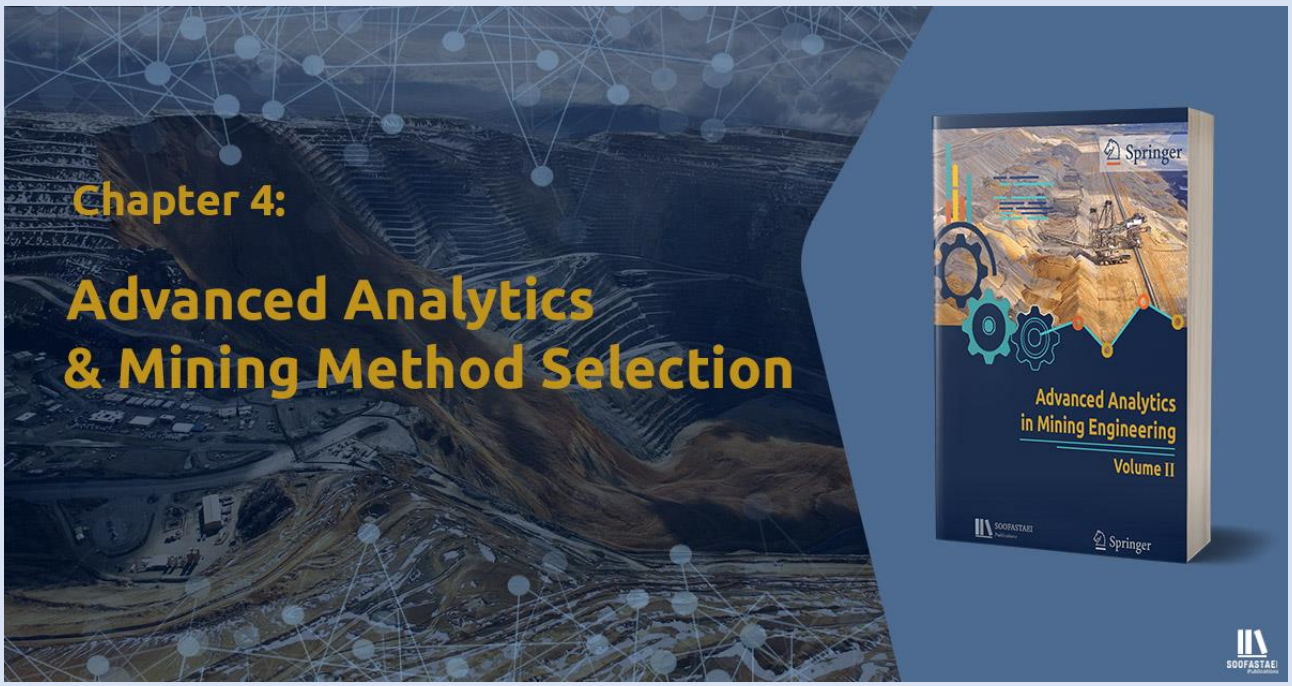
- Introduction to Deposit Assessment
- Geological Data Collection
- Geologic Interpretation, Modelling, and Representation
- Sample Preparation and Assaying
- Ore-Body Sampling and Metallurgical Testing
- Mineral Resource Estimation
- Valuation of Mineral Properties
- Mineral Property Feasibility Studies
- Cost Estimating for Underground Mines
- Cost Estimating for Surface Mines
- Summary

Chapter Description:

The unprecedented demand for natural resources is driving mining companies to strive for step-change in the efficiency and optimization of their business processes. Advanced analytics techniques are being applied in other industries to enable significant improvements in both strategic and operational business processes by optimizing decision making. Today, decisions are usually locally optimized but do not achieve optimum capability for the value chain. Although mining operations now collect more information than ever before, it is difficult to bring all this information to bear to make better decisions. This chapter looks at how these advanced analytics techniques can be applied to the fundamental challenges faced by the mine management. This chapter will cover some critical subjects in mine management, such as mine economics, management, and low, employee relations, and training, and finally, a global perspective on mining legislation.

Chapter Contents:

- Introduction to Mine Management
- Mine Economics, Management, and Law
- Economic Principles for Decision Making
- Management, Employee Relations, and Training
- A Global Perspective on Mining Legislation
- Summary



Chapter Description:

The selection of the mining method is one of the most crucial decisions in the design stage of mine that mining engineers have to make. Selecting a mining method for mineral resources is completely dependent on the uncertain geometrical and geological characteristics of the resource. It is necessary to the unique characteristics of each mineral resource be taken into account to select the suitable mining method for the extraction of a certain resource so that the utilized method would have the maximum technical-operational congruence with the geological and geometrical conditions of the mineral resource. To make the right decision on mining method selection, all effective criteria related to the problem should be taken into account. Increasing the number of evaluation criteria in the decision-making problem makes the problem more complex, but also the rightness of the decision increases. Therefore, there is a need for alternative methods, which can consider all known criteria related to surface and underground mining methods selection in the decision-making process. The sensitivity of this decision has led to different solutions introduced by different researchers. Advanced analytics has been introduced as one of the practical tools to decide to select the mining method. This chapter provides a comprehensive investigation of the use of advanced data analytics to compare the underground and surface mining methods. This investigation can open a new door in Infront of mining engineers and managers to make better decisions to select the mining method.

Chapter Contents:

- Introduction to Mining Method Selection
- Evaluation of Mining Methods and Systems
- Mining Methods Classification System
- Selection Process for Hard-Rock Mining
- Selection Process for Underground Soft-Rock Mining
- Comparison of Underground Mining Methods
- Comparison of Surface Mining Methods
- Summary

Chapter Description:

Rock breaking processes, including drilling and blasting, are the most economical techniques to achieve rock fragmentation in mines and quarries. The main objective of these processes is to realize the fragmentation in the desired size, keeping up with the constraints of ground vibration, air overpressure, fly-rocks, and stability. Analytics can be of help in several considerations by providing a better understanding of the process. An advanced analytics solution can help in faster decision-making and manage the data generated throughout the rock breaking process in mining. Additionally, data generated during the drilling and blasting operations can be stored in a central database, which can be used in the future. The power of advanced analytics can be used to evaluate the data, identify key performance variables, implement changes, and appraise the outcome. This presents an incredible opportunity to leverage the data generated during the rock breaking process such that improvements in terms of cost and fragmentation can be achieved. This chapter discusses the role of advanced analytics in mechanical rock breaking, drilling, and blasting.

Chapter Contents:

- Introduction to Rock Breaking
- Mechanical Rock Breaking
- Blast hole Drilling
- Explosives and Blasting
- Summary

Chapter Description:

Advanced Analytics is the autonomous or semi-autonomous examination of data or content using sophisticated techniques and tools, typically beyond those of traditional business intelligence (BI), to discover deeper insights, make predictions, or generate recommendations. Advanced analytic techniques include those such as data/text mining, machine learning, pattern matching, forecasting, visualization, semantic analysis, sentiment analysis, network, and cluster analysis, multivariate statistics, graph analysis, simulation, complex event processing, neural networks. Advanced analytics is a powerful tool in the field of ground mechanics. This chapter presents the application of advanced data analytics in hard and soft rock ground control, surface mine subsidence, tailing impoundments and dams, waste piles, and dumps.

Chapter Contents:

- Introduction to Ground Mechanics
- Soil Mechanics
- Slope Stability
- Rock Mechanics
- Geotechnical Instrumentation
- Hard-Rock Ground Control
- Soft-Rock Ground Control
- Mine Subsidence
- Tailings Impoundments and Dams
- Waste Piles and Dumps
- Summary

Chapter Description:

Advanced analytics—the ability to generate valuable insights from large amounts of data—has emerged as a powerful tool to understand and learn from the past performance as a guide to more accurately predict trends. Analytics creates value when big data and advanced algorithms are applied to business problems to yield measurable improvements. By identifying, sizing, and prioritizing the biggest opportunities, businesses can create an analytics strategy that generates value. Mine asset owners and industry professionals hold a tremendous amount of data on the condition, maintenance, and operation of infrastructure and services, and this data can be used to improve their capital-planning decisions greatly. Although infrastructure and services players in mining increasingly use advanced analytics, this industry still tends to lag behind others, such as retail, financial services, and automotive, in embracing advanced analytics comprehensively across the mining projects life cycle. As a result, many mine asset owners experience weaker capital productivity than what we see in other sectors, as they are making major decisions based on primarily qualitative rather than quantitative factors. Incorporating advanced analytics into the capital- mine planning phase can radically improve the ability of mine owners to make decisions based on the expected performance of their existing infrastructure and services. It can also help mine owners and operators generate deeper insights and value on maintenance versus replacement decisions and asset-longevity trends. This chapter provides the technical information that we need to use advanced analytics in mining infrastructure and services.

Chapter Contents:

- Introduction to Infrastructure and Services
- Electric Power Distribution and Utilization
- Compressed Air
- Mine Communications, Monitoring, and Control
- Mine Surveying
- Dewatering Surface Operations

- Dewatering Underground Operations
- Physical Asset Management
- Mine Infrastructure Maintenance
- Summary

Chapter Description:

The global mining industry is under pressure. In the short term, falling commodity prices are squeezing cash flow. Looking ahead, many existing surface mines are maturing, resulting in the extraction of lower ore grades and longer haul distances from the mine face; ore-body-replacement rates are in decline, and new surface mine-development times are increasing. The mining industry has shifted its focus to improving productivity by "sweating" existing assets, but this strategy will go only so far. Despite the industry's booms and busts, the nature of surface mining has stayed the same for decades. Achieving a breakthrough in productivity performance demands rethinking how mining works. The potential to achieve such a breakthrough is now coming within the industry's reach through digital and technology innovations that could transform key aspects of mining. This chapter provides a comprehensive study on the role of advanced analytics in surface mining operations, including open-pit planning and design, mechanical extraction, loading, hauling, equipment selection, and maintenance.

Chapter Contents:

- Introduction to Surface Mining
- Open-Pit Planning and Design
- Mechanical Extraction, Loading, and Hauling
- Selection and Sizing of Excavating, Loading, and Hauling Equipment
- In-Pit Crushing
- Design, Construction, and Maintenance of Haul Roads
- Strip Mining
- Highwall Mining
- Summary

Chapter Description:

The potential of using advanced analytics in underground mines is now coming within the industry's reach through digital and technology innovations that could transform key aspects of the mining industry. This chapter describes several digital technologies that have long been in the works and are now available and affordable enough to become operational at scale across the mining industry. The applications of advanced data analytics in underground mining include building a more comprehensive understanding of the resource base, optimizing material and equipment flow, improving anticipation of failures, increasing mechanization through automation, and monitoring performance in real-time. This chapter also presents the role of advanced analytics in underground equipment selection and sizing, underground horizontal and inclined development methods, construction, and underground ore movement.

Chapter Contents:

- Introduction to Underground Mining
- Hard-Rock Equipment Selection and Sizing
- Soft-Rock Equipment Selection and Sizing
- Underground Horizontal and Inclined Development Methods
- Construction of Underground Openings and Related Infrastructure
- Underground Ore Movement
- Summary

Chapter Description:

In the globalized market environment, increasingly significant economic and environmental factors within complex industrial plants impose importance on the optimization of global production indices; such optimization includes improvements in production efficiency, product quality, and yield, along with reductions of energy and resource usage. Mineral processing plants are one of the most data-rich parts of any mining operation. Historically, process analysis and optimization have been undertaken by skilled operators and metallurgists, experienced in monitoring fluctuations in behavior. However, this relies heavily on the presence of highly skilled people with sufficient experience in the operation to interpret results. Data from individual unit operations is often used in this process to support hypotheses, but the capability to use integrated data sets from across the operations has not been available. The development of advanced data analytics techniques, deep learning, machine learning, and artificial intelligence now means that the tools are available in mineral processing to better use the data. In recent years advances have been made in the development and implementation of tools such as Digital Twins, and today we will explore how those can be used to drive genuine improvements. This chapter presents the application of advanced data analytics in crushing, milling, grinding, classification by screens and cyclones, gravity concentration and medium-heavy separation, froth flotation, magnetic and electrostatic separation, and dewatering.

Chapter Contents:

- Introduction to Mineral Processing
- Crushing, Milling, and Grinding
- Classification by Screens and Cyclones
- Gravity Concentration and Medium Heavy Separation
- Froth Flotation
- Magnetic and Electrostatic Separation
- Dewatering
- Summary

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Chapter Description:

The mode of mine access (e.g., vertical shaft, inclined drift, in-seam access via outcrop, etc.) determines the nature of transport systems used to transport personnel and materials into the mine (shaft hoisting, drift haulage, or rubber tyred vehicle access). However, the large majority of mines today use diesel-powered, rubber tyred vehicles (RTV's) to transport both personnel and materials within the mine, largely because of the flexibility of that system, with occasional track vehicles for special purposes. The most popular type of materials transport involves using diesel load/haul/dump (LHD) machines as tractors to tow materials trailers. It is normal to have a "Quick Detach System" (QDS) fitting for the bucket so it can be easily removed and replaced with various attachments for the specific purpose (e.g., a work platform for high work, a reeler for cables, or conveyor belts, etc.). These results in a very versatile system where the prime movers can also be used for excavation or clean-up work and material transport and other miscellaneous work. With this system, it is normal to have a different type of vehicle for personnel transport, though personnel pods for the QDS are available. Rail transport throughout mines was once the prevalent system (before developing suitable rubber tyred transports) and is still used in some mines. Rail systems have some advantages because they are generally faster than free steered vehicles, and one operator can transport bigger loads. Much of this advantage is lost, however, at the tail end, which cannot be very close to the working faces. LHD machines or some similar arrangement are then required to complete the trip. The large equipment involved with modern longwalls requires the use of specialized transport equipment. Because this equipment is only required infrequently, it is normal practice to hire such equipment as required (or mining groups to carry such equipment to share between several mines). Nowadays, the mined material transportation systems inside the mines (haul trucks, conveyor belts, etc.) and outside the mines (locomotives, vessels, etc.) make the huge datasets daily big data is a general problem for mine material transportation in the mining industry. Advanced data analytics methods can perfectly help the mining companies to solve this issue and generation valuable information from raw data. This approach can reduce the total cost of mined material dramatically.

Chapter Contents:

- Introduction to Material Transportation
- Locomotive and Rail Ways and Material Shipment
- Summary

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Chapter Description:

The mining industry has a reputation for being a risky business, with health risks that are varied and often quite serious, and miners need to protect themselves accordingly. Nevertheless, mining doesn't have to be unsafe. With the introduction of strict safety legislation and protocol and advances in safety equipment, the industry has seen its fatality rate drop over time. Although the goal of zero harm has not yet been achieved, it remains the standard that mining companies continue to strive towards. Understanding and being aware of the environment is the first step to preventing illness or injury in the mining workplace. Some common health risks to watch out for in the mining industry include coal dust, noise, whole-body vibration, UV exposure, musculoskeletal disorders, thermal stress, and chemical hazards. The mining industry has made significant improvements in health and safety over the last decade, reducing fatalities and serious injuries. However, the mining industry still has one of the highest rates of fatalities of any industry. Advanced data analytics and auditing the work procedures can dramatically help the mining companies to improve safety and decrease the incidents rates in the mine sites. Developing prediction models can use historical datasets to predict new accidents, injuries, and fatalities. Optimization models can provide practical suggestions to change the procedures and decrease human and machine errors to increase safety. Moreover, the artificial intelligence algorithms can help managers to make better decisions in this field.

Chapter Contents:

- Introduction to Mining Health and Safety
- Mine Ventilation
- Health and Medical Issues in Global Mining
- Gas and Dust Control
- Heat, Humidity, and Air Conditioning
- Radiation Control
- Noise Hazards and Controls
- Summary

Chapter Description:

Environmental impacts of mining can occur at local, regional, and global scales through direct and indirect mining practices. Impacts can result in erosion, sinkholes, loss of biodiversity, contamination of soil, groundwater, and surface water by the chemicals emitted from mining processes. These processes also have an impact on the atmosphere from the emissions of carbon, which affect the quality of human health and biodiversity. Some mining methods may have such significant environmental and public health effects that mining companies in some countries must follow strict environmental and rehabilitation codes to ensure that the mined area returns to its original state. The impact of the mining industry on the environment has been a public concern, with a growing appreciation of the natural environment and increasing awareness of the possible harmful effects that the industry's activities can cause. The industry and government have responded with several initiatives and regulations to protect and manage the environmental effects of mining activities. The extractive nature of mining operations creates various impacts on the environment before, during, and after mining operations. The extent and nature of impacts can range from minimal to significant, depending on a range of factors associated with each mine. These factors include the characteristic of the ore body, the type of technology and extraction methods used in mining and the on-site processing of minerals, and the sensitivity of the local environment. The environmental impacts of mining, although significant, are generally confined to local areas. Apart from the direct physical impacts of extractive activities, contamination of air, land, and water may also result. However, mining in isolation may not be the mainland use that upsets ecological systems, as environmental effects are cumulative in nature, and other past activities or events may have contributed to these effects. This chapter discusses the main environmental impacts of mineral mining, such as wastes and the rate of resource use (where the supply of minerals depends on the rate of resource use, which is affected by the economic life of mineral deposits and the rate at which new reserves are discovered). This chapter also summarizes environmental management initiatives, such as using advanced data analytics to reduce the negative impacts of mining operations on the environment.

Chapter Contents:

- Introduction to Mine Sites Environmental Considerations
- Impacts and Control of Blasting
- Water and Sediment Control Systems

- Mitigating Acid Rock Drainage
- Waste Disposal and Contamination Management
- Closure Planning
- Summary