PRECISION HAUL TRUCK OPERATOR COACHING

Combining Machine Learning
and Targeted Simulator Training

A Partnership Study:

IMMERSIVE TECHNOLOGIES

CASCADIA SCIENTIFIC

INTRODUCTION

In mining, even small decisions made by an operator can add up to a big difference in how efficiently a site runs. Not through dramatic mistakes or headline-grabbing mishaps, but through the subtle, everyday decisions that compound over thousands of haul cycles. Cascadia Scientific's data tells a fascinating story: the gap between the most skilled operators and the least can stretch beyond 10% in fuel efficiency. And when you look across mine sites around the world, the same pattern repeats itself - quiet, consistent, and impossible to ignore.

That gap is the difference between a mine hitting its cost targets or quietly bleeding millions of dollars a year. And yet, in the shifting, unpredictable conditions of large-scale open-pit mining - where haul distances change, weather turns roads into rivers, and every shift looks different - pinpointing operator performance is notoriously difficult.

To close that gap, a major Colombian coal operation worked with Cascadia Scientific to deploy machine-learning-based operator scorecards, paired with targeted simulator training from Immersive Technologies. The goal was clear: measure performance accurately, identify where improvement was needed, and coach with precision.

What follows is the story of how that program worked - its methodology, its results, and why it offers a powerful blueprint for mining operations around the world.

Contents

FUEL EFFICIENCY PROGRAM

Cascadia Scientific's Operator Modelling + Immersive Technologies Simulator Training

At a leading open-pit mine, Cascadia Scientific partnered with Immersive Technologies to launch a cutting-edge fuel efficiency program for haul truck operators. By combining Cascadia's advanced data analytics and machine learning insights with Immersive's industry-leading simulator training, the program delivers targeted, actionable coaching that drove measurable improvements in operator performance and fuel consumption. This integrated approach empowers operators to optimize driving techniques in a safe, controlled environment while ensuring continuous improvement out in the field.

Operator Fuel Efficiency Program:

Operator Model → Coach → Train → Measure
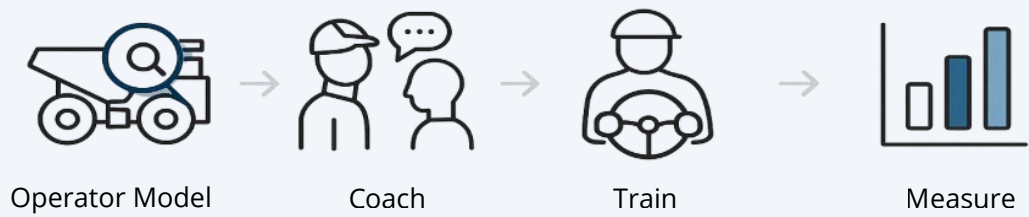
1. IDENTIFY UNDERPERFORMING OPERATORS (CASCADIA SCIENTIFIC)

Machine learning models were built to evaluate each operator's performance. Operators whose performance falls 1 standard deviation below the mean are flagged for progressive coaching.

2. PROGRESSIVE COACHING PLAN

Flagged operators (~16% of the roster) first received a letter; if performance did not improve, they met one-on-one with their manager, and if still below target, they were sent to Immersive Technologies for simulator-based training.

3. IMMERSIVE TECHNOLOGIES SIMULATOR TRAINING

Targeted fuel efficiency training, delivered through Immersive Technologies simulator programs, were deployed to correct specific operator behaviours.

4. MEASURE FUEL EFFICIENCY IMPACT IN THE FIELD

Post-training data was compared to pre-training performance to quantify real-world gains.

UNDERSTANDING THE MODEL

Data Collection - Including High Accuracy Fuel Flow Meters

They say a model is only as good as the data it's built on. Cascadia Scientific didn't leave that to chance. Their instrumentation package - equipped with fuel measurement systems providing over 99% accuracy - captured the story behind every drop of fuel burned. But fuel alone wasn't enough. By pairing this with detailed vehicle telematics - tracking operator assignments, payloads, cycle times, distances - they created a rich, reliable data tapestry. This wasn't just data; it was the foundation for a model that could truly understand the nuances of haul truck operator fuel use.

SmartRView

- *Fuel consumption (fuel flow meters)*
- *Loaded and unloaded distance*
- *Loaded and unloaded vertical travel*
- *Loaded and unloaded engine hours*
- *Payload*
- *Equipment:*
- *Year and Month*
- *Operator:*
- *Temperature*
- *Cumulative 12-hour precipitation*

Operator Efficiency Modelling

Imagine trying to predict fuel use on a haul truck, where every cycle varies - different payloads, haul profiles, weather, and more. Traditional averages just don't cut it. So, Cascadia Scientific builds machine learning model using gradient boosted trees - a technique that blends many simple decisions into one powerful prediction.

But predictions alone aren't enough. We need to understand why. That's where SHAP values come in. Borrowed from game theory, SHAP values reveal how much each factor - like payload, distance, idle time, or weather - contributes to fuel consumption on each cycle. By accounting for all these variables, it becomes possible to isolate the operator's unique impact on fuel use.

This means, no matter the truck or shift, Cascadia Scientific can fairly measure and compare how each driver's impact affects fuel efficiency.

Impact of Haul Cycle Variables on Fuel Consumption
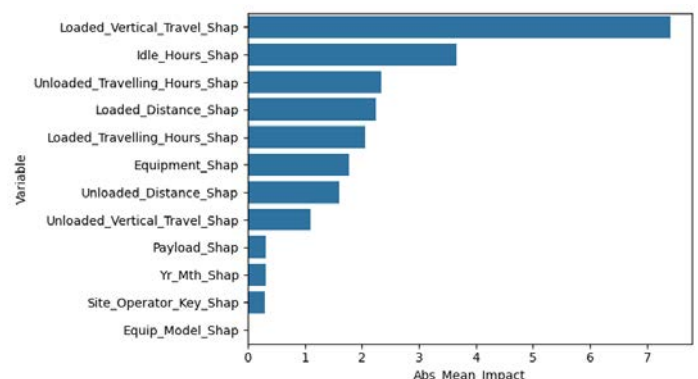
TARGETED OPERATOR TRAINING

Building fuel-efficient habits through Immersive Technologies training

Even seemingly small operator habits - especially less efficient ones - can quietly drain fuel and drive up costs. Cascadia's models flag the operators who need support, beginning with coaching and then moving them into Immersive Technologies' simulator program. There, in a safe and realistic environment, habits were reshaped with real-time feedback, turning practice into measurable gains in the field.

Operator Training Methodology:

ADVANCED EQUIPMENT SIMULATORS

Immersive Technologies simulators create realistic mine training environments for equipment operation. This allows operators to practice and master fuel-efficient operating techniques without risking equipment damage or causing production delays.

SKILLS DEVELOPMENT & BEHAVIORAL CHANGE

Training focuses on specific behaviors that lead to fuel waste, such as excessive engine RPM, proper brake usage, speed control and proper gear selection. By practicing these skills in a simulator where real time feedback and prompts are given, operators learn to operate more efficiently in the mine.

REDUCED RISK AND COST

Training on simulators eliminates the need for unproductive machine time and reduces the risk of machine damage, leading to fewer delays and lower overall costs for operations.

DATA-DRIVEN INSIGHTS

The simulator platform stores assessment data and all scores can be securely reported to management and trainers, allowing them to monitor workforce progress and identify areas for additional performance improvement.

THE RESULTS

From Worst to Better: How Every Low Performer Improved

At this site, the story starts with the operators who struggled most. Twenty-one drivers - already flagged with warning letters and one-on-one coaching - went through Immersive Technologies' simulator training. Every single one of them improved. On average, they cut their own fuel use by 11.45% compared to how they'd been driving before. That's a remarkable shift.

Across all haul cycles, modeled trucks averaged 39.43 gallons per hour. The gap between the best and worst operators was 3.37 gallons - 8.5% of total use. Simulator training didn't erase that gap, but it began to close it, tightening the spread. Trained operators used 0.386 fewer gallons per hour, shrinking the operator impact from 8.5% to 7.5% - a 1% lift in overall fleet efficiency. Small numbers, yes - but in mining, even small efficiency gains add up fast.

Distribution of Operator Performance Before and After Training
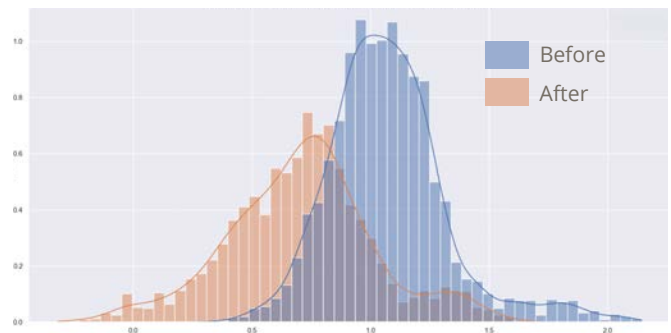
Operator Fuel Efficiency Program

802 TOTAL OPERATORS MODELLED

IDENTIFY UNDERPERFORMING OPERATORS
128 operators (16%) had performance greater than one standard deviation below the mean, triggering the start of the progressive training program.

PROGRESSIVE COACHING PLAN
128 operators got a letter; some had one-on-one manager meetings. Those who didn't improve were sent to Immersive training. 21 operators (~2.6% of the roster) completed simulator training.

MEASURE FUEL EFFICIENCY IMPACT IN THE FIELD
Post-training, operators cut fuel use by 0.386 gallons per hour - **an 11.85% improvement over their own baseline**, and nearly a 1% gain in overall fleet consumption.

CONCLUSIONS

In mining, the person behind the wheel quietly shapes the economics of an operation. This study showed that pairing Cascadia Scientific's data-driven operator insights with Immersive Technologies' simulator training can deliver real, measurable fuel savings.

It's important to recognize the study's scope. Only 2.6% of the operating roster - the lowest performers - were tracked through this program. Scaling this approach to more operators could unlock far greater savings. Also, the mix of mechanical and electric trucks introduces complexity; mechanically driven trucks may reveal even stronger operator effects.

The partnership between Cascadia Scientific and Immersive Technologies offers mines a full-circle solution: identify underperformers with precision, deliver targeted training, and measure results in the field. This is more than a pilot program - it's a blueprint for how mining operations can turn subtle operator habits into significant cost savings and sustainability gains.

The question now isn't whether operator training works, but how to embed it - combining continuous insight with targeted refreshers so performance becomes a sustained advantage rather than a passing win.

CONSISTENT RESULTS: ALL 21 TRAINED OPERATORS IMPROVED THEIR FUEL EFFICIENCY.

OPERATOR SPECIFIC BENEFIT: 11.85% FUEL EFFICIENCY BOOST FOR TRAINED OPERATOR.

HAULAGE FLEET IMPACT: CASCADIA SCIENTIFIC & IMMERSIVE TECHNOLOGIES' TRAINING LED TO A 1% IMPROVEMENT IN FUEL CONSUMPTION FLEET WIDE.

Acknowledgments:

We extend our sincere thanks to the dedicated operators and management team at the operation in question for their cooperation and commitment throughout this program. Their openness to innovation and continuous improvement made this study possible. Special thanks to the technical teams at Cascadia Scientific and Immersive Technologies for their expertise and collaboration in developing and delivering the integrated training solution.

We also acknowledge the data science and analytics teams whose rigorous work ensured the accuracy and reliability of the performance measurements. Finally, we appreciate the support from mine leadership in championing this initiative and fostering a culture that values both safety and efficiency.