Oil Sand Operation Simulation Using HAULSIM-Practical Guide

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ABSTRACT

Many sectors around the world want to optimize their operations to give the best and most effective ways of extraction. This is difficult to attain since experimenting on the grounds would be expensive. With the introduction of Industry 4.0, many mining companies are entering into an era of using software and digitization to make processes cost-effective and cheaper. The introduction of simulation software has made it easier for researchers to create scenarios to enable them to select the best scenario for the operation. This paper will focus on the use of HaulSIM, a mining simulation software that will be used for creating simulations of different scenarios. This paper will describe how discrete event simulation software HaulSIM is used to create a haulage network model. Discrete event simulation software is one of the few products that is recommended for developing real-time simulation models.

1. Introduction

Oil sands operations are one of the most popular operations in the North of Alberta. Oil sand is a combination of loose sands or partially consolidated sandstone containing a naturally occurring mixture of sand, clay, and water, soaked with bitumen, a dense and extremely viscous form of petroleum (Pierre-René, 2006). The extraction of oil is very expensive, so most oil sands companies want to find ways and means to mine oil sands without incurring any loss and efficiently optimize their equipment and processes. The use of simulation software such as HAULlSIM is a practical way that is used for simulating mining operations. Noriega and Pourrahimian (2022) have reviewed the applications of artificial intelligence and data-driven approaches in strategic open pit mining. Some of the instances of using simulation technique in mining optimization include the following; Afrapoli and Askari-Nasab (2020) have developed an integrated simulation-optimization framework truck dispatching in surface mining, Ben-Awuah et. al. have used discrete event simulation for hierarchical mine production scheduling. HAULlSIM is a mining simulation software that was developed by RPM Global. It uses discrete event simulation since it can capture everything around the environment. It quantifies the impact of changes in a haulage system and helps the user to test for "why" and "what-if" scenarios. This will enable the mine to select the most optimum and efficient method or process thereby improving safety and reducing costs. The features of HAULSIM include; Discrete Event Simulation, Electric vehicle, hydrogen, and hybrid simulation, Industry's largest public equipment library, Intuitive use, 3-D user interface, Trusted travel time calculations, and smart haulage decisions. We are going to give a brief guide on the use of HAULSIM for haulage networks in the oil sands operation. The most important thing to consider in modeling haulage systems in Oil Sands mines is to first receive accurate data from the surroundings of the area. The data should be accurate to prevent errors when simulating the model to give accurate results.

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In modeling an oil sands operation, one needs to first understand the haulage system in the oil sands operation. The material is mined with a shovel and dumped in haul trucks and hauled to the destination. In model development, HAULSIM is the software that will be used in the development of the simulation model. HAULSIM connects fleet assets, mining operational plans, and people to build a 'digital twin' of any mining operation - open pit or underground - to deliver an accurate representation of any mine site's haulage operations (RPM Global). The features of this software as listed above make it one of the most effective software for simulating mining operations. For this reason, HAULSIM will be the effective software for modeling this operation

2. Methodology

The data was obtained from the shell productivity database in which the EFH productivity table was used for the analysis. The model was therefore built from this data. The data included the following parameters; Year, Month, Day, Shift, Crew, DumpUnit, DumpLoc, EqmtUnit, EqmtType, Truck, Area, TruckOperName, Material, Tonnage, MeasuredTonnage, EmptyHaul, QueueTime, SpotTime, WaitToSpot], LoadingTime, FullHaul, DumpIdle, DumpingTime, CycleReady, CycleDelay, CycleSpare, CycleDown Speed, DistEH, LiftEH, LiftDistEH, DropEH, DropDistEH, DistFH, LiftFH, LiftDistFH and many more that is not listed. These parameters were used to build the model and analyze the data. The model was built with the HaulSIM software and will be analyzed with the PowerBI software. The following data will be analyzed and the future work will be proposed.

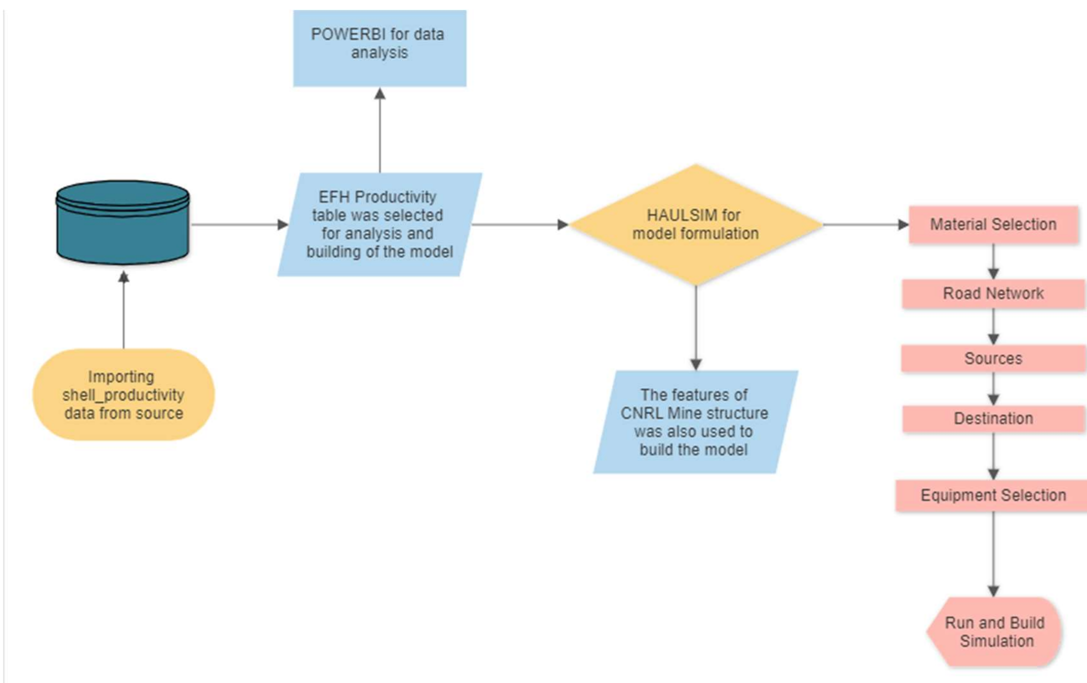

Figure 1 Flowchart of the model formulation.

2.1 Material Selection

The type of material that is hauled is really important in the analysis and simulation of the model. There are typically different types of material according to the data. But the material that is of most interest is the ore and waste. Since it is oil sands the material is loose sand and the material attributes such as the in-situ bank density, excavatability, swell factors and loose density, loader bucket fill factor, and load and haul or Load Carry Times should be considered. The values of the attributes of the material will be inputted by right-clicking on the material tab on the navigation pane, configuring it, and making the following changes to material attributes on the material pop-up pane. You click on add material and select earth-dry material and then review the information on the material pop-up menu. This information will give you the various attributes of the material such as the swell factor, in-situ density, the struck and the heaped capacity. You close the window and save the project.

2.2 Road Network

The road network of the mine is necessary for the modeling process. The importance of the road network is to determine the speed at which the equipment moves around. When you import a CSV file, it must contain the String ID (which represents the grouping of nodes that belong to the same road), as well as the coordinates of each X, Y, and Z node. Each node is shown on its own line in the file. The road network has various indications; Grey represents the waypoints; blue represents the intersection and yellow represents termination points. Understanding the signs can help you with route analysis when simulating equipment on the road. On the navigation panel; left click on the road network and import the file for the road network and then save it. You can also show the grades on the road network using the legend button on the toolbar. Configure cutting planes by changing the elevation on the Build toolbar and selecting Configure. This helps you understand the dimensions of the road from top to bottom.

2.3 Sources

In simulation modeling of the haulage operation, the material is moved from the source which is the Load and Carry and Load and Haul and hauled to the destination which can be the dump, stockpile, crusher, Haul Load point, and Ore Pass In. In this case, the material is hauled from the digging location and stockpiles to the destination. The material is hauled from the Load and Haul unit and either sent to the dump or stockpile in the oil sand Mine. To import the source file, you click on the location on the navigation pane, select sources, open the file, and import. The next step is to configure and make changes to the methodology to single or double-sided and save the file. The next step is to navigate around the grids. To do this you need to click on the navigation pane, expand the location tab and select source, right-click on the source tab, and choose to configure. Click on the filter icon to select and filter the preferred source. Close the pop-up window and then save the project.

2.4 Destination

Destination in HAULSIM is where the truck will dump the material from the source. It is the end route of the road network. These are the following destinations according to the data; dump, crusher, and stockpile. The destination file is imported or manually added just like the source file. In this model, we will be dealing with three destinations: dump, stockpile, and crusher.

To import the destination file, you click on the location on the navigation pane, select the location and then destination, click on import, and then select the file and import. The information on the file will appear on the import destination pop-up window, you click on next and import. The next step is to configure and make changes to the destination pop-up window which will give the user the liberty to make changes to the layout, crush rate, initial quantity, material, and capacity of the following three destinations listed above, and then save the project.

2.5 Equipment Selection

Finally, after configuring the material, road, sources, and destination. We need to be able to simulate the equipment thoroughly to better understand the effectiveness of the model. Adding equipment to the model is one of the closest steps to completing the model. There is various equipment such as loading units, load and haul units, load and carry units, ancillary units, conveyors, and feeders. The shovel is assigned at the source of the location, the shovel fills the haul units which are the dump truck. The dump truck hauls the unit to the destination which is either the dump, stockpile, or plant. The ancillary equipment is the equipment that is not involved in the material movement but makes hauling and loading easier. The grader is for creating an even surface on the road to prevent bumps on the road, and the dozer is for pushing the material into a heap for the loader to easily dig the material. The ancillary equipment such as the loader and the grader are added to the model to give it a more realistic scenario.

2.6 Run and Build Simulation

When the model is finally built, you can then run and build the simulation, you can select the start time and date and the duration of the haulage. You can also view the simulation in a 3D view and view the functionalities while the simulation is running. These are the following functionalities, yellow triangle- Loading; purple triangle- Travel loaded, green triangle- Travel empty, pink diamond- Waiting and Red Square-Blocked. The dashboard after the simulation has been run is used to view and track material movement, tasks, states, performance, and costs.

To run the simulation, you need to first click on the run tab, click and drag and type any value and then click run. Click the Task tab, click on the productivity tab and the material movement tab, and then save the project.

3. Data Analysis

We obtained data from CNRL, this data contained the various destinations, dig locations, equipment, cycle time, and material types that are found in the mine. With this data, we designed a simple model of the mine taking into consideration the following factors above.

With the data analysis, we will explore the data of the CNRL Data and analyze the given data. The data was stored in a structured form in a database form. From the database, 1000 rows of data were selected to be exported and analyzed. The data was exported to SQL Server and the data was analyzed using the PowerBI software.

3.1 Location of Sources and Destination with Measured Tonnage

This graph below shows the Measured payload among the destinations in the mine. The Measured payload is the difference between the Gross vehicle weight with the load in it and the actual weight of the vehicle without the load. The difference is the actual weight that the truck is hauling. From the bar graph, it can be deduced that the digging location has the most material. The least amount of material is in the stockpile, the crusher, and the in-transit material have almost the same amount of material, followed by the dump. From the data, it can be inferred that the digging location has the most material because that is where the material is taken from. Also, from the graph, the material taken to the crusher is a little higher than the dump.

At 66,195,224.73, Crusher had the highest Sum of Measured Tonnage and was 192,695.07% higher than In-Transit, which had the lowest Sum of Measured Tonnage at 34,334.50. Crusher accounted for 65.33% of Sum of Measured Tonnage. Across all 5 Dump Unit, Sum of Measured Tonnage ranged from 34,334.50 to 66,195,224.73.

From the second graph, the measured tonnage was plotted against the digging location in the mine. At 94,095,286.30, DigLoc had the highest Sum of Measured Tonnage and was 55,743,552.01% higher than Dump, which had the lowest Sum of Measured Tonnage at 168.80. DigLoc had the highest Sum of Measured Tonnage at 94,095,286.30, followed by Stockpile at 7,231,189.46 and Dump at 168.80. DigLoc accounted for 92.86% of Sum of Measured Tonnage. DigLoc had 94,095,286.30 Sum of Measured Tonnage, Stockpile had 7,231,189.46, and Dump had 168.80.

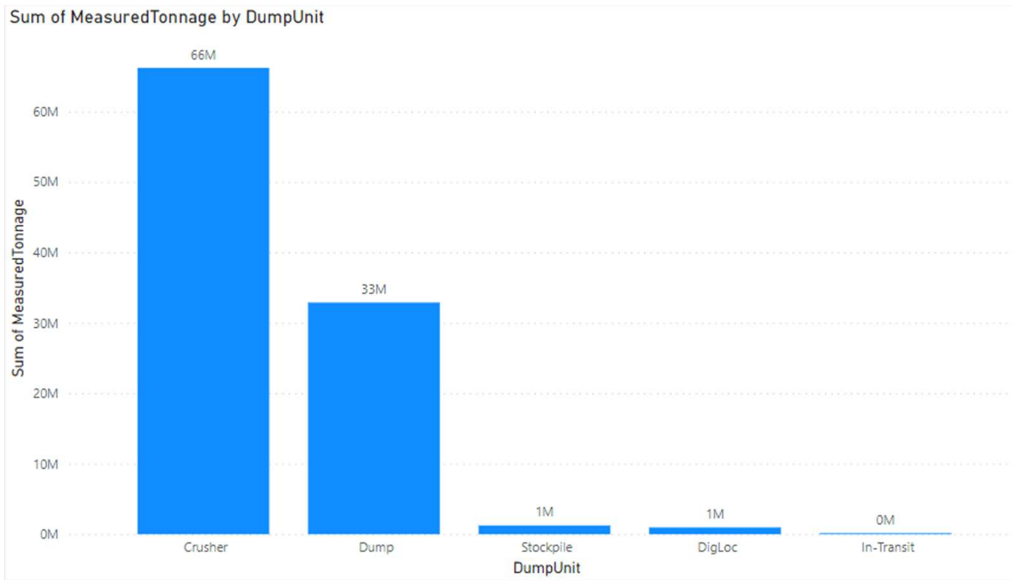

Figure 2. Graph showing Measured tonnage against dump unit.

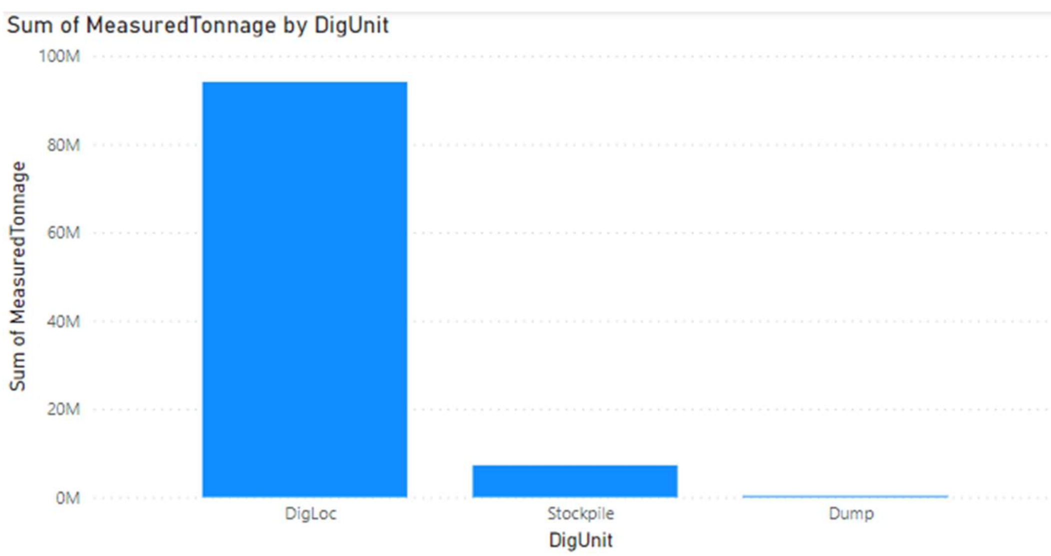

Figure 3. Graph showing Measured tonnage against dump unit.

3.2 Measured Tonnage with Truck and Shovel Types

Just from the last graph that showed the different types of trucks and their capacity, this graph also shows the different types of shovels and their measured tonnage. The BE 495B2 loads the most material, looking at the graph. The MISC loads the least material in the mine. From this graph, the mine can select the type of shovel in any case of a future purchase or replacement. They might purchase the machine with the most productivity or further assign those shovels to dig locations where the material is crucial to be moved that week. At 56,534,182.83, BE 495B2 had the highest Sum of Measured Tonnage and was 1,614,562.62% higher than Cat 330CL, which had the lowest Sum of Measured Tonnage at 3,501.30. BE 495B2 accounted for 55.79% of Sum of Measured Tonnage. Across all 9 tblDataShovelType, Sum of Measured Tonnage ranged from 3,501.30 to 56,534,182.83.

From the second graph, the various types of trucks were plotted against the measured payload. The types of trucks and their payload amount. The CAT 797B and the CAT797 have the most amount of material, compared to the CAT785. It can be inferred the most of the material is hauled by the CAT 797 compared to the CAT 785. Sum of Measured Tonnage for Cat 797B (90,749,247.90) was higher than Cat 785 (10,577,396.67). Cat 797B accounted for 89.56% of Sum of Measured Tonnage. Cat 797B had 90,749,247.90 Sum of Measured Tonnage and Cat 785 had 10,577,396.67.

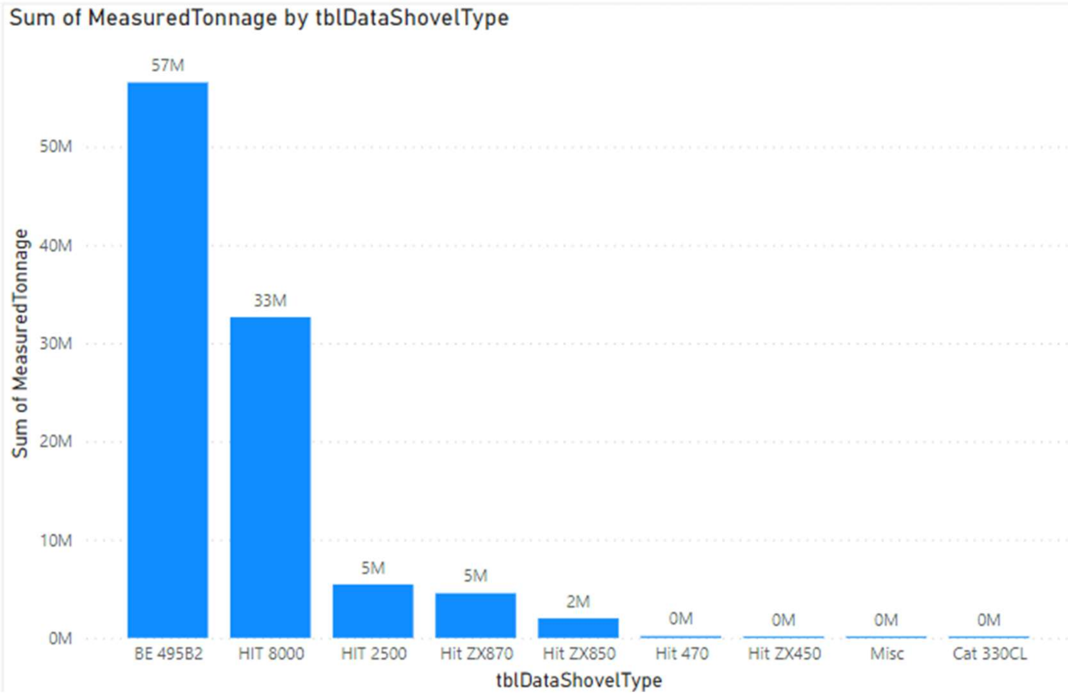

Figure 4. Graph showing Measured tonnage against shovel type.

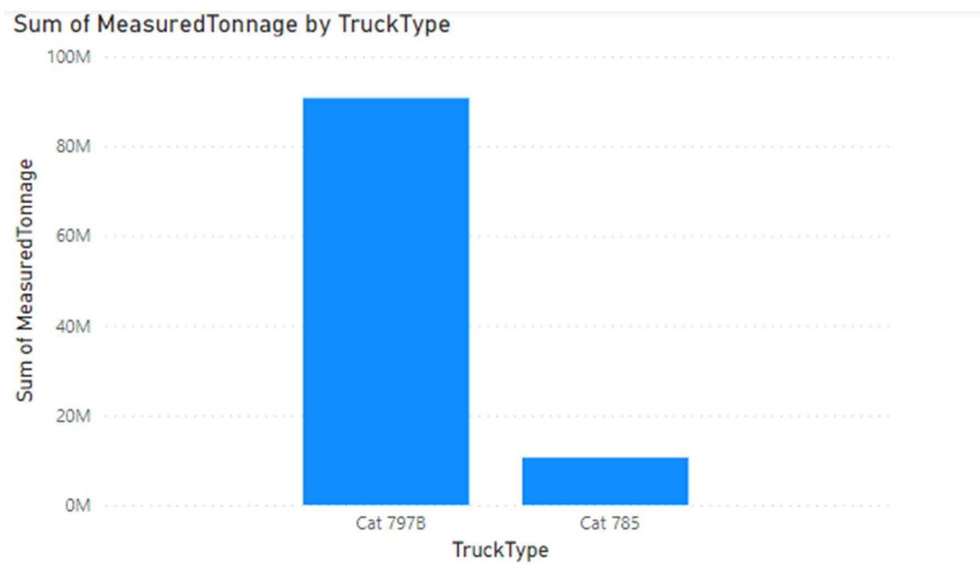

Figure 5. Graph showing Measured tonnage against truck type.

3.3 Measured Tonnage with Material Types

The measured tonnage was plotted against the material found in the mine. Of the various types of material and the measured tonnage, the most amount of material is the type 1 material which is the in-transit material, followed by the ore and the least amount of material is the type 6 material. The second most moved material is the ore which is good but other more material which is not profitable to the mine is also moved. The mine must find a way to move less material that is unprofitable to the mine. At 61,712,616.30, Ore had the highest Sum of Measured Tonnage and was 56,409,968.96% higher than Reclaim, which had the lowest Sum of Measured Tonnage at 109.40. Ore accounted for 60.90% of Sum of Measured Tonnage. Across all 25 Material, Sum of Measured Tonnage ranged from 109.40 to 61,712,616.30.

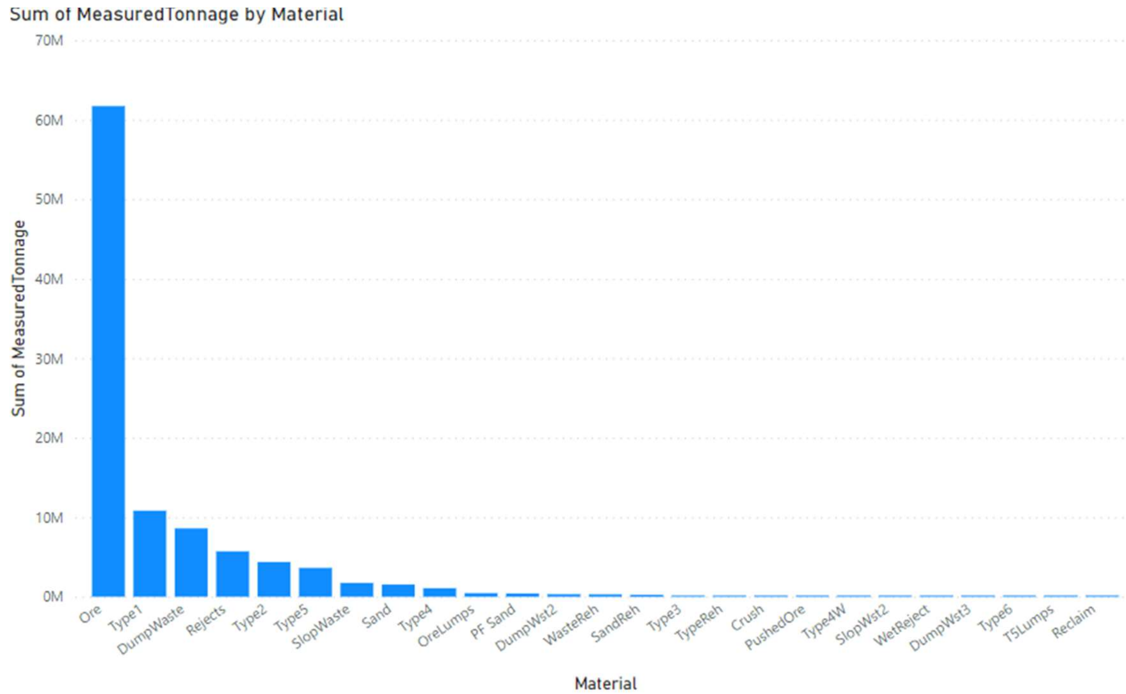

Figure 6. Graph showing Measured tonnage against Material type.

3.4 Cycle Time for Trucks

The cycle times for both trucks were recorded as part of their data. The graph of the loading and queuing times was shown and from the chart, it can be seen that the loading times for the CAT 797B and CAT 797 were shorter than the CAT 785. From the queuing time, you can see that the CAT 797B and the CAT 797 have longer queued times than the CAT 785. This is because of its fast loading it tends to queue faster than the CAT 785. Due to the higher queuing time, it tends to have a higher overall cycle time as shown above. Even with its shorter loading times due to its long queue times, the overall cycle time tends to be higher. At 4.40, Cat 785 had the highest Average of Loading Time and was 45.58% higher than Cat 797B, which had the lowest Average of Loading Time at 3.02 minutes. Cat 785 had the highest Average of Loading Time at 4.40, followed by Cat 797 at 3.26 and Cat 797B at 3.02 minutes. Cat 797B had 3.02 Average of Loading Time, Cat 797 had 3.26 minutes, and Cat 785 had 4.40 minutes. At 1.53 minutes, Cat 797B had the highest Average of Queue Time and was 18.74% higher than Cat 785, which had the lowest Average of Queue Time at 1.29 minutes. Cat 797B had the highest Average of Queue Time at 1.53 minutes, followed by Cat 797 at 1.32 minutes and Cat 785 at 1.29 minutes. Cat 797B had 1.53 minutes of average Queue Time, Cat 797 had 1.32 minutes, and Cat 785 had 1.29 minutes. At 26.39 minutes, Cat 797 had the highest Average of Cycle Ready and was 6.82% higher than Cat 785, which had the lowest Average of Cycle Ready at 24.70 minutes. Cat 797 had the highest Average of Cycle Ready at 26.39, followed by Cat 797B at 26.02 minutes and Cat 785 at 24.70 minutes. Cat 797B had 26.02 minutes Average of Cycle Ready, Cat 797 had 26.39 minutes, and Cat 785 had 24.70 minutes. The cycle times for both trucks were recorded as part of their data. The graph of the loading and queuing times was shown and from the chart, it can be seen that the loading times for the CAT 797B and CAT 797 were shorter than the CAT 785. From the queuing time, you can see that the CAT 797B and the CAT 797 have longer queued times than the CAT 785. This is because of its fast loading it tends to queue faster than the

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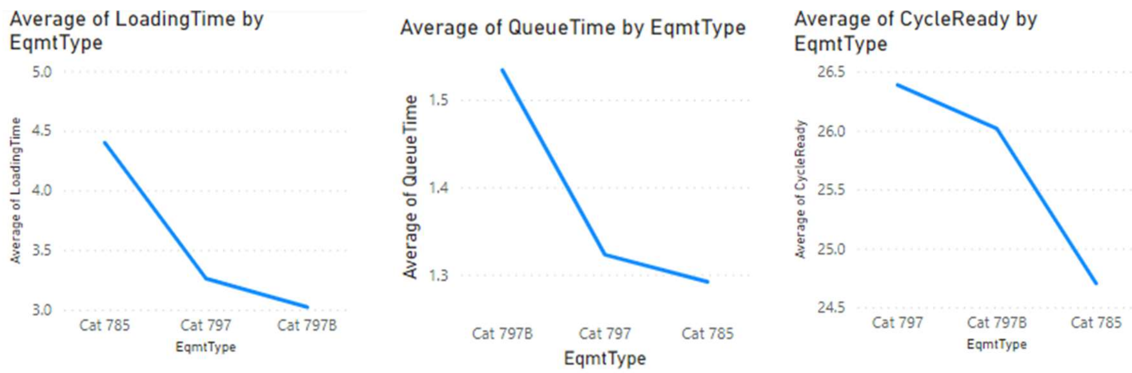

Figure 7 Loading time, Queue time and Full cycle time for each truck type.

4. Future Work

The development of discrete event simulation is revolutionizing the effectiveness of managing data and predictions in fleet management systems. The goal of this study is to comprehend the state of the CNRL sand operations and analyze the data. There are a lot of studies into fleet management and its applications. This kind of work will be applied to the real-life scenarios in mining operations where several scenarios are simulated and the one with the best results is selected. Mine operations can also be simulated to give the most optimal performance that the industry must take. The advent of discrete event simulation will decrease cost, increase profit and boost the effectiveness of the operation thereby removing any lagging situation that may compromise the operation.

5. Conclusion

The CNRL data was given and a simple model using the HAULSIM discrete event simulation was used to create a model of the fleet system. The data was analyzed using graphs created by the PowerBI software. Discrete event simulation is very important in simulating real-life scenarios since it captures everything. The collection of data is important for analysis and future prediction in the mine. Creating scenarios and analyzing the data collected will help the mine in the future to make predictions that will help them in a cost-effective way and optimize processes. From the analysis, it can be inferred that the production or material movement of the mine is not bad, but the productivity of the mine is not bad comparing the volume of the material and the cycle times of the machines. Also from the data, more non-production material is moved out of the mine than production material. The mine should therefore find a way of optimizing the processes, to reduce non-production material and increase more production material. From the analysis of the cycle time, there is a lot of queuing for the CAT 797 B and CAT 797 thereby making the cycle time very long for both trucks. The mine should effectively assign trucks to dig locations to minimize the queuing or eradicate it. Eradicating the queuing in the trucks will help improve the productivity of the mine.

This is the analysis of the data I have made so far with the data. I strongly believe all mining companies should incorporate Industry 4.0 in their processes. The use of simulations and other digital technologies is going to save mining companies from loss and underproduction. Making future predictions is going to help the mine make more profit, improve safety and optimize its operations and processes. Since the world is moving into the digitization age it's very important that the mine moves in that direction from its exploration to its closure stage.

6. References

[1] Pierre-René Bauquis (2006). What the future for extra heavy oil and bitumen: the Orinoco case. World Energy Council.

[2] RPM Global. “Mining Software, Consulting & Training Solutions.” *RPMGlobal*, 25 Jan. 2023, rpmglobal.com/.

[3] Noriega, R. and Pourrahimian, Y. (2022). A systematic review of artificial intelligence and data-driven approaches in strategic open-pit mine planning. Resources Policy, 77, p.1027-27.

[4] Afrapoli, A.M. and Nasab, H.A. (2020). A stochastic integrated simulation and mixed integer linear programming optimisation framework for truck dispatching problem in surface mines. International Journal of Mining and Mineral Engineering, 11(4), p.257.

[5] Ben-Awuah, E., Kalantari, S., Pourrahimian, Y. and Nasab, H.A. (2010). Hierarchical mine production scheduling using discrete-event simulation. International Journal of Mining and Mineral Engineering, 2(2), p.137.