Truck haulage is responsible for a majority of cost in a surface mining operation. Diesel fuel, which is costly and has a significant environmental footprint, is used as a source of energy for haul trucks in surface mines. Reducing diesel fuel consumption would lead to a reduction in haulage cost and greenhouse gas emissions. The determination of fuel consumption is complex and requires multiple parameters including the mine, fleet, truck, fuel, climate and road conditions as input. Data analytics is used to simulate the complex relationships between the input parameters affecting truck fuel consumption. This technique is also used to optimize the input parameters to minimize fuel consumption without losing productivity or further capital expenditure for a specific surface mining operation.
The aim of this research work is to develop an advanced data analytics model to improve the energy efficiency of haul trucks in surface mines.

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The Application of AI in Mining Indust

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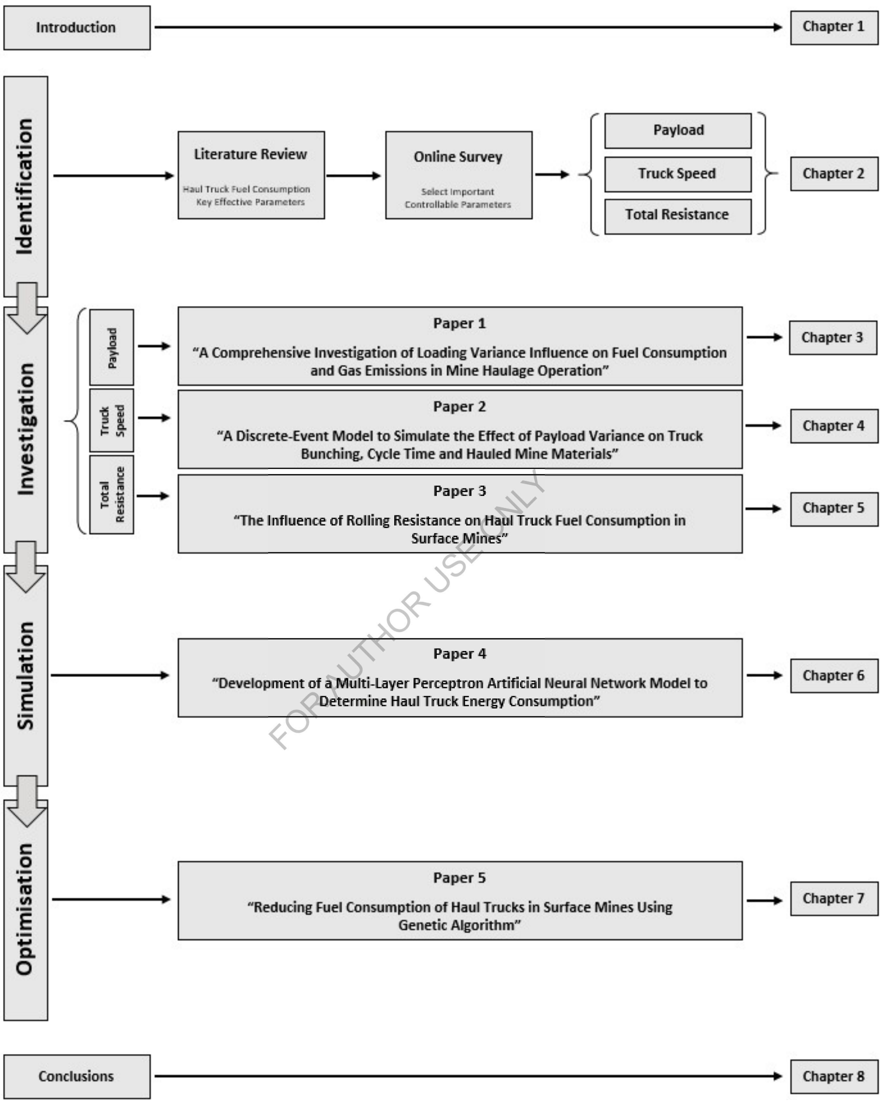
Abstract

Truck haulage is responsible for a majority of cost in a surface mining operation. Diesel fuel, which is costly and has a significant environmental footprint, is used as a source of energy for haul trucks in surface mines. Reducing diesel fuel consumption would lead to a reduction in haulage cost and greenhouse gas emissions. The determination of fuel consumption is complex and requires multiple parameters including the mine, fleet, truck, fuel, climate and road conditions as input. Data analytics is used to simulate the complex relationships between the input parameters affecting the truck fuel consumption. This technique is also used to optimise the input parameters to minimise the fuel consumption without losing productivity or further capital expenditure for a specific surface mining operation.

The aim of this research thesis is to develop an advanced data analytics model to improve the energy efficiency of haul trucks in surface mines. The most important controllable parameters affecting fuel consumption are first identified, namely payload, truck speed and total resistance. These parameters are selected based on the results of an online survey. A comprehensive analytical framework is developed to determine the opportunities for minimising the truck fuel consumption. The first stage of the analytical framework includes the development of an artificial neural network model to determine the relationship between truck fuel consumption and payload, truck speed and total resistance. This model is trained and tested using real data collected from some large surface mines in USA and Australia. A fitness function for the haul truck fuel consumption is successfully generated. This fitness function is then used in the second stage of the analytical framework to develop a computerised learning algorithm based on a novel multi-objective genetic algorithm. The aim of this algorithm is to estimate the optimum values of the three effective parameters to reduce the diesel fuel consumption.

The following studies are also conducted to enhance the analysis of haul truck fuel consumption. First, a comprehensive investigation of loading variance influence on fuel consumption and gas emissions in mine haulage operation is carried out. Then, a discrete-event model to simulate the effect of payload variance on truck bunching, cycle time and hauled mine materials is developed. The influence of rolling resistance on haul truck fuel consumption in surface mines is investigated.

Book structure



Glossary of Terms

ANN	Artificial neural network
B	Bucket of loader
b	Bias
CCS	Carbon dioxide capture and storage
CC_S	Core case scenario
CO_2-e	CO_2 equivalent
$CO_{2\ Index}$	CO_2 index (kg/ (hr. tonne))
$CO_2\text{-}e_{Index}$	CO_2 equivalent index (kg/ (hr. tonne))
D	Dumping
E	Summation function
EEF	Energy efficiency factor (%)
EF	Emission factor
EIA	Energy information administration
f	Fill factor
F	Transfer function
F_a	Activation function
FC	Truck fuel consumption (L/hr)
FC_{Index}	Fuel consumption index (L/ (hr. tonne))
FD	Fuel density (kg/L)
F_i	Fuel input rate (L/sec)
G	Gradient (%)
g	Gravity (m/s^2)
GHG_S	Greenhouse gases
GR	Grade resistance (%)
GVW	Gross vehicle weight (tonne)
GWP	Global warming potential
GA	Genetic algorithm
H	Hauling
HC_S	High cost scenario
I	Counter of sub segment

i	Input
J	Counter of time or timer (s)
j	Counter of input variables
k	Counter of trucks (k = 0 → N)
k	Counter of neural network node in hidden layer
LA_S	Limited alternatives scenario
LF	Engine load factor (%)
l	Length of segment (m)
L	Total length of haul road; Total length of return road (m)
LF	Engine load factor (%)
L_O	Loading
M	Number of cycles
m	Number of neural network nodes in hidden layer
M_A	Manoeuvring
M_I	Maintenance interval (Day)
MSE	Mean square error
Max	Maximum
N	Number of trucks
n	Decision variable for checking velocity of truck
n_o	Normalised
$NGHG_S$	Non-greenhouse gases
NIO_S	No International offsets scenario
O	Output
Out	Final output
P	Payload (tonne)
p	Maximum loader passes to fill the truck tray
Po_f	Fuel input power (kW)
Por	Rimpull power (kW)
PW	Truck engine power (kW)
QL	Queuing for loading
QD	Queuing for dumping

q	Number of input variables
r	Truck wheel radius (m), Number of cycle in each shift
R	Rimpull (tonne)
RF	Rimpull force (kN)
RR	Rolling resistance (%)
R_e	Returning
RFF	Rolling friction force (N)
RMSE	Root mean square error
R^2	Correlation coefficient
S, V	Truck speed, Truck velocity (km/hr)
S_{max}, V_{max}	Maximum truck speed, Maximum truck velocity (km/hr)
SFC	Engine specific fuel consumption (kg/kW.hr)
T	Traveling
t	Time (sec)
T_r	Torque (N.m)
TR	Total resistance (%)
T_{rq}	Torque (N.m)
TP	Tyre pressure (kPa)
U	Decision variable for first segment of haul road
V_b	Bucket rated capacity (m^3)
VIMS	Vehicle information management system
W_{ikj}	Number of trucks at queue in front of truck (k) at time (j) in sub segment (i)
w	Weight of the variables
X	Value of parameter to calculate standard deviation
x	Input variable
y	Target (real) output
Z	Number of available data for each parameter to calculate standard deviation
z	Estimated output
μ	Mean
ρ	Density ($tonne/m^3$)
σ	Standard deviation

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