

## Determination of Volvo A45G Trucks' operating and consumption standards for Camarioca East deposit

## Determinación de las normas de explotación y consumo del Volvo A45G para el yacimiento Camarioca Este

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**Abstract:** The operating and consumption standards of Volvo A45G motorized haulage were determined for Camarioca East deposit. To fulfill the purpose of this research, fieldwork was carried out to monitor the trucks, conducting a productivity and fuel consumption study which involved characterizing the existing exploitation technology at Camarioca East deposit. The cycle time of Volvo A45G trucks was also calculated to determine these vehicles' operating and fuel consumption standards.

**Keywords:** mining roads, open pit mining, mine haulage

**Resumen:** Se determinaron las normas de explotación y consumo del transporte automotor Volvo A45G para el yacimiento Camarioca Este. Para el desarrollo de esta investigación se realizó un trabajo de campo donde se efectuó el monitoreo de los camiones, realizándose el estudio de la productividad y consumo de combustible, para la cual se caracterizó la tecnología de explotación existente en el yacimiento Camarioca Este. Se calculó además el tiempo de ciclo de los camiones Volvo A45G, para determinar las normas de explotación y consumo de los vehículos.

**Palabras clave:** caminos mineros, minería a cielo abierto, transporte minero

## Introduction

Mineral haulage is a process of great importance in mining companies to guarantee increased productivity. Haulage selection and operation demands the utmost rigor in terms of its economic feasibility and technical availability (Masule, 2017; Belette-Fuentes *et al.*, 2024).

Haulage in an open-pit mine is varied and is selected based on haul distances to the deposit or processing plant, the material being hauled, and production volumes (Riquelme-Bastías, 2022; Ojeda Pardo *et al.*, 2022; Canelón, Carrasco & Rivera, 2024; Shao & Kumral, 2024). It impacts on how effective, constant, and productive the deposit exploitation is and on the achievement of efficient technical-economic parameters (Maguiña, 2023; Cavalcante Oliveira & Costa, 2024).

Motorized haulage is the most widespread in open-pit mining (García-De la Cruz, Ulloa-Carcassés & Belete-Fuentes, 2013; Sonhi-Manassa, Polanco-Almanza & Legrá-Lobaina, 2019). At Ernesto Guevara nickel company, mining and transportation equipment has been studied extensively to increase the mine's productive performance (Legrá-Cepero, 2012; Galano Quintero *et al.*, 2021; Montero-Gainza *et al.*, 2021; Rubino-de la Cruz, 2022).

The overall performance of working faces mining production at Ernesto Guevara company's mines in Moa has been below the established average exploitation productivities for each of the equipment lines of the excavation-loading-transportation technological set (Belete-Fuentes, Estenoz-Mejía & Diéguez-García, 2016). The current operating equipment fleet (technological and auxiliary) for ore haulage, in the different stages of technological flow, must guarantee a technical availability above 90 %, hence acquisition planning must be complied with. In the company, mineral extraction and haulage by multiple or longitudinal benches without fan-shaped deepening, primarily employ hydraulic excavators, ESH-545 draglines, and Volvo A45G articulated trucks, accounting for over 80% of the mine's equipment.

To guarantee its efficiency, haulage system performance is measured by determining its main technical and productive indicators based on the calculation of the work cycle of each piece of equipment and is linked to the loading system used. This performance factor is related to the real exploitation productivity, equipment operating conditions,

and the costs incurred, thus denoting the efficiency of haulage system used in mineral resources exploitation.

Despite several measures have been applied, a specific operating regulation have not been implemented yet for the different trucks and mining equipment of Camarioca East deposit. The objective of this paper is to determine the operating and consumption standards for the Volvo A45G motorized haulage for this deposit, exploited by Ernesto Guevara Nickel Mining Company.

### **Camarioca East Deposit Characteristics**

Camarioca East deposit is located in the northeastern part of Holguín province, in Moa municipality. It covers a 19.53 km<sup>2</sup> area where two sectors of 1.80 and 3.51 km<sup>2</sup>, respectively, have been developed with a detailed exploration grid.

Mineral extraction and haulage are the mine's fundamental activities. They are subjected to the industrial process demands and the deposit's natural conditions, requiring a reception, processing, and homogenization point to balance fluctuations in mineral volumes and quality.

### **Materials and Methods**

A mathematical-statistical method was used to calculate and determine technical-productive indicators for vehicle operation parameters.

The following technical indicators were considered: loading time, maneuvering time, loaded haul time, unloading time, and empty travel time.

Loaded haul distance (Km)

$V_{rc}$ : Loaded haul speed (Km/h)

$L_{rv}$ : Empty miles distance (Km)

$V_{rv}$ : Empty miles speed (Km/h)

Thirty-eight trucks operating in the work shifts were monitored, carrying out 237 trips of loaded and empty trucks from the excavation working face to the unloading points.

Volvo A45G trucks characteristics were referenced from Volvo Construction Equipment (2022), Construction Equipment Guide (2024), and Van Keppel (2024) catalogs.

The following equations were used to calculate the motorized haulage equipment productivity:

Hourly Truck Productivity

$$Q_H = \frac{60k_u q_{rc}}{T_{cc}}$$

Where:

$q_{rc}$ : Real payload capacity of the truck;t

Shift productivity:

$$Q_t = Q_H \cdot T_t \cdot K_{ut}$$

Where:

$T_t$ : a shift duration

Daily productivity:

$$Q_d = Q_t \cdot N_t$$

Where:

$N_t$ : number of shifts per day

### **Determination of Factors Affecting Automotive Haulage Equipment Performance**

Key factors influencing motorized haulage effectiveness and performance in lateritic deposit exploitation are: the work zone's mining-technical conditions; equipment's technical characteristics; weather conditions; work regime; operator's experience; mechanical availability; haul distance; and cycle times. These factors' influence will determine the performance of motorized haulage used in nickel mining, allowing the creation of a methodology to evaluate equipment performance.

## Calculations of Motorize Haulage's Technical Indicators

For exploitation calculations, rational technical, technological, and organizational parameters of motorized haulage are established for actual excavation-loading conditions.

### Truck Cycle Time

Trucks working cycle includes loading, loaded travel, sampling, unloading, truck bed cleaning, return to the loading point and intermediate maneuvering operations. Each operation duration is established based on working shifts nomination in the different extraction areas.

$$T_{cc} = t_{car} + t_{des} + t_{mc} + t_{rc} + t_{rv} + t_{esp} + t_{md} + t_{lm} + t_{fr}$$

Where:

$t_{car}$ : Truck loading time (min)

$t_{des}$ : Truck unloading time (min)

$t_{mc}$ : Maneuvering time for loading (min)

$t_{rc}$ : Loaded travel time (min)

$t_{rv}$ : Empty travel time (min)

$t_{esp}$ : Waiting time (min)

$t_{md}$ : Maneuvering time for unloading (min)

$t_{lm}$ : Sampling time plus bed cleaning time (min)

$t_{fr}$ : Preparation and/or feeder lines (min)

### Truck loading time

It was determined under equal conditions based on disaggregated density of the load to be hauled:

$$Y_d = \frac{Y}{K_e}$$

When  $Y_d > \frac{q_c}{v_c}$ , the loading time is determined based on the truck's load capacity  $q_c$ , so:

$$q_{cubo} = \frac{V_{cubo} K_{ll} Y}{K_e} = V_{cubo} K_{ll} Y_d$$

$$N_c = \frac{q_c}{q_{cubo}}$$

$$t_{car} = N_c \frac{t_c}{60}$$

When  $Y_d < \frac{q_c}{V_c}$ , the loading time is determined from the truck's volume.

$$V_{rcubo} = V_{cubo} K_{II}$$

$$N_c = \frac{V_c}{V_{rcubo}}$$

Where:

Vc: truck geometric volume, transferred to in-situ mineral mass (m<sup>3</sup>)

Yd: volumetric mass of disaggregated mineral (t/m<sup>3</sup>)

Y: volumetric mass of in-situ mineral (t/m<sup>3</sup>)

tc: excavation cycle duration (s)

Vcubo: bucket volume (m<sup>3</sup>)

qc: truck load capacity (m<sup>3</sup>)

Nc: number of buckets (m<sup>3</sup>)

Unloading time ranges between 25 and 40 seconds.

**Maneuvering Time:** it depends on exploitation conditions, trucks technical state, operational organization, and weather conditions.

**Loaded and Empty Travel Time:** it rests on the speed the truck can reach, which depends on several factors as well: primarily the equipment and communication routes technical state, and the weather conditions. Speed is also limited by work safety standards.

$$t_{rc} + t_{rv} = \frac{60L_{rc}}{V_{rc}} + \frac{60L_{rv}}{V_{rv}}$$

Where:

L<sub>rc</sub>: Loaded haul distance (Km)

V<sub>rc</sub>: Loaded haul speed (Km/h)

L<sub>rv</sub>: Empty miles distance (Km)

V<sub>rv</sub>: Empty miles speed (Km/h)

**Haul Distance:** the distance to be traveled and the transportation conditions are the most important factors, based on which the equipment must be operated to perform efficient work.

**Mechanical Availability:** Indicates each equipment available time based on the time planned for maintenance and breakdown repair. For comparison between haulage equipment lines, availability is the same for each piece of equipment, at 83% it is not considered a parameter inherent to the equipment type depending on the use it has been exposed to.

**Rain Utilization Factor:** indicates the loss of time caused by climatic disturbances during extraction and transportation.

**Operational Shift Utilization Factor:** remaining time of the work shift that does not include planned time losses for shift changes, snack breaks, lunch, and time used to prepare equipment. When determined through standardization, the time for working faces preparation or other time lost in operations is subtracted.

### **Technological Process of Mineral Loading and Transportation Description**

The work cycle, which includes vehicle inspection, loading maneuvering at the working face, and unloading maneuvering at the reception point, ranges between 35 and 50 minutes relative to the distance of the current working faces.

### **Interruptions Occurring During Shifts**

These happen due to articulated trucks waiting time at the loading point due to working faces cleaning, technical run, topographic surveying, sampling and cut inspection, changes of the excavator or backhoe position, articulated trucks waiting time at the unloading point due to hopper clogging or the arrival of two or more trucks at once, in addition to cleaning of mineral adhered to the articulated trucks dump body.

## Calculation method to determine the pv according to the mean velocity (vm)

### Truck travel time

Trucks travel time depends on factors such as the time to reach cruising speed or full and empty regime, the haul distance to achieve regime speed and to stop, and the terrain slope.

### Procedure for Speed Determination

The instantaneous speed of the trucks was measured when traveling the first 50 m and then, every 100 m during the journey, and 50 m before reaching the destination under 0-5% and 6-10% slope conditions on the outward and return trips (Table 1).

Table 1. Truck speed according to slope

Parameters	Slopes between	Slopes between
	0 and 5%	6 and 10 %
Cruising speed	26.7 km/h	28.2 km/h
Distance to reach cruising speed	0.215 km	0.260 km
Braking distance	0.185 km	0.235 km

To determine the average outward and return speed for a  $\leq 0.2$  km distance, with 0-5 % and 6-10 % average slopes, a series of equations was developed for cases where stops occur. These equations provide a high degree of accuracy for determining trucks average speed, as they are based on this type of truck performance curve, which differs little from the different brands used in this mine.

The cycle elements were taken by the traditional method, timing and photographs, and were classified into three groups.

First group: Cycle times when the truck is not transporting nor traveling back, which are mandatory:

Maneuvering time for loading

Loading time

Maneuvering time for unloading

Unloading time

**Second group:** Cycle interruptions that occur during the shift and are proportional to the number of trips in all shifts are dump body, hopper and loading dock cleanings. In daytime shifts, interruptions are given by technical run, topographic surveying, and cut sampling.

**Third group:** Shift interruptions occur due to equipment checking such as refueling with water and fuel and technical inspection.

First and second groups are considered as fixed times (Tf) and the third group as workday utilization (kh). Travel time is variable depending on distance and road conditions.

Productivity is calculated by the formula:

$$P = \frac{Cv \cdot Vm \cdot kh}{2D + Eq}$$

$$Eq = \frac{Tf \cdot Vm}{3600}$$

Where

P: productivity

Cv: Truck load capacity (t)

D: One-way transportation distance (Km)

Kh: Workday utilization coefficient

Eq: Equivalent in distance traveled to Vm in the fixed times (Km)

Vm: Variable depending on distance and road (Km/h)

### **Standard for the 2 shifts where these operations are not performed**

A short time is worked where only the net cycle elements influence productivity, Kh = 1 and Tf only includes the first group.

### **Results of Volvo A45G Truck Productivity**

Productivity of an average A45G truck for the 2 shifts. First case

$$K_h = \frac{480 - 70}{480} = 0.85$$

$$C_v = 27 \text{ t}$$

$$P = 37.72 \text{ Tm/h}$$

Productivity of A45G truck. Second case

$$K_h = \frac{480 - 50}{480} = 0,986$$

$$C_v = 27 \text{ t}$$

$$P = 37.13 \text{ Tm/h}$$

Productivity of A45G truck for short time periods without any interruption. Third case

$$K_h = \frac{480 - 0}{480} = 1$$

$$C_v = 27 \text{ t}$$

$$P = 44.37 \text{ Tm/h}$$

Productivity of VOLVO A45G truck, average for the two shifts. First case

$$K_h = \frac{480 - 70}{480} = 0.85$$

$$C_v = 20 \text{ t}$$

$$P = 37.72 \text{ Tm/h}$$

Productivity of VOLVO A45G truck in the shift. Second case

$$K_h = \frac{480 - 50}{480} = 0.89$$

$$C_v = 20 \text{ t}$$

$$P = 39.49 \text{ Tm/h}$$

Productivity of VOLVO A45G truck for a time period. Third case

$$K_h = \frac{480 - 0}{480} = 1$$

$$Cv = 20 t$$

$$P = 44.37 Tm/h$$

### **Consumption Standards of A45G Trucks at Camarioca East Deposit**

The standard study was conducted on 100% of the available mining equipment at Camarioca East deposit. In all cases, the optimal state of the equipment, hours worked, kilometers traveled, operational skill, and operation scenarios were considered.

#### **Methods used to determine the consumption standard**

- Refueling to maximum capacity the fuel tank and recording readings from the hour meter and odometer before starting operation.
- Upon concluding operation, readings of the hour meter and odometer are taken again, calculating the hours worked and kilometers traveled by difference.
- Fuel consumed by display. In some cases, refueling to maximum capacity was performed, and it was verified that the difference between the consumed amount shown on the display and the amount supplied is +/- 10 L, which may be associated with platform leveling, inappropriate filling, and fuel temperature in the tank.

The consumption standards were determined at Camarioca East deposit in different work scenarios. These scenarios were:

- Loading and transporting mineral from the mining working face to the mineral reception and classification plant (Object 01).
- Loading and transporting mineral from the mining face to the mineral deposit (Platform) (Table 2).

Table 2. Articulated trucks average results according to scenarios

Working Scenarios	Consumption Standard	
	l/h	Km/l
Face A Obj. 01	29.42	0.55
Face A Deposit	29.90	0.53
General Total	29.66	0.54

## Conclusions

The factors influencing the effectiveness and performance of motorized haulage exploitation in nickel mining were established.

Motorized haulage technical-productive and consumption indicators were calculated, allowing to determine the operating and consumption standards of Volvo A45G trucks.

The consumption standard parameters were determined to be in a range of 26 to 40 l/h, and the operating standards in a range of 35 to 50 min.

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