Unisanta Science and Technology, 2015, 6, July
Published Online 2015 Vol.4 N°1 http://periodicos.unisanta.br/index.php/sat)

UNISANTA
Science and Technology
ISSN 2317-1316

Selection of Industrial Transport Systems for Surface Mining Project: Ore Pipeline, Trucks, Belt Conveyors

Fábio Almeida CHAVES; Luis Renato Bastos LIA; Deovaldo de MORAES JÚNIOR; Aldo Ramos SANTOS and Marlene Silva de MORAES

Unisanta – Universidade Santa Cecília –Programa de Mestrado em Engenharia Mecânica -PPGEMec
Rua Oswaldo Cruz, 266- Santos-SP, Brasil
E-mail*:* fabio.achaves@uol.com.br
Received may, 2015

Abstract: This study aimed to present a method for comparing industrial transportation systems of a phosphate concentrate surface mining project. The transportation systems assessed were: ore pipeline, long distance belt conveyors (LDBC) and off-road trucks. As a result, the impacts on economic behavior, energy consumption and greenhouse gas emissions of each of the above mentioned systems for a distance of 8 to 9 km, were assessed. In light of the above criteria, it was found that the ore pipeline, was regarded as being the best industrial transportation system for phosphate concentrate, this because long distance belt conveyors being 43% more expensive than the latter system, as well as off-road trucks also being 12% more expensive.

Keywords: ore pipeline, belt conveyors, trucks, phosphate concentrate.

Seleção de Sistemas de Transportes Industriais para um Projeto de Mineração em Superfície: Mineroduto, Caminhões fora de Estrada, Transportadores de Correia

Resumo: O presente estudo teve por objetivo apresentar um método para comparar sistemas de transportes industriais de um projeto de mineração em superfície de concentrado fosfático. Os sistemas de transporte avaliados foram: transporte hidráulico (mineroduto), transportadores de correia de longa distância (TCLD) e caminhões fora de estrada. Como resultado, avaliaram-se os impactos no comportamento econômico, consumo de energia e gases de efeito estufa de cada sistema supramencionado para uma distancia entre 8 e 9 km. Mediante os critérios acima citados, verificou-se que o mineroduto, mesmo sendo menos eficiente energeticamente entre os sistemas estudados (0,00763 Gcal/t), foi considerado a melhor alternativa de transporte industrial de concentrado fosfático, pelo fato dos transportadores de correia de longa distância terem sido 43% mais caros que tal sistema, bem como os caminhões fora de estrada 12% mais onerosos.

Palavras chave: mineroduto, transportadores de correia, caminhões, concentrado fosfático.

1. Introduction

The phosphate mining industry takes on a growing importance in the global economy, given that per capita income growth in emerging economies also increases food consumption. Connolly and Orsmond (2011) showed the mining industry's evolution, taking into account revenue, investment and employability over a period of 45 years existence.

On the effect of global crisis, operations and mining projects, have an increasing need for strict and monitored control of its capital costs, operating costs, energy consumption and greenhouse gas emissions. Thus, the study regarding the selection of industrial transportation systems for a phosphate concentrate surface mining project of the stretch between the concentration plant and the rock terminal will contribute towards the industrial community in order to identify the best system for medium distances, given that for short and long distances, it is clear that a choice shall be made from the above mentioned alternatives.

Christina Burt and Lou Caccetta (2013) described the problems in the selection of equipment and/or systems in a context of surface mining. The mineral complex assessed aims to produce 1.09 million tons per year (using an ore power of 10.7% of P_2O_5).

The project envisages a total production time of 33 years of mining and it is located between the states of Minas Gerais and Goias in Brazil. The operating scheme will be 8.059 hours per year, with 10% of production being used for the manufacture of an ultrafine phosphate concentrate and 90% being used for the manufacture of a conventional phosphate concentrate.

2. Objective

This study aimed to select the best industrial transportation systems for a phosphate concentrate surface mining project of the stretch between the concentration plant and the rock terminal, it being of major importance the impacts on costs and also important the impacts on the energy optimisation process and the greenhouse gas effects.

3. Methods

In selecting the industrial transportation systems, we developed a method subsidised by a simulator to check on the technical and economic performance of the systems studied. In this simulator, we initially carried out an overall balance of the mass of the next volume control (vc): mine, concentration plant and rock terminal. In a complementary manner, we carried out a mass balance of the systems studied. This way, and using the Mass Preservation Law (Moraes; Silva, Moraes 2011), we have the following equation:

$$W_{s,vc} - W_{e,vc} + dM/dt = 0 \qquad (1)$$

Where:
$W_{s,vc}$ is the flow rate per unit of time that exits the vc;
$W_{e,vc}$ is the flow rate per unit of time entering the vc;
dM/dt = the accumulated mass per unit of time in the vc.

Given that there was no accumulation in the volume control (vc), $dM/dt = 0$. Therefore,

$$W_{s,vc} = W_{e,vc} \qquad (2)$$

According to Brown and Heywood (1991), the products being transported in the ore pipeline were assessed, using the identification of the following key - parameters: internal pipe diameter, volume of transport duct, net volume, and critical transport speed, loss of cargo, power energy consumption and operating time. Subsequently, we assessed the products that would be transported using off-road trucks, and took into account the number of trucks required, freight costs, fuel consumption and cargo handling time.

Finally, and in compliance with CEMA (1997), we carried out an assessment of the products being displaced using long distance belt conveyors (LDBC), taking into account the stretches of belts, the power consumption and operating time. Based on this information, we identified the CAPEX (capital expenditure) for each industrial transportation system, in order to identify the amount that would be assigned to the purchase of capital goods.

To complement the aforementioned analysis, we identified the OPEX (operational expenditure) of such systems, in order to verify the cost associated to maintaining the same.

The technical assessments were conducted using the company's project documentation, as follows:

a) Descriptive memorandum, project reports and criteria (S-RL-1000-00- 3509-00 - Final Technical Report of the industrial complex, S-RL-1420-60-3501-00 - Final Technical Report of the ore pipeline, S-CP 1100-20-3501-01 - Basic Data & criteria - General Mine, S-CP-1420-60-3501-01 - Basic Data & criteria - concentrate transfer system, S-RL-1420-60-3504-01-Comparative report between centrifugal pump x GEHO, S-MD-1420-60-3501-01 – Descriptive memorandum of the transfer process, S-MD-1700-60-3501-01-Descriptive memorandum of the process – general rock terminal, S-MD-1700-71- 3501-01 - Descriptive memorandum - construction and installation of the ore pipeline);

b) Lists(S-RL-1000-50-3501-02- Demand study, S-LE-1000-60- 3501-02 - List of equipment), Flowcharts (S-FL-1000-60-3514-01 - Process - terminal - ultrafine filtering and expediting, S-FL-1000-60- 3515-01 - Process - terminal - conventional storage and filtering, S-FL-1000-60-3516-01 - Process - concentrate shipping);

c) Plants (S-DE-1420-30-3504-01 - Pipe plant - concentrate transfer, DE-S-1420-71-3508-01 -Route Map - concentrate transfer, S-DE-1700-30-3501-0; Master plan - plant and terminal interconnection, S DE-1700-30-3502-02 - General repairs - Terminal rock, S-DE-1700-30-3503-02 - Master Plan - Rock terminal, S-DE- 1743-30- 3501-01 - General plant - storage shed - Rock terminal, S-FL1420-60-3502-01 - Process - concentrate transfer system);

d) Data Sheets (S-FD-1700-30-3501- 01 - Data Sheet - Belt Conveyor).

4. Results and Discussion

The results of the simulation of the industrial transportation systems indicated the system having better technical and economic performance based on the following index: capital cost per dry ton, operating cost per dry ton, energy consumption per ton and greenhouse gas effect.

In the composition of capital cost, the following parameters were taken into account: discount rate: 15% per annum, project amortisation period: 10 years, repayment period and life span of truck: 3 years (for calculation of off-road truck freight), repayment period and life span of loader: 5 years (for calculation of off-road truck freight).

In the composition of operating cost, the following parameters were taken into account: Electric power US$ 56.168/ MWh, untreated water: US$ 0.168/m3, Diesel oil: US$ 0.537/litre, 40-ton truck freight: US$ 2.819/km (calculated for off-road truck), 35-ton truck freight: US$ 3.356 (road freight), maintenance of conveyer belt 5% of the value of the equipment per year, LDCB maintenance: 5% of the value of the equipment per year, road and bridge maintenance: 2% of the value of implementation per year, off-road truck maintenance: 15% of the value of the equipment per year, maintenance of loader: 15% of the value of the equipment per year.

Christina Burt and Lou Caccetta (2013) confirmed the composition of the operating cost of the off-road trucks in question when they referred to such costs being directly proportional to their carrying capacity.

The calculations were presented in an Excel spreadsheet 13-214-27-MC-P-02-R3 Concentrate Transport Spreadsheet. For comparison purposes, the hydraulic transportation system (ore pipeline) was regarded as the base, from which were calculated the economic differences and technical differences.

The choice fell upon this system because it was the alternative considered in the basic design stage.

Figures 1, 2, 3, 4, 5 and 6 show the economic behavior, energy consumption and greenhouse gas emission of all transportation systems.

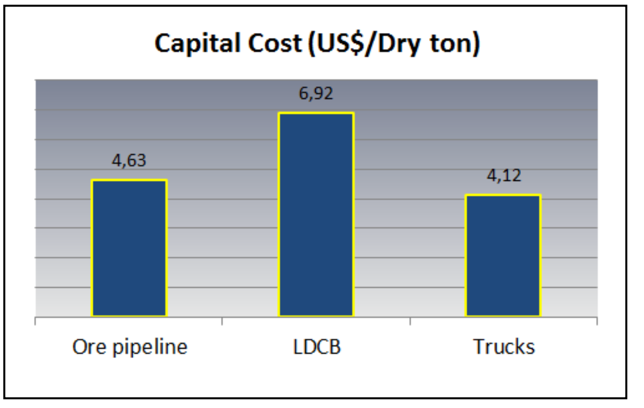

Figure 1. Capital cost of transportation systems.

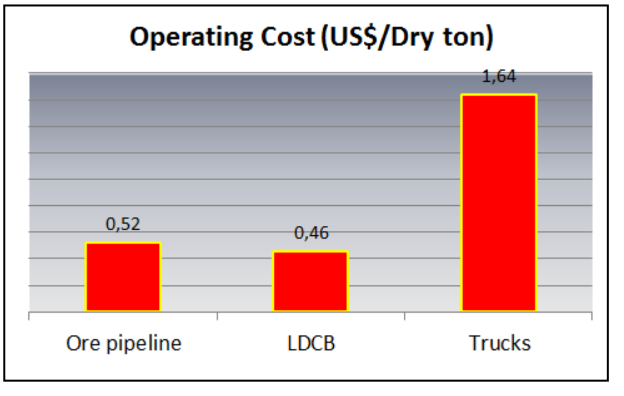

Figure 2. Operating cost of transportation systems.

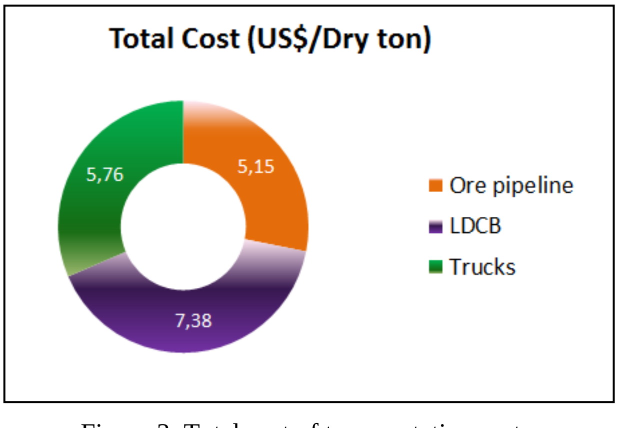

Figure 3. Total cost of transportation systems.

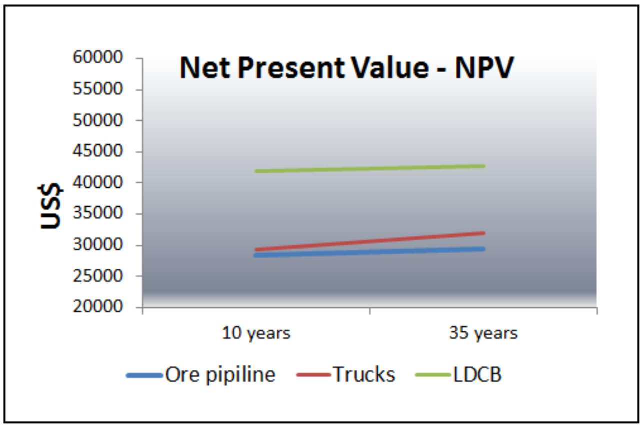

Figure 4. Net Present Value of transportation systems.

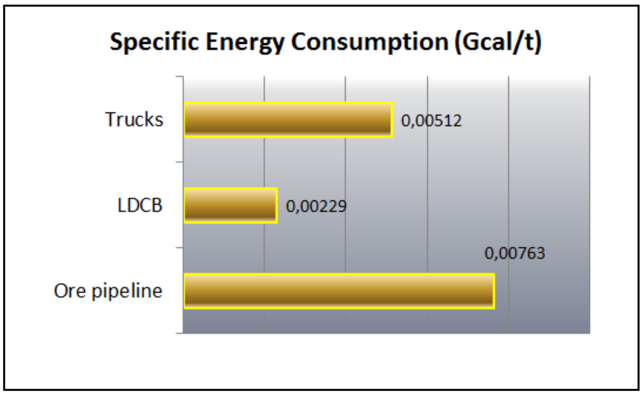

Figure 5 – Specific energy consumption of transportation systems.

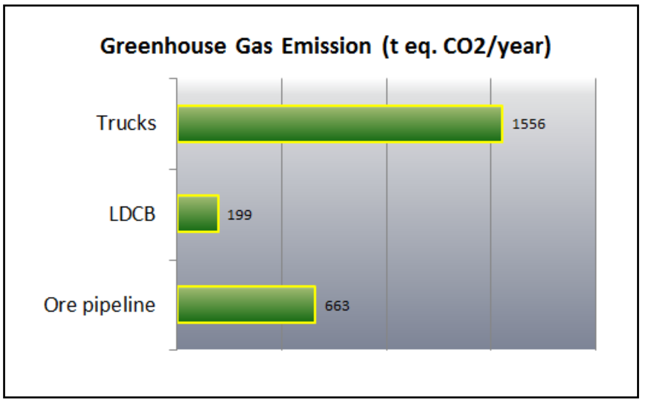

Figure 6 – Greenhouse gas emission of transportation systems.

The ore pipeline under study has an internal diameter of 8 inches, a length of 8 km, a design flow of 257.7 m3/h and a transportation speed of 2.14 m/s.

The final design of the LDCB is made in 4 stretches. Whereas the design system for off-road trucks comprised 5 off-road units, the construction of a 9 km access road and a 40 m wide bridge for heavy traffic.

The results showed a clear advantage in the industrial transportation system done using the ore pipeline. When comparing road transports, one can see that the higher initial investment (US$ 4.63 /ton on the ore pipeline against US$ 4.12 /ton on the road) was quickly offset by the lower operating costs (US$ 0.52 /dry ton in the ore pipeline against US$ 1.64 /dry ton on the road).

Transportation using the LDCB was economically unviable due to its initial investment (US$ 4.63 /ton on the ore pipeline against US$ 1.36 /ton on the LDBC) and its operating cost was not enough to offset such increase in capital cost (US$ 0.52 /dry ton on the ore pipeline against US$ 0.46 /ton on the LDCB).

One of the factors leading to the high investment was the incompatibility of the low product flow when compared to the long distance covered, i.e., the low flow involved a narrow belt, which would make the carrier cheaper, however the long distances resulted in high voltages that would thus require wider belts.

Due to this, it was necessary to use wider belts for calculating the CAPEX estimates. From an energy point of view, the LDBC showed a lower specific fuel consumption (0.00229 Gcal/t) when compared to the ore pipeline (0.00763 Gcal/t) and to the road transport (0.00512 Gcal/t).

The composition of the electricity consumption was based on the operating time and power required for each transportation system.

The consumption of diesel oil was obtained from the technical specifications of truck manufacturers.

As regards greenhouse gas emissions, the LDBC had the lowest environmental impact (199 t eq. CO2/ year) when compared to road transportation (1556 t eq. CO2/ year) and to the ore pipeline (663 t eq. CO2/ year). This index was calculated based on the average emission factor of the Brazilian grid between the period ranging from January to December 2012.

5. Conclusion

Because this is a project and not an existing operation, i.e., where the main driver is the economic assessment, it was understood that the ore pipeline, albeit less energy efficient, proved to be the system with best value for money, as well as the one presenting the lowest impact as regards greenhouse gas emissions. Given the above, the ore pipeline was presented as the system most suitable in a phosphate concentrate surface mining project for distances ranging between 8 to 9 km. In the future it would be appropriate to implement a method for medium transportation distances in excess of those studied and using other minerals.

Referências

BROWN, N.P.; HEYWOOD, N.I. Slurry Handling: Design of solid-liquid systems; New York, Elsevier Handling and Processing of Solid Series, Elsevier Science Publishers, 1991. 680p.

MORAES JR, D.; SILVA, E. L.; MORAES, M.S. Aplicações industriais de estática e dinâmica dos fluidos I; Edição do autor, 2011. 360p.

BURT, C.; CACCETTA, L. Equipment selection for surface mining: A review. Department of mathematics and statistics of University of Melbourne and Curtin University of Technology. Draft Paper 2013, Austrália. p.33.

CONNOLLY, E.; ORSMOND, D. The mining industry: From bust to boom. Reserve bank of Australia. Research discussion paper (RDP), 2011, Austrália. p.12-13.

The CEMA Belt Book, Belt Conveyors for Bulk Materials, fifth edition, CEMA – Conveyor Equipment Manufacturer Association, 1997. 196p.

