Proceedings of the 2012 Winter Simulation Conference
C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, eds

ANALYSIS OF CARBON MONOXIDE EMISSIONS IN A OPEN SOURCE DISCRETE-EVENT SIMULATOR

João José de Assis Rangel

Instituto Federal Fluminense
273 Dr. Siqueira st, Pq. Dom Bosco
Campos dos Goytacazes, RJ, 28030-130, BRAZIL

Gabriel Lima de Oliveira

Petrobras - Petróleo Brasilero SA
665 Elias Agostinho st, Centro
Macaé - RJ, 27913-350, BRAZIL

Túlio Almeida Peixoto
Leonardo das Dores Cardoso
Ítalo de Oliveira Matias
Eduardo Shimoda
Universidade Candido Mendes
100 Anita Pessanha st, Pq. São Caetano
Campos dos Goytacazes, RJ, 28030-335, BRAZIL

ABSTRACT

This paper describes an analysis of emissions of carbon monoxide (CO) using a discrete event simulator of open source. It was built a simulation model to evaluate gas emissions emitted by a fleet of trucks during transportation of raw materials in a typical supply system of sugarcane in producer mills of ethanol. The simulation model was implemented in the open source simulator (Ururau) and in a traditional simulator (Arena). The model results presented high correlation, with no significant difference between them. It was also possible to contribute with the proposed simulator through a designed specific component able to account the CO emissions.

1 SYSTEM AND SIMULATION MODEL

A hypothetical transport logistics system of sugarcane in mills producers of ethanol was idealized. Data from this model were obtained from the work of Rangel et al. (2010) and Iannoni and Morabito (2002).

The process is simulated as follows: The trucks already loaded with sugarcane are addressed to the mill in the shortest possible time so as not to compromise the quality of raw material transported. The trucks wait their turns to unload when arriving at the mill. This wait is done with the trucks turned off, therefore, their time in the calculation of the inventory of the CO emissions is not taken into consideration. Once unloaded, the trucks return to the HF source in order to restart the transport cycle.

For execution of experiments, it was followed the Resolution 315/02 of CONAMA (National Council of Environment, governing body of pollutants in Brazil). The CONAMA created the PROCONVE (Program of Control of Air Pollution by Motor Vehicles), which follows the Euro standards concerning the rules of emissions of pollutants from automobiles sold in the countries of the European Union (adopted by the European Union since 1991). This study examined only the CO emission, which occurred during the transport of the fleet, whose randomness is considered by the model in the time factor. The analysis with only one gas (CO) helped achieve the verification and validation of the model with greater precision. Similarly, it was also possible to better evaluate the performance of the new open source

978-1-4673-4781-5/12/$31.00 ©2012 IEEE

Simulator. It was considered that 90% of the available total power (130 hp) of the truck is used in the transport of sugarcane from the harvest front to the mill and that only 40% of the available power of the truck is used in the return of this from the mill to the HF, for being empty. Therefore, it is deduced that the emission of pollutants in the return is lower due to the lower load transported.

The amount of emissions generated by the burning of the fuel is a function of several parameters, including the fuel type, power of the truck engine and the time that the engine is running (Manicom et al. 1993). The results of this study provided a list of emission coefficients in units of grams per kilowatt hour (g / kW · h) to various types of fuels including diesel, allowing the relation shown in Equation 1:

$$E_X(t) = Cco*Pot*t \quad (1)$$

Where the emissions produced "E" of the vehicle "x" over the time interval "t" are equal to the emission coefficient Cco (of the vehicle x) times the power of the truck in kilowatts "Pot" times the time "t" (Zhou and Kuhl, 2010).

2 RESULTS

We obtained the averages and standard errors of each software (Arena and Ururau) in the two trajectories (round trip) and in the all scenarios being these averages compared by t-test to verify differences between the software. It was also obtained an equation of linear regression of the result observed in the software Arena according to the observed in the Ururau, where there were no significant differences between the software in any of the scenarios or trajectories.

The simulation model developed in this study corroborated with the raised possibility of being able to analyze the emission of greenhouse gases as a typical discrete event system. Likewise, the high correlation between the results of the models developed in Ururau and Arena demonstrated the feasibility of being able to build simulation models with the open source simulator Ururau. Furthermore, for being used in different programming levels, the open source simulator allowed the development of a specific component for the proposed model. This fact made the Ururau similarly able to count emissions generated by a fleet of vehicles, such as toolkit developed for the software Arena by Zhou and Kuhl.

The functionality for accounting of emissions was added to the official code of the Ururau, found in its latest version. This was only possible due to the Ururau be an open source simulator, which allows different users to collaborate including other components to the software.

This study compared the analysis only of the CO emissions. However, the model can be expanded to count the other greenhouse gases such as hydrocarbons, nitrogen oxides, particulate materials, among others. Also, other models could be performed using mixed fleets (vehicles of different years of manufacture, which meet different emissions standards). Thus, in general, the intention is also, in subsequent steps of this project, extend the analysis to the other gases and, thus, be able to calculate the emissions inventory of a supply chain, for example.

REFERENCES

Iannoni, A. P. and Morabito, R. (2002). Análise do Sistema Logístico de Recepção de Cana-de-Açúcar: Um Estudo de Caso Utilizando Simulação Discreta. *Gestão e Produção*, São Carlos, SP, Brazil, Vol. 9, Issue 2, P. 107–128.

Manicom, B. Green, C. and Goetz, W. 1993. Methyl Soyate Evaluation of Various Diesel Blends in a DDC 6v-92 TA Engine. *Mississauga*, Ontario: Ortech International.

Rangel, J. J. A. Cunha, A. P. Azevedo, L. R. and Vianna, D. S. 2010. A Simulation Model to Evaluate Sugarcane Supply Systems. *In Proceedings of the 2010 Winter Simulation Conference*, Edited by B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yucesan, 2114–2125. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Zhou, X. and Kuhl, M. E. 2010. Design and development of a sustainability toolkit for simulation. *In Proceedings of the 2010 Winter Simulation Conference*.