SIMULATION MODEL IN A FREE AND OPEN-SOURCE SOFTWARE
FOR CARBON MONOXIDE EMISSIONS ANALYSIS

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ABSTRACT

This paper describes an analysis of emissions of carbon monoxide (CO) using a discrete event simulator of open source. A simulation model was built 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 and a traditional simulator. 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 component able to account the CO emissions.

1 INTRODUCTION

In recent work, Zhou and Kuhl (2011) presented the structure of a toolkit of simulation tools to analyze the emission of greenhouse gases. This toolkit allows the use of discrete event simulation (DES) in systems where factors related to the emission of greenhouse gases can be analyzed. In these systems, the vehicle (truck) is represented as an entity that flows through the logic of the simulation model. Therefore, when an entity is created, the attributes of a truck with the variables that want to visualize are defined for it. The module created by the system is called "Emissions", which the values of the emission of gases generated along the route are calculated and stored. Byrne et al. (2010) also demonstrated that the use of DES can capture the dynamic and stochastic effects aggregated to the emission of gases in logistics systems, thus, being able to show, more precisely, the environmental costs involved in supply chain operations, for example.

Similar to Zhou and Kuhl (2011), the work of Rangel et al. (2012) also presented a model of DES capable of analyzing the emissions of carbon monoxide (CO) produced by a fleet of trucks. This model simulated the CO emissions, using only the modules inherent to the Arena software. The analysis was applied in a system of sugarcane transport, in sugarcane mills producers of ethanol, and proved to be efficient.

In the context of the ethanol production, one of the main problems is related to the transportation of sugarcane between the harvest and the mill. The quality of the raw material is directly linked to the shipping time (Rangel et al. 2010). Also in the context of ethanol production, environmental issues such as the control of the emission of pollutant gases and the reduction of waste that affect the environment have become increasingly present in the center of the main organizational decisions. The current sustainable vision of the companies, either because of punishment or by the concern to achieve proper environmentally goals, has led to reconsider the importance of the reduction of the emissions of pollutant gases in the production context, as well as raise the importance of this factor in the making of business decisions (Widok and Wohlgemuth 2011).

On the other hand, the use of computational simulation in Brazilian companies is still unusual due to the high monetary value spent on importation of commercial software for the development of simulation models. An alternative presented is the possibility of using a Free and Open-Source Software (FOSS) simulator, such as the recent Ururau (Peixoto et al. 2011). The Ururau is a discrete event simulator which, being open source, provides more freedom to the modelist. In the development environment of Ururau, the modelist can manipulate from the graphical user interface to the more internal code.

In this sense, this paper describes a model of DES used to evaluate CO emissions produced by a logistics system consisting of a fleet of trucks for transportation of sugarcane. The simulation model was developed using the Ururau, and the results were compared with another model of the same system developed in the software Arena.

2 DESCRIPTION OF THE SYSTEM

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). Figure 1 shows, schematically, the supply system, which is, typically, found in Brazilian sugarcane mills.

There are five harvest fronts (HF), each providing the same amount of sugarcane for the same mill. Five trucks are allocated to each HF, where the time of departure of trucks from the HF follows the same probability distribution. The distances of each HF to the mill are shown in the legend.

LEGEND

HF 1 - 10Km
HF 2 - 15Km
HF 3 - 20Km
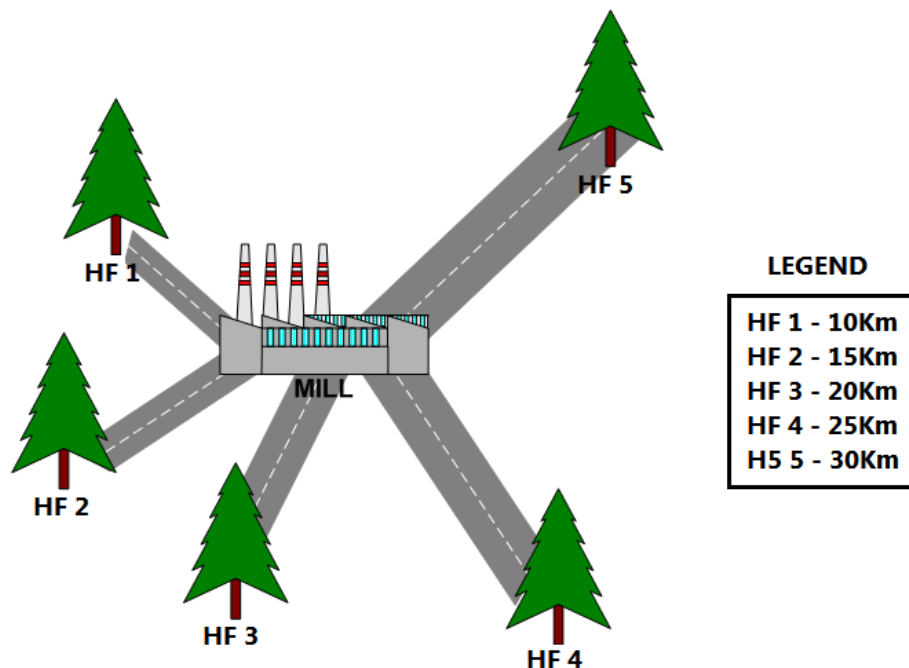HF 4 - 25Km
H5 5 - 30Km

Figure 1: Scheme of the simulated system.

The system is composed, solely, for the transportation and subsequent unloading of trucks. The loading process of sugarcane in a truck at a HF and the unloading of the respective trucks at the mill are mechanically done. Therefore, it can be considered that the truck engine is turned off at that moment because the time for this case is relatively short, not being emitted polluting gases.

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 the raw material transported. The trucks wait their turns to unload when arriving at the mill. This waiting process is done with the engine of the trucks off. Therefore, the 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.

3   SIMULATION MODEL

The methodology by Banks (2009) was followed to prepare this simulation project, according to the next steps: formulation and analysis of the hypothetical problem; construction of the conceptual model; construction of the simulation model; verification and validation; experimentation; and interpretation and statistical analysis of the results.

From the IDEF-SIM technique (Montevechi et al. 2010), it was possible to construct the conceptual model of the process with a visual aspect of easy understanding and logic similar to that used in programming of the computational model. The conceptual model to carry out computer simulations was translated into Ururau and Arena (Kelton, Sadowski, and Sturrock 2009). Figure 2 shows the conceptual model of the system.
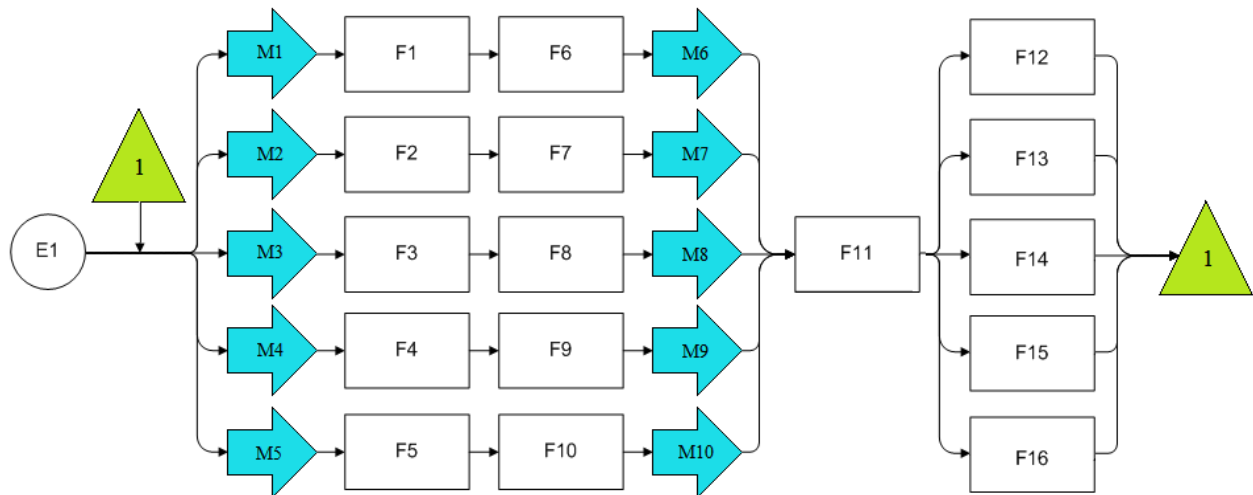

Figure 2: Conceptual model of the system.

It was used, in addition, the methodology proposed by Sargent (2011) for verification and validation of the model. It is worth mentioning that the computational model was constructed after the conceptual model was performed, fully verified and validated.

The simulated system begins with the time needed, by the simulation model, for the departure of each truck (E1) to the corresponding HF. This path has variable time since they are at different distances from the mill and may suffer changes generated by factors as traffic.

Then, the trucks go to their respective HF (M1, M2, M3, M4 and M5). In that way, the pollutants are emitted, with emissions recorded in CO emissions inventory through the functions F1, F2, F3, F4 and F5. After arriving at the HF, the trucks are loaded (F6, F7, F8, F9 and F10). The loading and unloading periods of time are not considered in the emissions inventory since they are performed with the engine off.

Once loaded, the trucks return to the mill. This step is represented by functions M6, M7, M8, M9 and M10. There, they wait until the unloading of sugarcane is done (F11). The functions F12, F13, F14, F15 and F16 register the emissions generated by their return to the mill. After this process is conducted, a new loading cycle is started.

4 URURAU SIMULATION ENVIRONMENT

The Ururau is the extension of the project of the Java Simulation Library (JSL), proposed by Rossetti (2008). Figure 3 shows the architecture of the Ururau. It was used the Java language in all layers. The library JSL is in the lower layer and converts the model, which consists of a series of process commands, into a sequence of discrete events. The middle layer is the core of the Ururau, which is composed of commands of the JSL processes, such as creation of entities, Seize, Delay, Release, among others. The uppermost layer is the conversion of the graphic model, which comprises a graph directed to a sequence of commands of the Ururau core.
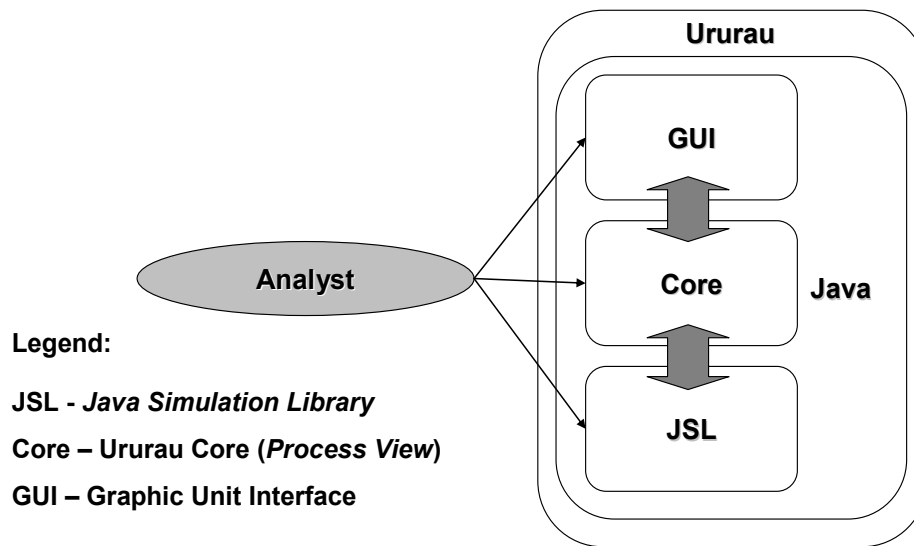

Figure 3: Arquitetura do Ururau.

Figure 4 shows the graphical interface of the Ururau. The purpose of the graphical interface is to facilitate the creation of simulation models. Note that, in Figure 4, the set of functions (Modeling Elements) is on the left. These, in turn, are built by the analyst on the desktop (Desktop). At the bottom left, an overview of the model is presented, if it does not fit on the screen. The representation language of the model is based on the IDEF-SIM. For the construction of the simulation model, the modeler needs only to drag and drop with the mouse the modeling elements to the desktop, according to the logic of the system under analysis. Then, the module is edited by clicking with the right button on it to open it. In the edit box, the data of the model can be inserted as the times of events, the operating rules of the system, among other functions.

The development team of the Ururau uses the versions controller for FOSS named Bitbucket. The Bitbucket is a site for collaborative development, i.e., allows multiple developers working on the same source code. Thus, the interested developer in cooperating registers and the project manager allows the developer submitting the code changes to the site. However, everyone has access to the code without having to register. In other words, just install the Mercurial (https://mercurial.selenic.com), and make the command "hg clone https://bitbucket.org/ururau/ururau".

Then, for the development and use of the Ururau, the site https://bitbucket.org/ururau can be freely accessed. After downloading the zip file, unzip it into a directory and run ururau.jar. You must have Java

installed on your computer Enviroment Runtime (JRE) version 6.0 or higher, which can be obtained in http://java.com/getjava.

To build the model using the source code, it is necessary a development environment - Integrated Development Environment (IDE), preferably NetBeans 7.0, which can be obtained in http://www.netbeans.org. The environment of the Ururau is composed, internally, by one or more process commands, which extend JSL functionalities. The file README.TXT, which presents an explanation of how each command works, can also be downloaded at the address of the software.
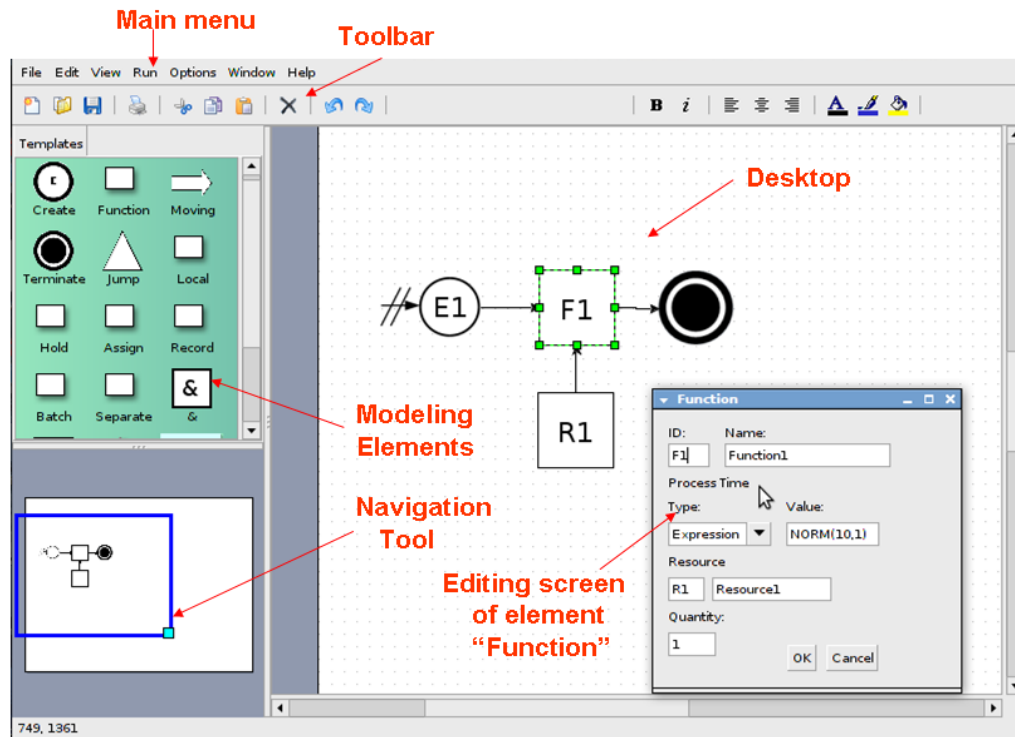

Figure 4: Interface of the Ururau.

5   SIMULATED EXPERIMENTS

For the execution of the experiments, it was followed the Resolution 315/02 of CONAMA (National Council of Environment, governmental body of pollutants in Brazil), which main purpose according to its 1st Art is to "Reduce the emission levels of pollutants in automotive vehicles and promote national technological development, both in design engineering and manufacturing, as in methods and equipment to control the emission of pollutants" (Brasil 2002).

The CONAMA created the PROCONVE (Program of Control of Air Pollution by Motor Vehicles), which follows the model of 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). Table 1 illustrates the situation in Brazil since the beginning of the implementation of such standards (P1) with the PROCONVE in 1989. Currently, the P6 is used with much lower emission levels compared to those allowed from the start. It is observed that while Brazil adopts the P6 that follows the Euro 4 standard, the European Union already adopts the Euro 5 standard. Although the level of CO is the same in Euro 4 and 5 standards, it is noteworthy that the levels of emission of other pollutants have been reduced from one standard to another.

This study examined only the CO emission, which occurred during the transportation of the fleet, which 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 simulator.

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

Table 1: Emission limit for heavy diesel vehicles.

PROCONVE	EURO	CO (g/kWh)	TERM	STANDARD (CONAMA)
Phase I (P1)	Without Specification	14,00	1989 a 1993	Res. 18/86
Phase II (P2)	Euro 0	11,20	1994 a 1995	Res. 08/93
Phase III (P3)	Euro 1	4,90	1995 a 1999	Res. 08/93
Phase IV (P4)	Euro 2	4,00	2000 a 2005	Res. 08/93
Phase V (P5)	Euro 3	2,10	2006 a 2008	Res. 315/02
Phase VI (P6)	Euro 4	1,50	2009 a 2012	Res. 315/02
Phase VII (P7)	Euro 5	1,50	Starts in 2012	Res. 403/08

Source: Adapted PROCONVE - Program of Control of Air Pollution by Motor Vehicles

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 $(g / kW \cdot h)$ for various types of fuels, including diesel, allowing the relation shown in Equation (1):

$$E_X(t) = Cco*Pot*t \tag{1}$$

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).

Table 2 shows the results of the scenarios simulated with the Arena and Ururau. 6 scenarios related to the 6 phases of the gas emissions standards, shown in Table 1, were simulated. The difference between the scenarios is in the emission levels. Scenario 1 follows the standard P1, which limits an emission of 14g/kW.h until scenario 6, which uses the data of the standards P6 and P7 (1.50 g / kWh).

It can be observed the trend of reduction of CO emissions while the scenarios range from 1 to 6. The scenarios were replicated 10 times in each simulation.

The emission reductions generated from HF1 to HF5 remains similar in both the model Arena and in Ururau in each scenario. This relation is because the HFs are at different distances in relation to the mill. Therefore, the HF more distant will emit more CO than the closer to the mill in all scenarios.

It was also noted that, at the time of implementation of the norms of PROCONVE, in 1090 (P1), the emission levels were very high (400,833 g / kWh) compared to current emissions levels, which has 42,946 g / kWh. Thus, in a period of 22 years, there was a reduction of almost 90% of the levels of CO emissions, that was also observed in the results of the two simulations.

Table 2: Results of the scenarios - Data in g/kWh.

Scenario	HF	Emissions on Going		Total on Going		Emissions on Return		Total on Return		Grand Total	
		Arena	Ururau	Arena	Ururau	Arena	Ururau	Arena	Ururau	Arena	Ururau
1	1	47013	50773			18365	19491				
	2	53987	56927			21915	21555				
	3	58189	58773	284602	296313	22350	22276	109556	110777	394158	407090
	4	59368	63480			23032	23380				
	5	66045	66360			23894	24075				
2	1	37611	40619			14708	15593				
	2	43190	45541			17532	17244				
	3	46551	47018	227706	237050	17880	17820	87660	88621	315366	325671
	4	47518	50784			18425	18704				
	5	52836	53088			19115	19260				
3	1	16455	17770			6435	6822				
	2	18896	19924			7670	7544				
	3	20366	20570	99622	103708	7823	7796	38352	38771	137974	142479
	4	20789	22218			8061	8183				
	5	23116	23226			8363	8426				
4	1	13432	14506			5253	5569				
	2	15425	16264			6262	6158				
	3	16625	16792	81323	84659	6386	6364	31308	31649	112631	116308
	4	16971	18137			6580	6680				
	5	18870	18960			6827	6878				
5	1	7052	7616			2758	2923				
	2	8098	8539			3287	3233				
	3	8728	8816	42695	44447	3353	3341	16437	16615	59132	61062
	4	8910	9522			3455	3507				
	5	9907	9954			3584	3611				
6	1	5037	5440			1970	2088				
	2	5784	6099			2348	2309				
	3	6235	6297	30496	31747	2395	2386	11741	11867	42237	43614
	4	6364	6801			2468	2505				
	5	7076	7110			2560	2579				

6   STATISTICAL ANALYSIS OF RESULTS

Statistical analysis were performed in software "Systems for Analysis Statistics and Genetic" (SAEG 9.1), adopting the 5% level of significance. We obtained the averages and standard errors of each software (Arena and Ururau) in the two trajectories (round trip) and the 6 scenarios as illustrated in Figure 5, being these averages compared by t-test to verify differences between the software.

It was also acquired an equation of linear regression of the result observed in the software Arena according to the noticed in the Ururau, shown in Figure 6, where there were no significant differences between the software in any of the scenarios or trajectories.

Also in Figure 6, it can be observed that the results obtained by the two software are related by linear regression, being the equation obtained significant (P<0.0001) and with a high coefficient of determination (R^2 = 99.8%). The angular coefficient of the regression (0.962) is close to the value 1, which shows that the results of the simulation displayed by the Ururau are close to the results obtained by the Arena.
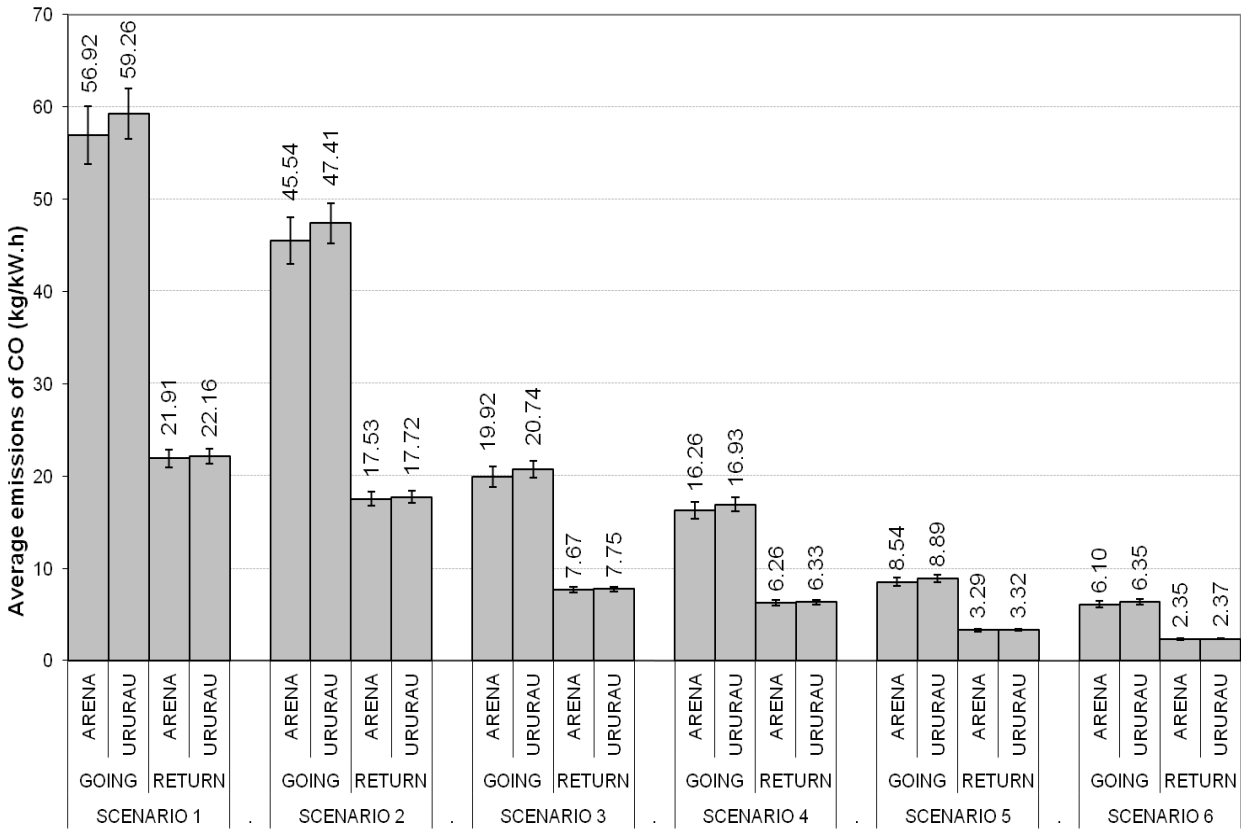

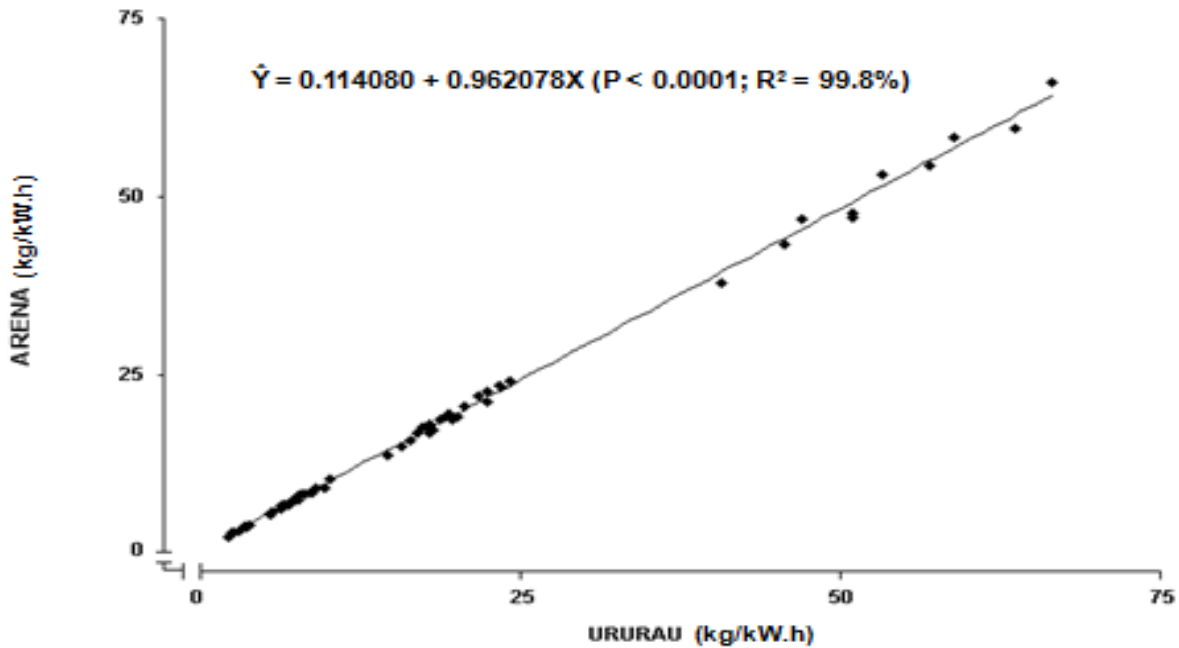Figure 5: Average emissions of CO. Data in kg/kWh.

$$\hat{Y} = 0.114080 + 0.962078X \ (P < 0.0001; R^2 = 99.8\%)$$

Figure 6: Linear Regression of results of the Arena in function of the Ururau.

7   CONCLUDING REMARKS

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, open source simulator allowed the development of a 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, and 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.

A   **APPENDIX (**Parameters of the Conceptual Model - Figure 2)

CODE	DESCRIPTION	PARAMETER
E1 to E5	Truck	5 entities; Time of Creation: EXPO (1) min
F1	Transport sugarcane from the HF1	NORM(0.5, 0.1) hours
F2	Count CO – Going HF1	$V\_Cont\_going\_1 + (V\_Comb\_1*0.9*V\_Pot\_1*V\_Temp\_going\_1)$
F3	Unload	NORM (5.0, 0.5) min
F4	Back to the HF1	NORM (0.45, 0.045) hours
F5	Count CO - Back HF1	$V\_Cont\_Back\_1 + (V\_Comb\_1*0.4* V\_Pot\_1*V\_Temp\_Back\_1)$
F6	Transport sugarcane from the HF2	NORM(0.7, 0.14) hours
F7	Count CO - Going HF2	$V\_Cont\_Going\_2 + (V\_Comb\_2*0.9*V\_Pot\_2*V\_Temp\_Going\_2)$
F8	Back to the HF2	NORM(0.63, 0.063) hours
F9	Count CO - Back HF2	$V\_Cont\_Back\_2 + (V\_Comb\_2*0.4* V\_Pot\_2*V\_Temp\_Back\_2)$
F10	Transport sugarcane from the HF3	NORM (0.9, 0.18) hours
F11	Count CO - Going HF3	$V\_Cont\_Going\_3 + (V\_Comb\_3*0.9*V\_Pot\_3*V\_Temp\_Going\_3)$
F12	Back to the HF3	NORM (0.81, 0.081) hours
F13	Count CO - Back HF3	$V\_Cont\_Back\_3 + (V\_Comb\_3*0.4* V\_Pot\_3*V\_Temp\_Back\_3)$
F14	Transport sugarcane from theHF4	NORM (1.1, 0.22) hours
F15	Count CO - Going HF4	$V\_Cont\_Going\_4 + (V\_Comb\_4*0.9*V\_Pot\_4*V\_Temp\_Going\_4)$
F16	Back to the HF4	NORM (0.99, 0.099) hours
F17	Count CO - Back HF4	$V\_Cont\_Back\_4 + (V\_Comb\_4*0.4* V\_Pot\_4*V\_Temp\_Back\_4)$
F18	Transportar cana-de-açúcar da FC5	NORM (1.3, 0.26) hours
F19	Count CO - Going HF5	$V\_Cont\_Going\_5 + (V\_Comb\_5*0.9*V\_Pot\_5*V\_Temp\_Going\_5)$
F20	Back to the HF5	NORM (1.17, 0.117) hours
F21	Count CO - Back HF6	$V\_Cont\_Back\_5 + (V\_Comb\_5*0.4* V\_Pot\_5*V\_Temp\_Back\_5)$

REFERENCES

Banks, J., J. S. Carson, B. L. Nelson, and D. M. Nicol. 2009. *Discrete-Event System Simulation*. 5th ed. Upper Saddle River, New Jersey: Prentice-Hall, Inc.

Brasil, D. F. 2002. "Provides for the New Stage of the Program for Vehicle Emission Control - PROCONVE." Technical Report No. 315, October 29 DIARY Official Union.

Byrne1, P.J., C. Heavey, P. Ryan, and P. Liston. 2010. "Sustainable Supply Chain Design: Capturing Dynamic Input Factors". *Journal of Simulation* 4:4:213–221

Iannoni, A. P., and R. Morabito 2002. "Análise do Sistema Logístico de Recepção de Cana-de-Açúcar: Um Estudo de Caso Utilizando Simulação Discreta." *Gestão e Produção* 9:2:107–128.

Kelton, W. D., R. P. Sadowski, and N. B. Sturrock. 2007. *Simulation with Arena*. 5th ed. New York: Mcgraw-Hill.

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

Montevechi, J. A. B., F. Leal, A. F. Pinho, R. F. S. Costa, M. L. M. Oliveira, and A. l. F. Silva "Conceptual Modeling in Simulation Projects by mean adapted IDEF: an Application in a Brazilian company." In *Proceedings of the 2010 Winter Simulation Conference*, edited by B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yucesan, 1624-1635. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Peixoto, T. A., J. J. A. Rangel, and I. O. Matias. "Ururau - Um Ambiente de Simulação a Eventos Discretos." In *Proceedings of the* 2010 *XLIII Simpósio Brasileiro de Pesquisa Operacional (SBPO),* 1–2.

Rangel, J. J. A., A. P. Cunha, L. R. Azevedo, and D. S. Vianna "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.

Rangel, J. J. A., G. L. Oliveira, T. A. Peixoto, L. D. Cardoso, I. O. Matias, and E. Shimoda "Analysis of Carbon Monoxide Emissions in a Open Source Discrete-Event Simulator." In *Proceedings of the 2012 Winter Simulation Conference,* edited by C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, 1-2. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Rossetti, M. D. 2008. "Java Simulation Library (JSL): An open-source object-oriented library for discrete-event simulation in Java." *The International Journal of Simulation and Process Modelling*, 4: 1:69–87.

Sargent, R. G. 2011. "Verifications and Validation of Simulations Models." In *Proceedings of the 2011 Winter Simulation Conference*, edited by S. Jain, R. R. Creasey, J. Himmelspach, K. P. White and M. Fu, 183–198. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Widok, A. H., and V. Wohlgemuth "Enhancing Event-Discrete-Simulation Software with Sustainability Criteria." In *Proceedings of the* 2011 *The Third International Conference on Advances in System Simulation*. Barcelona – Spain. 190–195.

Zhou, X. and Kuhl, M. E. "Design and Development of a Sustainability Toolkit for Simulation." In *Proceedings of the 2010 Winter Simulation Conference*, edited by B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yucesan,1601–1612. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Zhou, X. and Kuhl, M. E. "A Sustainability Toolkit for Simulation: Recent developments and future capabilities." In *Proceedings of the 2011 Winter Simulation Conference*, edited by S. Jain, R. R. Creasey, J. Himmelspach, K. P. White and M. Fu, 850–858. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

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