Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2020, 7(5):161-169**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

A multi-agent approach for balancing the quantity of CO_2 in an urban center by dosing the sources of emissions and absorptions

Harouna Dan Djari*, Harouna Naroua

Département de Mathématiques et Informatique, Faculté des Sciences et Techniques, Université Abdou Moumouni, B.P.10662, Niamey, Niger
E-Mails: *harouna83@yahoo.fr, hnaroua@yahoo.com

Abstract This article presents a multi-agent simulation aimed at balancing the quantity of CO_2 by dosing the sources of emissions and absorptions in an urban center. The ability of multi-agent systems to handle complex problems has been deployed to model the main sources in the form of agents, taking into account their characteristics and the context of their use. A dosing protocol has been proposed based on parameters such as the types of sources selected, the dosing period, and the number of agents to inject. The results of the simulations show a disparity of influence between the sources of emissions and an inadequacy of the choice of the sources of absorption as sources to be dosed.

Keywords Simulation, Multi-agent model, Counterbalance, Platform, Protocol, Greenhouse gas

1. Introduction

The speed of growth of cities no longer needs to be demonstrated [1]. However, the perpetual phenomenon of urbanization generates daily growing needs in all socio-professional sectors [2-5]. Cities are continually facing the need for energy, transport, housing, waste management, etc. Satisfying these demands very often resorts to excessive consumption of fossil fuels which are the main sources of CO_2 emissions. For the adoption and integration of reliable policies in CO_2 mitigation, it is urgent to have technological tools to simulate and apprehend its possible counterbalances depending on its sources of emissions and absorptions. Among the best simulation approaches of the moment, multi-agent systems can be considered. They are used to simulate complex problems in various fields [6-18]. Using a multi-agent model, this article presents a procedure for balancing the quantity of CO_2 by dosing its sources of emissions and absorptions. An algorithm describing the protocol for coordinating the counterbalance has been proposed and implemented for practical purposes.

2. A multi-agent model for balancing the sources of CO_2 emissions and absorptions

In the search for counterbalance, only the main sources of CO_2 emissions [19-20] and absorptions [21] were considered. Five sources of emissions were selected which are mobile engines, stationary engines, air flights, households and waste (solid and liquid). The absorbers selected are trees, shrubs and herbaceous plants. All these sources have been modeled in the form of temporary agents named Mobile Engine Agent (MEA), Household Agent (HA), Air Transport Agent (ATA), Stationary Engine Agent (SEA), Solid Waste Agent (SWA), Liquid Waste Agent (LWA) and Absorber Agent (AA). The coordination of all activities is ensured by permanent agents which are IPS (Principal Interface SMAGCO), AMA (Agent manager), CTRA (Controller Agent), CONFA (Configurator Agent), IA (Interpreter Agent) and TERMA (Terminator Agent).

The following equations (1) - (7) define the contributions of the selected sources [19-21] where , v, PCI, FE_a, Activity, Purity are respectively the density, the volume, the net calorific value, the emission factor of type a fuel, the quantity of urea additives consumed in catalytic converters and the mass fraction of urea in urea additives. The estimation of CO_2 emissions from air flight is limited to landing and take-off (LTO) phases. For absorption sources, estimates are made on the basis of the number of trees of category i and type j (NA_{ij}) and of the average annual accumulation of carbon per tree of category i and type j (Cij).

$$\begin{cases} \text{Emission(MEA)} = (\rho.v.10^{-6}.\text{PCI}.\text{FE}_a) + \left(\text{Activity}.\frac{12}{60}.\text{Purety}.\frac{44}{12}.10^6\right) \ldots\ldots\ldots\ldots (1) \\ \text{Emission(SEA)} = \rho.v.10^{-6}.\text{PCI}.\text{FE}_a \ldots\ldots\ldots\ldots (2) \\ \text{Emission(HA)} = \text{QC}_{burned}.\text{PCI}.\text{FE}_a \ldots\ldots\ldots\ldots (3) \\ \text{Emission(ATA)} = \rho.v_{AA}.10^{-6}.\text{PCI}.\text{FE}_a \ldots\ldots\ldots\ldots (4) \\ \text{Emission(SWA)} = \text{DSM}.\sum_j \left(\text{WF}_j.\text{dm}_j.\text{CF}_j.\text{FCF}_j.\text{OF}_j.\frac{44}{12}\right) \ldots\ldots\ldots\ldots (5) \\ \text{Emission(LWA)} = \sum_i (\text{AL}_i.\text{CL}_i.\text{OF}_i).\frac{44}{12} \ldots\ldots\ldots\ldots (6) \\ \text{Absorption(AA)} = \frac{44}{12}.\sum_{ij} \text{NA}_{i,j}.\text{C}_{i,j} \ldots\ldots\ldots\ldots (7) \end{cases}$$

The search for counterbalance is performed by injection of emitters and/or absorbers. Depending on the parameters to dose, the deployed agents are classified into two groups: agents to be dosed (gradually put into service) and agents not to be dosed (directly put into service). The parameters are essentially the start and end dates, the tolerance, the number of agents to inject, the dosing period, and the type(s) of agents. The following algorithm describes the process while the figures 1 and 2 illustrate its sequence and activity diagrams.

Algorithm: counterbalanceByDosage ()
entry : deployed temporary agents, toleranceCounterbalancePerDosage,
dateStartCounterbalancePerDosage, periodJet, dateLimitCounterbalancePerDosage,
nbAgentsPerJet and typeOfJet, periodGrowth.
output : progression of emissions and absorptions, offset date
known : permanent agents, emission factors, absorption factors and city
variable :
GlobalValue, MEAvalue, HAvalue, ATAvalue, SEAvalue, LWAvalue, SWAvalue, AAvalue,
toleranceCounterbalancePerDosage, globalPREVIOUS: **real ;**
dateStartDosingCounterbalance, dateLimitDosingCounterbalance, dateCurrent: **date ;**
listAgentsJet, listAgentsNoJet, listAgentsCurrent: **list of agents ;**
ctrlEndCounterbalancePerDosage, endSaveEmissionAbsorption,
ctrlEndAuthorizationEmissionAbsorption: **boolean ;**
numberReceptionExpected, nbAgentsPerJet: **integer**
typeOfJet[]: string ;
periodJet, cptPeriod: integer ;
periodGrowth[]: integer ;
growth: boolean ;
begin:
typeOfJet ← empty;
USER starts the counterbalance process from the main interface ;
IPS displays the entry parameters;
while(invalid dateStartDosingCounterbalance**or** invalid dateLimitDosingCounterbalance**or** invalid nbAgentsPerJet**or** invalid toleranceCounterbalancePerDosage**or** invalid periodJet **or** invalid typeOfJet **or** not growth)
growth ← true ;
USER selects typeOfJet ;
USER selects the dates (dateStartDosingCounterbalance, dateLimitDosingCounterbalance) ;
USER enters (toleranceCounterbalancePerDosage, nbAgentsPerJet, periodJet) ;
if (*USER* chooses the agent growth option) **then**
USER enters periodGrowth;
endIf

IPS validates (dateStartDosingCounterbalance, dateLimitDosingCounterbalance, toleranceCounterbalancePerDosage, nbAgentsPerJet, periodJet, periodGrowth) of *USER*;
if(invalid periodGrowth) **then**
growth ← false
endIf
endWhile
IPS sends the validated parameters to *CONTROLLER* ;
CONTROLLER receives the parameters ;
CONTROLLER determines the two lists of agents based on typeOfJet :
listAgentsJet ← list of agents to be dosed ;
listAgentsNoJet ← list of agents not to be dosed ;
if (listAgentsJet is empty) **then**
CONTROLLER sends a notification message to *IPS* ;
IPS asks the *USER* to select agents ;
else
CONTROLLER initializes all agents of listAgentsNoJet with periodGrowth ;
foreach temporary agent of listAgentsNoJet**do**
receive the initialization request ;
initialize ;
endFor
dateCurrent ← dateStartDosingCounterbalance ;
ctrlEndCounterbalancePerDosage ← false
ctrlEndAuthorizationEmissionAbsorption ← false ;
endSaveEmissionAbsorption ← true ;
cptPeriod ← periodeJet ;
dateCurrent ← dateStartDosingCounterbalance ;
while ((not ctrlEndCounterbalancePerDosage) and endSaveEmissionAbsorption)
if(cptPeriod=0)
cptPeriod ← periodeJet ;
if(size (listAgentsJet) >nbAgentsPerJet) **then**
CONTROLLER moves nbAgentsPerJet agents of listAgentsJet to listAgentsCurrent ;
else
CONTROLLER moves listAgentsJet to listAgentsCurrent
endIf
endIf
cptPeriod ← cptPeriod -1 ;
CONTROLLER initializes all agents of listAgentsCurrent with periodGrowth;
CONTROLLER updates the Counterbalance parameters ;
foreach temporary agent of listAgentsCurrent**do**
receive the initialization request ;
initialize;
endFor
CONTROLLER inserts listAgentsCurrent in listAgentsNoJe t;
CONTROLLER notifies to *IPS* the end of initialization ;
IPS receives notification from *CONTROLLER* ;
IPS sends the control authorization to *CONTROLLER* ;
CONTROLLER receives control authorization from *IPS* ;
CONTROLLER sends size **(**listAgentsNoJet) to *INTERPRETER* ;
CONTROLLER authorizes the listAgentsNoJet agents to emit or absorb ;
CONTROLLER sends end of authorization to *INTERPRETER* ;
foreach temporary agent of listAgentsNoJet**do**
receive authorization for emission or absorption ;
quantify the quantity ofCO_2 to be emitted or absorbed ;
send the quantity ofCO_2 to *INTERPRETER* ;
endFor
INTERPRETER receives size (listAgentsNoJet) ;

```
                    INTERPRETER updates numberReceptionExpected :
                    numberReceptionExpected ← size (listAgentsNoJet) ;
                    INTERPRETER receives notification of the authorization end ;
                    INTERPRETER updates ctrlEndAuthorizationEmissionAbsorption :
                         ctrlEndAuthorizationEmissionAbsorption ← true ;
                    while (numberReceptionExpected> 0)
                         if (INTERPRETER receives an emission or an absorption)
                              thenINTERPRETER treats CO2 quantity ;
                               numberReceptionExpected ← numberReceptionExpected -1 ;
                    endIf
                    endWhile
                    if((numberReceptionExpected=0) and (ctrlEndAuthorizationEmissionAbsorption =
                      true)) then
                         if( (dateCurrent<dateLimitDosingCounterbalance)  and ( (GLOBALvalue< -
                              toleranceCounterbalancePerDosageandglobalPREVIOUS<0) or
                              (GLOBALvalue>toleranceCounterbalancePerDosageandglobalPRE
                              VIOUS>0) ) then
                              INTERPRETER sends to IPS (GLOBALvalue, MEAvalue,
                              HAvalue, ATAvalue, SEAvalue, SWAvalue, AAvalue,
                              dateCurrent) ;
                              dateCurrent ← next date ;
                              ctrlEndAuthorizationEmissionAbsorption ←false ;
                              endSaveEmissionAbsorption ←false ;
                              globalPRECEDENT ← Globalvalue
else

                              INTERPRETER sends to IPS (GlobalValue, MEAvalue, HAvalue,
                              ATAvalue, SEAvalue, SWAvalue, AAvalue, dateCurrent) and the
                              notification of the end of counterbalance) ;
                              ctrlEndCounterbalancePerDosage ← true ;
                          endIf
                    endIf
                    ifIPS receives a message containing only the values of emissions and absorptions
                      (GlobalValue, MEAvalue, HAvalue, ATAvalue, SEAvalue, SWAvalue, AAvalue,
                      dateCurrent) then
                         IPS saves all emissions and absorptions with their current date ;
                         IPS sends the end of backup message to CONTROLLER ;endIf
                    ifIPS receives the values of emissions and absorptions (GlobalValue, MEAvalue,
                      HAvalue, ATAvalue, SEAvalue, SWAvalue, AAvalue, dateCurrent) and the
                      notification of the end of counterbalance then
                         IPS saves all emissions and absorptions with their current date dateCurrent ;
                         IPS informs the USER of the end of counterbalance while specifying the
                           termination context (normal end or the counterbalance deadline
                           reached);
                    endIf
                    ifCONTROLLER receives a notification of end of backup then
                     endSaveEmissionAbsorption ←true ;
                    endIf
endWhile
endIf
end
```

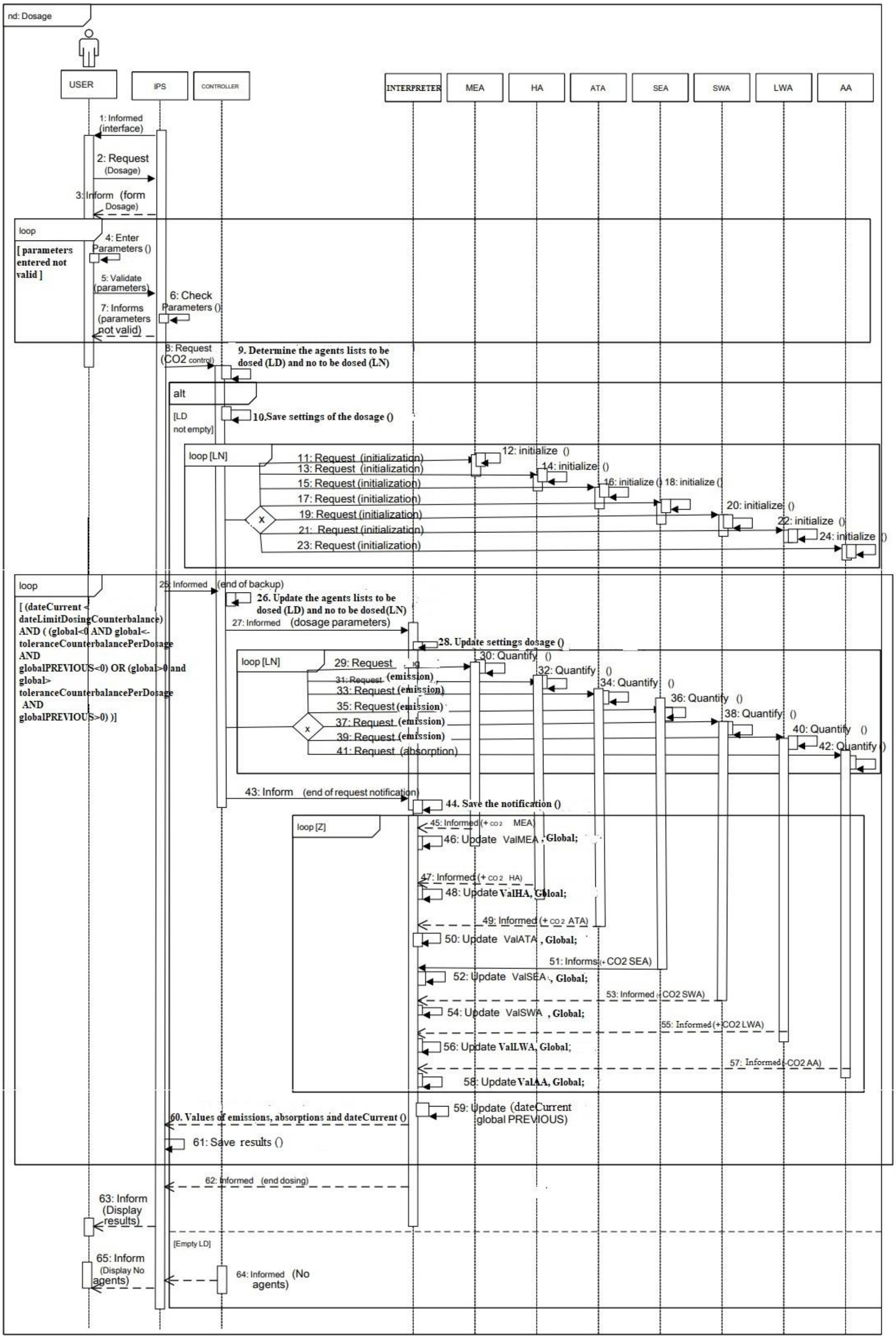


Figure 1: Sequence diagram of counterbalance by dosing the sources

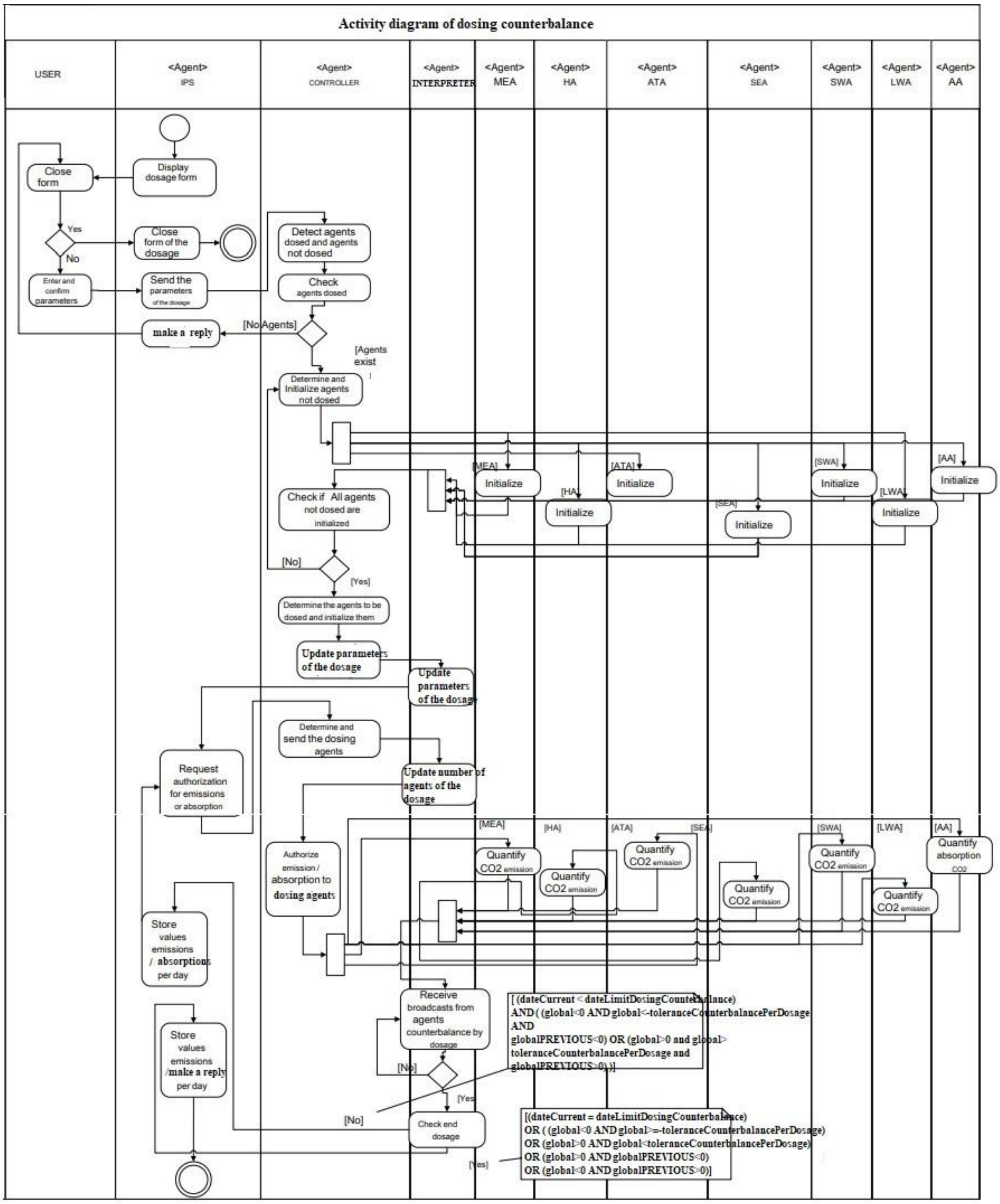


Figure 2: Activity diagram of counterbalance by dosing the sources

3. Results and Discussion

In order to test the search for a CO_2 counterbalance by dosing the sources, several series of simulations were carried out. The following table describes the characteristics of the temporary agents used.

Table 1: Characteristics of temporary agents

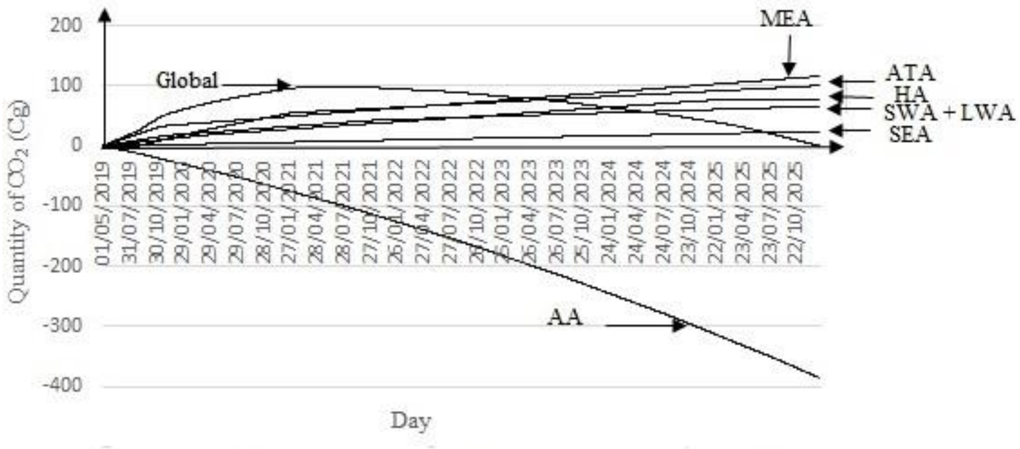
Agents	Characteristics
MEA	Reference, Type, Owner, Fuel Used, Consumption / Day, Activity, Purity, Number of Occurrences, Start Date, Stop Date.
ATA	Reference, Type, Owner, Consumption /LTO (Landing and Take-Off), Number of Occurrences, Start Date, Stop Date.
SEA	Reference, Type, Owner, Fuel Used, Consumption / Day, Number of Occurrences, Start Date, Stop Date.
HA	Reference, Type, Household Head, Fuel Used, Consumption / Day, Number of Occurrences, Technology, Humidity, Start Date, Stop Date.
SWA	Reference, Population, Burning Waste Fraction, Waste Volume / Habitant / Day, Burned Waste Volume / Habitant / Day, Number of Occurrences, Waste Components, Fraction of Type / Material, Dry Matter Content, Total Carbon Content, Fossil Carbon Fraction, Oxidation Factor, Burning Start Date, Burning Stop Date.
LWA	Reference, Volume, Carbon Content, Oxidation Factor, Number of occurrences, Burning Start Date, Burning Stop Date.
AA	Reference, Type, Species, Age, Number of Occurrences, Date of Beginning of Existence, Date of End of Life.

The counterbalance process is carried out through a coordination of interactions between processing agents and temporary agents which progressively measures the dates, the tolerance, the number of agents to inject, the dosing period, the type(s) of agents, and the period of growth.

Figure 3 illustrates a model of the results of a counterbalance search by dosing the sources. The global curve is the sum of emissions (by MEA, HA, ATA, SEA, SWA, LWA) minus the absorptions (by AA). The global value is zero when the counterbalance is reached.

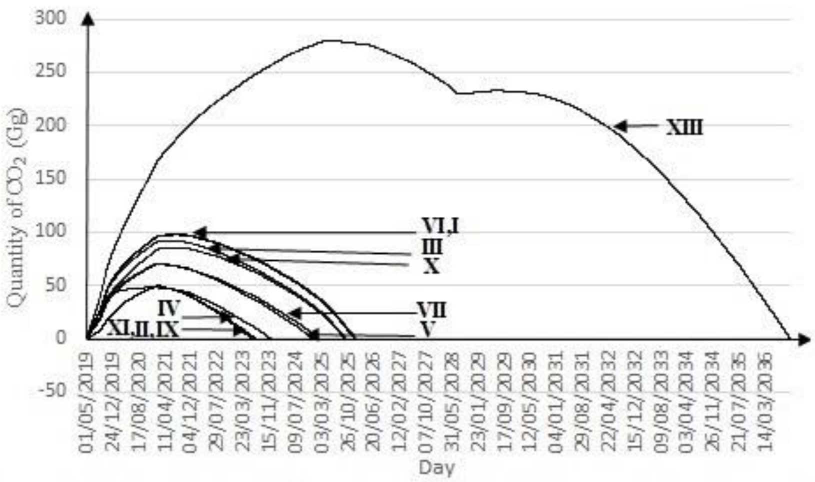
Figure 4 illustrates the search for a counterbalance as a function of the parameters and it was found that:

- Dosing the emission sources is the best strategy for rapid achievement of counterbalance ;
- Dosing the transport sources (air and land) leads to a faster counterbalance due to the fact that they are the main CO_2 emitters in the cities. This result is in agreement with Mehsen et al [22] ;
- Dosing the absorption sources yields a longer counterbalance. Efforts to create and multiply these sources are necessary to mitigate CO_2 emissions. This result is in agreement with several scientific works such as Privitera et al [23] and Kombate et al [24] ;
- An increase in the number of agents to inject decreases the time for counterbalance search;
- An increase in the dosing period increases the counterbalance time;
- A decrease in the tolerance value considerably reduces the search time;
- Reducing and controlling the combustion of fossil fuels are key strategies in policies to limit CO_2 emissions in the cities;
- The counterbalance search is a strategy to be considered in the development of policies to control air pollution due to CO_2.



MEA	SEA	ATA	HA	SWA	LWA	AA
15 000	75 000	300	7 500	700	75 000	30 000 000

Figure 3: Sample results for a counterbalance search by dosing the sources



Series	MEA	SEA	ATA	HA	SWA	LWA	AA	Dosing period	Agents to injec	Tolerance	Agents to dose
I	15 000	75 000	300	7 500	700	75 000	30 000 000	initial	initial	initial	initial
II	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.000001	MEA
III	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.000001	SEA
IV	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.000001	ATA
V	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.000001	HA
VI	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.000001	SWA
VII	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.000001	LWA
VIII	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.000001	AA
IX	15 000	75 000	300	7 500	700	75 000	30 000 000	730 days	10	0.000001	MEA
X	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	100	0.000001	MEA
XI	15 000	75 000	300	7 500	700	75 000	30 000 000	365 days	10	0.01	MEA

Figure 4: Search of counterbalance by dosing the sources

3. Conclusion

In the efforts to reduce greenhouse gases, multi-agent systems can make a major contribution. The search for an equilibrium in the quantity of CO_2 by dosing the sources shows a disparity of influence between emitters and an inadequacy of the choice of absorbers as sources to be dosed. In order to understand and measure the magnitude and scale of the quantity of CO_2, it is essential to promote multi-agent simulations.

References

[1]. Laurence M. (2019). Dakar ville moderne: la médiation des entrepreneurs sénégalais en Chine. Canadian Journal of African Studies/Revue canadienne des études africaines. 53(1): 89-107.

[2]. Comentale B. (2019). Les anciennes carrières de pierre en ville, un élément du géopatrimoine: exemples de Paris et de Nantes. Physio-Géo. Géographie physique et environnement. 13(1): 1-24.

[3]. Eric C. & Charles Étienne B. (2018). Les statuts particuliers des grandes villes au Canada: promesses et limites. Wydawnictwo Uniwersytetu Śląskiego. 9(2): 256-271.

[4]. Holleaux D. (2019). Les enjeux de la transition énergétique en Asie du Sud-Est. Revue internationale et stratégique. 113(1): 145-153.

[5]. Rajaa M., & Ibnoulkatib G. (2019). La logistique Urbaine: Identification des Concepts Clés (Revue de Littérature). European Scientific Journal. 15(2): 57-71.

[6]. Balama G. & Paul D. (2019). Proposition of an Intelligent Multi-Agent System for Learning. Journal of Advanced Research in Computer Technology & Software Applications. 3(1): 1-5.

[7]. Nicolas P. (2018). Simuler la science: un modèle multi-agents de l'évolution des idées scientifiques. Thèse, Philosophie, Université du Québec à Montréal (Canada).

[8]. Habib J. & De Corbière F. (2018). Proposition d'un design de recherche pour l'analyse des processus complexes et émergents en systèmes d'information : De l'intérêt de combiner étude (s) de cas et simulation multi-agents. Systèmes d'Information et Management. 23(3) : 127-153.

[9]. Meriyem C. (2017). Conception et Réalisation d'une Plateforme de Gouvernance des Systèmes d'Information à base des Workflows inter-organisations, du Web sémantique et des Systèmes Multi Agents. Thèse, Génie Informatique, Université Hassan II, Casablanca (Maroc).

[10]. Reulier R., Delahaye D., & Viel, V. (2019). Agricultural landscape evolution and structural connectivity to the river for matter flux, a multi-agents simulation approach. Catena. 174: 524-535.

[11]. Jiang W. (2018). Contrôle de la formation et du confinement variable dans le temps et entièrement distribué pour les systèmes multi-agents/multi-robots. Thèse de doctorat, Ecole centrale de Lille.

[12]. Ghazi S., Dugdale J. & Khadir T. (2018). A Multi-Agent based Approach for Simulating the Impact of Human Behaviours on Air Pollution. Informatica. 42(2): 199-209.

[13]. Gao Y., Liu G., Casazza M., Hao Y., Zhang Y. & Giannetti B. F. (2018). Economy-pollution nexus model of cities at river basin scale based on multi-agent simulation: A conceptual framework. Ecological Modeling. 379: 22-38.

[14]. Najjar A., Picard G., et Boissier O. (2018). Négociation multi-agents résistante aux pics de charge pour améliorer l'acceptabilité des services d'un fournisseur SaaS ouvert. Revue d'Intelligence Artificielle. 32(5): 603-625.

[15]. Guériau M., Armetta F., Hassas S., Billot R., & El Faouzi N. E. (2018). Apprentissage constructiviste à base de systèmes multiagents. Une application au problème complexe de la régulation coopérative du trafic. Revue d'Intelligence Artificielle. 32(2): 249.

[16]. Monticolo D., Gabriel A. & Barrios P. C. (2018). Une approche de conception de systèmes multi-agents dédiés à la gestion des connaissances. Ingenierie des Systemes d'Information. 23(2) : 61-88

[17]. Dan Djari H. & Naroua H. (2019). Modeling and multi-agent simulation of CO_2 management in an urban center. ARPN Journal of Engineering and Applied Sciences, 14(3): 686-693.

[18]. Dan Djari H. & Naroua H. (2019). A simulative and multi-agent study for balancing the quantity of CO_2 in an urban area by fixing the sources of emissions and absorptions. Journal of Scientific and Engineering Research. 6(3): 128-139.

[19]. Eggleston H.S., Buendia L., Miwa K., Ngara T. et Tanabe K. (2006). Lignes directrices 2006 du GIEC pour les inventaires nationaux de gaz à effet de serre, préparé par le programme pour les inventaires nationaux de gaz à effet de serre. Volume 2, Energie, GIEC, Japon

[20]. Eggleston H.S., Buendia L., Miwa K., Ngara T. et Tanabe K. (2006). Lignes directrices 2006 du GIEC pour les inventaires nationaux de gaz à effet de serre, préparé par le programme pour les inventaires nationaux de gaz à effet de serre. Volume 5, Edition IGES, Japon, 2006.

[21]. Eggleston H.S., Buendia L., Miwa K., Ngara T. et Tanabe K. (2006). Lignes directrices 2006 du GIEC pour les inventaires nationaux des gaz à effet de serre, préparé par le programme pour les inventaires nationaux des gaz à effet de serre. Groupe d'experts intergouvernemental sur l'évolution du climat. Volume 4, Edition IGES, Japon.

[22]. Mehsen A. K, Jocelyne A.G et Hervé F. (2019). La perception de la pollution de l'air à Beyrouth - Territoire en mouvement. Revue de géographie et aménagement [En ligne], 41 | 2019, mis en ligne le 04 avril 2019, consulté le 22 avril 2019. URL: http://journals.openedition.org/tem/5279; DOI: 10.4000/tem.5279.