Reducing product's carbone footprint with crowd-logistics in the last mile delivery : A dynamic simulation of crowd behavior under sustainability constraint

Omar ELGHAFFOULI
2nd year student
Ecole Centrale Casablanca
Casablanca, Morocco
omarelghaffouli2001@gmail.com

Hakima EL QUAZBARI
2nd year student
Ecole Centrale Casablanca
Casablanca, Morocco
Hakima.elqazbari@centrale-casablanca.ma

Ibrahim ENOUALI
2nd year student
Ecole Centrale Casablanca
Casablanca, Morocco
ibrahim.enouali@centrale-casablanca.ma

Tariq CHELLALI
2nd year student
Ecole Centrale Casablanca
Casablanca, Morocco
Tariq.chellali@centrale-casablanca.ma

Ahmad El ACHAM
2nd year student
Ecole Centrale Casablanca
Casablanca, Morocco
Ahmad.elacham@centrale-casablanca.ma

Mohammed Amine BOURICHI
2nd year student
Ecole Centrale Casablanca
Casablanca, Morocco
Mohamed-Amine.Bourichi@centrale-casablanca.ma

Abstract

Last mile delivery has economic and environmental inefficiencies. It's the costliest part in the supply chain process and it induces high carbon emissions. The emergence of green logistics has transformed delivery process since concerns about product's carbon footprint in delivery has grown and the demand of environmental transparency by clients and investors has become frequent. Collaboration in the last mile delivery has been proved as the best way to achieve economic and environmental gains. Crowd logistics is one of the collaborative concepts operating in last mile delivery and believed to be the best way to achieve sustainability. In this article, we investigate crowd behavior in a crowd logistics platform under environmental constraint. We use evolutionary game theory and dynamic systems theory to find equilibrium that ensure the continuity of the platform. Equilibrium has been found only under government or non-governmental financial aid for the crowd logistics platforms. Platforms should keep less than the half of aids for management and distribute the rest to drivers to keep the platform operational.

Keywords—Last mile delivery, Collaboration, Crowd logistics, Sustainability.

I. INTRODUCTION

The last mile is the final part of a package's journey to the customer. It is the final mile in which a package is delivered from the distribution center to the customer's house. This final leg of delivery often involves a high-carbon mode such as air, truck, or train. The carbon footprint of last-mile delivery is a hot topic right now. It's the final step in the supply chain - delivering goods to your door - but it can leave out an important aspect of sustainability: the environment[1].

Carbon emissions from last mile delivery is a major issue in the world of e-commerce and logistics. The last mile delivery contributes to over 90% of total carbon emissions from e-commerce, with each customer's package requiring 5-10 miles to deliver. It's estimated that "operationally, last-mile delivery across the world uses about 1.8 billion liters of fuel per day [2]. There are various reasons for this increase in emissions. One contributor is the increased frequency of deliveries due to e-commerce. This has led to more distribution centers being built, which increases traffic congestion and CO2 emissions. Secondly, about two thirds of global deliveries are carried by trucks or vans, which are less efficient than public transit services like buses or light rail[3]. This is an alarming figure that needs addressing if we want to reduce global carbon emissions. In addition, as customers demand more express options, they are incentivizing companies to make more deliveries as well as increasing the distance traveled with each shipment.

As companies are becoming more conscious about their contribution to climate change, they are looking for ways to make their deliveries cleaner and more sustainable. Many companies have committed to using electric vehicles for their last-mile deliveries, but there are some logistics to consider before you go all in on an electric fleet. One question is who will maintain these vehicles? Electric cars require charging stations, which need maintenance by qualified professionals. The cost of maintaining these vehicles can be daunting. These electric cars also require space to charge, so the company must find a way to make space for charging stations. Another question is where will you charge your electric vehicles? There are many different types of chargers, and they all have their pros and cons. For example, a slow charger takes longer to charge the vehicle but uses less energy than a fast charger[4]. Some companies choose not to hire employees specifically for last-mile delivery, instead paying their workers time-and-a-half or double time on delivery days. This allows them to save on overhead costs when it comes to hiring someone who's solely dedicated to charging and maintaining these electric vehicles.

To address this problem, many scholars think that collaborative methods in the last mile delivery may be a great solution. Companies share their logistics resources and coordinate in their deliveries to reduce the amount of vans and employees. Scholars have shown that collaborative methods reduce last mile delivery cost and are very eco-friendly. Several problems rise in collaborative methods such as fair cost allocation between involved companies. A large number of articles try to find fair cost allocation methods to keep up the collaboration for the long-term.

Speaking Collaboration, the crowd logistics is a booming concept in the field of last mile delivery. Many scholars have studied this new delivery mode and have demonstrate his economic and environmental efficiency. For Mehmann, Frehe, and Teuteberg, crowd logistics designates “the outsourcing of logistics services to a mass of actors, whereby the coordination is supported by a technical infrastructure. Crowd logistics aims to achieve economic benefits for all stakeholders »[5]. While Rouquet, and Roussat define it as « initiatives that tap into the logistical resources of the crowd to perform logistics services »[6]. And for Le and Ukkusuri, it’s « a system which connects couriers and requesters through an app- based platform for a first or last mile intra-urban delivery »[7] .

The applicability of this concept is proved when Paloheimo, Lettenmeier and waris studied the system of crowd logistics in a library in Finland. They showed that there is clear benefit for all collaborators[8]. In addition, it can reduce an average of 1.6 kilometers driven by cars[9].

Crowd logistics seems to be an efficient eco-friendly method for goods delivery to final customers. Although many scholars have studied this concept, have calculated how much cost it saves and compared with traditional methods its environmental positive impact however, its applicability still not ensured and face a lot of problems because of uncoordinated strategies between participants.

Crowd logistics delivery platforms (CLDP) are emerging web applications that allow participants to meet so that they can ensure the delivery services. In Morocco, there isn’t a platform that operates 100% in crowd logistics however, we can find some platforms like “Blinc” and “Indriver” operating in the ride-hailing sector that works the same way as a CLDP. The infrastructure of “Glovo” application can work for a crowd logistics platform but the delivery company is not using the mass to provide deliveries.

In the CLDP, we find shippers who wants to deliver products to the final customers. Zhang Yi, Chuankai Xiang, Lanxin Li & Hong Jiang identified, in addition to CLDP, two other stakeholders and named them drivers and shippers[10]. Shippers can be retailers, restaurants or any other person who wants to get a delivery done. Drivers are people who provides deliveries. Those people can be professionals, students, pedestrians, or part time workers who have cars, vans, bicycles, and motorcycles. Those stakeholders aim to maximize their profits in the CLDP and each one has his own strategy to make more profits.

This is a classic problem from game theory where participants are involved in a game and where they can develop their strategies and learn over time. Dynamic system theory is used to find the equilibrium of participants strategies so that the platform stays operational. CLDP are the game field where gamers are playing with their own strategies.

Since many studies focus on studying the crowd logistics in the last mile delivery and evaluate its positive economic and environmental impact. This paper focuses on studying how to keep crowd logistics delivery platforms operational under the environmental constraint by studying crowd behavior.

II. LitERETAURE Review

A. Last mile delivery economic and environmental inefficiency

The last mile delivery is an important process in the e-commerce because it can be assumed that a bad delivery can leave a negative effect on the customer [11]. This process is not just the most cost-intensive part of the supply chain[12], but it’s also the most polluting part[13]. The last mile delivery accounts at least 28% of the total delivery cost[14]. Moreover, in this process, carbon emissions are basically caused by the fuel consumption or power consumption of distribution vehicles[15]. There are many distribution modes in the last mile delivery such as the traditional mode, Intelligent express cabinet, crowdsourcing and the third-party collection mode. Each of these modes has his own advantages and limitations[13]. Since concerns about sustainable delivery have become bigger, new distribution modes have been innovated.

B. The emergence of green logitics and its challenges

With the revolution of the supply chain management during the 1990s, the term green logistics has appeared[16]. Before green logistics, companies were looking only for the economic benefits, but after the green logistics arrival, the best way of the supply chain management has been when the activity attains the environmental and economic benefits at the same time and companies has become more concerned about their environmental footprint because the demand of transparency in sustainability by customers and investors has grown[17]. But despite that, the logistic activities still cause an increase of the Carbone emission especially in the last mile delivery[2].This situation is due to many factors like **the absence of the collaboration** and the frequent dissipation of resources. For that, as solutions proposed by numerous scholars, we find the collaboration distribution and the third-party distribution[17]. In addition, only 10% of companies are actively adjusting their supply chain carbon footprints and have executed successful sustainability initiatives[18]. While 83% of companies decided to include environmental benefits in their strategic decisions, yet only 35% of companies have proved a green supply chain[19]. The environment consideration in supply chain strategies seems to be increasing with time.

C. Collaboration in the last mile delivery as way to achieve economic and environmental gains.

With the objective to reduce costs and improve operational efficiency, many scholars test out diverse approaches and try to develop some solutions for sustainable deliveries. Among these solutions, Emel Aktas, Michael Bourlakis & Dimitris Zissisthere used the Capacitated Vehicle Routing Problem with Time Window. It focuses on minimizing the delivery distance while delivering to several customers and typically reduce the cost, the time, and the CO2 emission[20]. They created a collaboration using the concept of micro hubs which leads to lower distance and fewer routes for each vehicle [21].This concept applies in the horizontal collaboration where every company drop the products ordered by all costumers to the nearest hub center, and within a time window, the products stored in micro hubs are delivered to all costumers once time. To minimize the total distance of the deliveries, some systems enable the couriers to detect the most minimal distance. Those systems may apply for example the graph theory or the vehicle routing problem (VRP) and its variants to reach all the points which means in this case the destinations of deliveries.[21]

Another way to minimize delivery costs and achieve the environmental purpose is by using the concept of end crowdsourcing service stations (ECSSs) suggested by Kexin Bi, Mengke Yang, Latif Zahid and Xiaoguang Zhou[13]. It allows to companies to build collaboratively ECSSs in the optimal places that minimize the distance travelled by products and use the mass to fulfill deliveries (friends, neighbors, or the final client himself). However, when each customer gets his delivery with the fact that there is no guarantee that he will not be using a vehicle, it's turn out that this method can be very polluting than any traditional other method.

Another type of horizontal collaboration is by using service clustering in last mile delivery. we suppose that in one region there are three collaborators, those collaborators sell a particular product common between them. This concept tries to allow each collaborator to deliver a specific product and not all of them by clustering using a baduk board game and multi-objective programming to generate the model[22]. This method tries to provide collaborative deliveries by products clusters between companies. However, coordination between participants is hard to establish since the collaboration is in a volatile environment where participants objectives may not remain the same.

Numerous studies try to adapt the collaboration in the last mile delivery to different types of products, for example in the horizontal collaboration, for food deliveries, they innovated multi-compartment vehicles to maintain each product's quality by conserving the temperature degree necessary for each product; generally, this type of vehicles contains two areas, the first one is for fresh products and the second one is for frozen products. The question investigated in the article is how much travel distance savings can be achieved by horizontal collaboration of retailers in last mile food deliveries using multiple compartment vehicles versus no collaboration[23].

There is a large literature studying collaborative methods in logistics and each article set up a distribution mode in the last mile delivery, evaluate its cost savings and its sustainability. However, collaboration in other levels like information sharing is always supposed despite the fact that many problems occur in the collaboration from the lack of transparency.

Collaboration is the best way for cost saving between companies and to be more cost efficient and to be fairer and to have more transparency, some scholars have invented cost allocation methods and models to distribute fairly costs between companies in collaboration. Collaborative game theory (CGT) sets the fundamental theory to study strategies of players who are collaborators in this case. Each player tries to maximize his profit collaborating with his rivals. Many scholars have used the Shapley value from CGT to model cost allocation. There is a large literature in cost allocation methods. From Nucleolus Method, Allocation model based on volume or stand-alone cost and Equal profit method to Weighted relative savings model. Christine Vanovermeire, Dries Vercruysse and Kenneth Sörensen provide a detailed article of all cost allocation methods and decision tree-based model to allow companies to choose the best method of their own case[24].

Generally, Collaboration in the last mile not only achieves economic benefits, but it also achieves an environmental benefit by reducing the delivery distance thanks to the strong correlation between the distance travelled and carbon emissions[21].

D. Crowd logistics as a collaborative concept for sustainability

Many articles have studied crowd logistics and the literature about it can be classified into scholars who have modelled the crowd logistics concept and others who have evaluated its applicability. There are also scholars who have studied some influencing parameters of crowd logistics and others who have evaluated factors influencing crowd participation. Volker Frehe, Jens Mehmann and Frank Teuteberg have established and evaluated business models for companies in crowd logistics for more sustainable models[25]. Kexin Bi, Mengke Yang, Latif Zahid, Xiaoguang Zhou have innovated a crowd logistics-based model and evaluated its sustainability and applicability in China. Their model reduces Carbone emission by 23.79% to 28.49% in the last mile delivery[13]. Zhang Yi, Chuankai Xiang, Lanxin Li & Hong Jiang have studied crowd behavior in crowd logistics platforms using evolutionary game theory and dynamic systems without any environmental constraints[10].

In fact, the crowd logistic has been one of the active topics discussed in the business world and the development of this concept will actively impact the delivery area[6]. The applicability of this concept is proved when Paloheimo, Lettenmeier and waris studies the system of crowd logistic in a library in Finland, and it gains a diverse benefit for the three collaborators[8].

Uber and Lyft, for example, are successful crowd logistics provider and there are other companies who are also beginning to use crowd logistic for last mile delivery [19]. Also, Amazon has decided to use his customers as a crowd or mass of people for the last-mile-deliveries in June 2015 for applying the crowd logistic[5]. But the environmental aspect of crowd logistics and its applicability still needs more studies[26].

What is the problem? Reviewing the literature, we found out that many scholars have tried to create crowd logistics models and simulate crowd behavior but only to show economic profit and far from environmental constraints.

In this paper, we will focus on the environmental dimension in the crowd logistics. The following theorical study determine the impact of an environmental constraint on the crowd behavior specifically drivers to understand their possible behavior. Which means if drivers would stay or leave the platform under the environmental constraint and if the platform will continue to deliver delivery services and what's to be done in the case of sustainability constraint to ensure platform's service continuity.

III. SIMULATION OF CROWD BEHAVIOR UNDER SUSTAINIBILITY CONSTRAINT

A. *Game description*

CLDP is a platform where shippers and drivers meet and provide delivery services for shipper's final clients. The duty of this platform is to provide enough drivers that can match the demand and avoid customers frustrations. Shippers are the direct service providers to the client. They want to ship the delivery using crowd logistics platforms. Drivers are vehicle owners, students, part time workers or professionals.

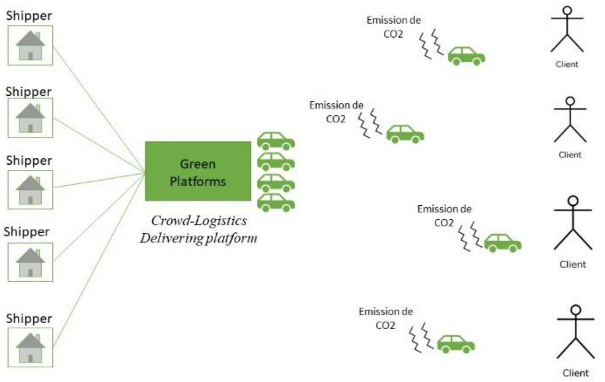

Figure 1: Description of game's field between shippers, drivers and CLDP under environmental constraint

Here is some a brief description of players strategies under environmental constraint:

(1) Participants learn strategies from each other with the goal of profits maximization.
(2) Drivers have two strategies: either joining the platform or leaving it.
(3) Shippers must respect the price given by the platform.
(4) α is the probability that drivers respect the environmental constraint, and the 1-α is the probability that drivers don't respect the environmental constraint. γ is the probability that drivers stay in the platform, and then $1-\gamma$ is the probability that drivers leave the platform.

B. *Game logic*

Crowd-Logistics Delivering platform (CLDP) gathers shippers and drivers. Shippers pay for service fees F_1 while accessing the platforms. By using the platform services, they obtain a gain P_{11}. The platform imposes an environmental constraint. Drivers can either respect this constraint or pay for a penalty K. P_{12} is the extra profit of drivers when they don't respect the constraint. We have $K > P_{12}$ and $P_{12} < P_{11}$.
Drivers and shippers pay for the platform service. Drivers pay a cost F_2 to the platform. P_{21} and P_{22} are CLDPs profit from shippers and drivers respectively. By accessing the platform, drivers make a profit of P_{31}. The platform tends to keep $P_{31} > F_2$, in order to keep more drivers in the platform.

Variables	Meaning of the Variables	Notes
F_1	Service fees paid by shippers while accessing the platforms	$F_1 > 0$
F_2	Cost paid by drivers to the platform	$F_2 > 0$
P_{11}	Gain obtained by shippers for using the platforms	$P_{11} > 0$
P_{12}	Extra Profit of drivers if they don't respect the constraint	$0 < P_{12} < P_{31}$
P_{21}	CLDPs Profits from shippers	$P_{21} > 0$
P_{22}	CLDPs Profits from drivers	$P_{22} > 0$
P_{31}	Drivers Profits while using the platform	$P_{31} > 0$ P31>F2
K	Penalty paid by drivers for not respecting the environmental constraint	$K > P_{12}$
U	Driver's profits ratio of disengaged-joined the platform	$-1 \leq U \leq 1$
N	Equals U times the drivers` expect income under join platform	$N > 0$
α	The probability to respect the environmental constraint	$0 \leq \alpha \leq 1$
γ	Driver's probability of staying in the platform	$0 \leq \gamma \leq 1$

Table1: game variables description

In the game field, each participant has his own strategies and learn from other strategies. We present below the most decisive and influencing strategies in maintaining crowd logistics services continuity.

Participant's strategies		Drivers join the platform	Drivers disengage platform
Respect environmental constraint	Platform's income	$P_{21} + P_{22}$	P_{21}
	Driver's income	$P_{31} - F_2$	N
Doesn't respect environmental constraint	Platform's income	$P_{21} + P_{22} + K$	$P_{21} + K$
	Driver's income	$P_{31} - F_2 - K + P_{12}$	N

Table2: game players strategies

To find the equilibrium solutions for our system, we are going to use the EGT (evolutionary game theory). More specifically, we will use replicator dynamics to represent the evolution of drivers in crowd logistics while applying the environmental constraint.

$$\begin{cases} U_\alpha = P_{21} + \gamma P_{22} \\ U_{1-\alpha} = P_{21} + \gamma P_{22} + K \\ U_c = \alpha U_\alpha + (1-\alpha) U_{1-\alpha} = P_{21} + \gamma P_{22} + (1-\alpha) K \end{cases}$$

Where U_α represents the expected benefits of CLDP while drivers respect the environmental constraint and $U_{1-\alpha}$ represents the expected benefits of CLDP while drivers do not respect the environmental constraint. And U_c is the average expected benefits of CLPD.
Based on the replicator dynamics, the change rate of α is:

$$P(\alpha) = \frac{d\alpha}{dt} = \alpha(1-\alpha)(U_\alpha - U_{1-\alpha}) = -\alpha(1-\alpha)K$$

Moving to the expected benefits of drivers while staying or leaving platform:

$$\begin{cases} U_\gamma = P_{31} - F_2 - (1-\alpha)(K - P_{12}) \\ U_{1-\gamma} = U\,[P_{31} - F_2 - (1-\alpha)(K - P_{12})] \end{cases}$$

Where U_γ represents the expected benefits of drivers while staying in the platform and $U_{1-\gamma}$ represents the expected benefits of CLDP while drivers do not respect the environmental constraint:

$$D(\gamma) = \frac{d\gamma}{dt} = \gamma(1-\gamma)(1-U)[P_{31} - F_2 - (1-\alpha)(K - P_{12})]$$

C. Analysis of equilibrium solutions

Equilibrium solutions are the zeros of the following system:

$$\begin{cases} P(\alpha) = \frac{d\alpha}{dt} = \alpha(1-\alpha)(U_\alpha - U_{1-\alpha}) = -\alpha(1-\alpha)K = 0 \\ D(\gamma) = \frac{d\gamma}{dt} = \gamma(1-\gamma)(1-U)[P_{31} - F_2 - (1-\alpha)(K - P_{12})] = 0 \end{cases}$$

Therefore, we find four equilibrium solutions of pure strategy:

$$E_1(0,0), E_2(1,0), E_3(0,1), E_4(1,1)$$

To find out the stabilities of these solutions, we ought to calculate *the Jacobian* Matrix of the system.

$$\begin{bmatrix} -(1-2\alpha)K & 0 \\ \gamma(1-\gamma)(1-U)(K-P_{12}) & (1-2\gamma)(1-U)\big(P_{31} - F_2 - (1-\alpha)(K-P_{12})\big) \end{bmatrix}$$

Then, we need to determine the signs of each eigenvalue $\boldsymbol{\lambda_1}$ and $\boldsymbol{\lambda_2}$.

After resolving the dynamic system, we study below the stability of each point to find players convergence to a common strategy where they all make profit. Stable point are the only ones who are important for us to make decision.

Equilibrium solutions	λ_1	λ_2	**Stability**
$E_1(0,0)$	-K	$(1-U)(P_{31} - F_2 - + P_{12})$	Stable under the condition: $K > P_{31} - F_2 + P_{12}$
$E_2(1,0)$	K	$(1-U)(P_{31} - F_2)$	Unstable Point
$E_3(0,1)$	-K	$(1-U)(K - P_{31} + F_2 - P_{12})$	Stable under the condition: $K < P_{31} - F_2 + P_{12}$
$E_4(1,1)$	K	$-(1-U)(P_{31} - F_2)$	Saddle point

Table 3: The study of game conditions to stable points

Under the condition $K > P_{31} - F_2 + P_{12}$, we find one only stable equilibrium solution $E_1(0,0)$. In this position, we find total disengagement of drivers. Which is intuitive because drivers wouldn't gain any benefits in this strategy.

Choosing $K < P_{31} - F_2 + P_{12}$, then there is also one stable equilibrium solution $E_3(0,1)$. In this position, we find total engagement of drivers. However, this equilibrium doesn't respect the environmental constraint. In this case, the strategy maximizes CLDP profit, but it comes in the cost of total disregard to carbon emissions.

From this we find that $P_{31} - F_2 + P_{12}$ is a critical term for the constraint K, so if K is inferior to this point the system can stabilize at $E_3(0,1)$, and in the contrary case it stabilizes at $E_1(0,0)$.

From this study we conclude that while the system can stabilize, it's not where every driver respects the constraint. But the system can take equilibrium at $E_4(1,1)$ which is the best-case scenario, but not stably as this point is a saddle point.

As a conclusion the adding of an environmental constraint in this scenario doesn't lead stably to more respect to the environment, But the strategy might be worthwhile if K inferior to $P_{31} - F_2 + P_{12}$ as we don't risk losing the drivers but can still aim for attaining equilibrium at $E_4(1,1)$.

D. Model improvement

In the previous case, we concluded that the environmental constraint doesn't lead to reduce carbon emissions at the same time keeping drivers in the platform. This time, let suppose that the government or non-governmental organizations helps green platforms. Therefore, the CLDP receives subsidies S>0. θ is the percentage of subsidies taken by platforms and $(1-\theta)$ is the percentage of subsidies taken by drivers.

Let see mathematically what we will get. The matrix of strategies will be as follows:

Participant's strategies		Drivers join the platform	Drivers disengage platform
Respect environmental constraint	Platform's income	$P_{21} + P_{22} + \theta * S$	P_{21}
	Driver's income	$P_{31} - F_2 + (1-\theta)S$	N
Doesn't respect environmental constraint	Platform's income	$P_{21} + P_{22} + K$	$P_{21} + K$
	Driver's income	$P_{31} - F_2 - K + P_{12}$	N

Table 4: game players strategies in the improved model

Using the same calculations in the last section, we find:

$$P(\alpha) = \frac{d\alpha}{dt} = \alpha(1-\alpha)(U_\alpha - U_{1-\alpha}) = \alpha(1-\alpha)(-K + \theta S) = 0$$

$$D(\gamma) = \frac{d\gamma}{dt} = \gamma(1-\gamma)(1-U)[P_{31} - F_2 - (1-\alpha)(K - P_{12}) + \alpha(1-\theta)S] = 0$$

The solutions of the system are B (0,0), B (1,0), B (0,1) B (1,1).

And then the form the Jacobian Matrix:

$$\begin{bmatrix} -(1-2\alpha)(K-\theta S) & 0 \\ \gamma(1-\gamma)(1-U)(K+S-P_{12}) & (1-2\gamma)(1-U)(P_{31}-F_2-(1-\alpha)(K-P_{12})+\alpha(1-\theta)S) \end{bmatrix}$$

Let us now calculate each eigenvalue corresponding to position of the equilibrium.

Equilibrium solutions	λ_1	λ_2	Stability
$B_1(0,0)$	-K + θS	$(1-U)(P_{31}-F_2-K+P_{12})$	**Stable under the condition:** $K > P_{31}-F_2+P_{12}$ $K > \theta S$
$B_2(1,0)$	K - θS	$(1-U)(P_{31}+(1-\theta)S-F_2)>0$	**Unstable Point Or saddle point if** $K < \theta S$
$B_3(0,1)$	-K + θS	$(1-U)(K-P_{31}+F_2-P_{12})$	**Stable under the conditions:** $K < P_{31}-F_2+P_{12}$ $K > \theta S$
$B_4(1,1)$	K - θS	$-(1-U)(P_{31}+(1-\theta)S-F_2) < 0$	**Stable equilibrium Under the condition** $K < \theta S$

Table5 : The study of game conditions to stable points of the improved model

IV. *Discussion*

Since we are interested only in stable equilibrium, we observe three kinds of stabilities. For $B_1(0,0)$ and $B_3(0,1)$ their stability depends on the conditions $K > P_{31} - F_2 + P_{12}$ and $K < P_{31} - F_2 + P_{12}$ respectively and $K > \theta S$.

At the same time, for the position $B_4(1,1)$, which is the most important point to keep drivers in the platform while respecting sustainability. both eigenvalues are negative. Wich means $B_4(1,1)$ is a stable point under the condition $K < \theta S$. In other words, drivers respect the environmental constraint while staying in the platform.

To motivate drivers to stay in the platform, they should perceive that the penalties are less than the financial aid. This is a hook to keep drivers in the platform. So, to achieve this, we should have $K < (1-\theta)S$. This is possible only if $\theta < \frac{1}{2}$. Indeed, drivers see a potential in the first strategy to maximize their profits.

This improvement is valid because all stakeholders are maximizing their profits while staying friendly to the environment.

V. *Conclusion*

Since sustainability in last mile delivery has gained a lot of importance. We investigated in this article, using evolutionary game theory and dynamic systems, crowd behavior under environmental constraint in a crowd logistics Platforms. We have found that, only under governmental or non-governmental financial aid the platform will continue to be operational since drivers will stay in the platform. CLDP must maintain less than half of the financial aid and distribute the rest to drivers to encourage drivers to stay in the platform under environmental constraint. Governments should establish ecosystems and set legislations to help maintaining crowd logistics platforms since they are economically and environmentally efficient.

VI. *Acknowledgment*

We would like to thank Ecole Centrale Casablanca for giving us the opportunity to invest our efforts within the scientific project and to discover this hot field research about sustainable logistics. We also thank Ms*. **Salma Mouatassim*** for proposing this research topic under the name of “Sustainability in last mile delivery through collaboration”.

VII. *References*

[1] J. B. Edwards, A. C. McKinnon, and S. L. Cullinane, “Comparative analysis of the carbon footprints of conventional and online retailing: A ‘last mile’ perspective,” *International Journal of Physical Distribution and Logistics Management*, vol. 40, no. 1–2, pp. 103–123, 2010, doi: 10.1108/09600031011018055.

[2] J. R. Brown and A. L. Guiffrida, “Carbon emissions comparison of last mile delivery versus customer pickup,” *International Journal of Logistics Research and Applications*, vol. 17, no. 6, pp. 503–521, Nov. 2014, doi: 10.1080/13675567.2014.907397.

[3] M. Viu-Roig and E. J. Alvarez-Palau, “The impact of E-Commerce-related last-mile logistics on cities: A systematic literature review,” *Sustainability (Switzerland)*, vol. 12, no. 16. MDPI, Aug. 01, 2020. doi: 10.3390/su12166492.

[4] L. Andaloro, G. Napoli, F. Sergi, S. Micari, G. Agnello, and V. Antonucci, “Development of a new concept electric vehicle for last mile transportations.”

[5] W. 1959- Kersten, T. Blecker, C. M. 1974- Ringle, Technische Universität Hamburg-Harburg Institut für Logistik und Unternehmensführung, and Technische Universität Hamburg-Harburg, *Innovations and strategies for logistics and supply chains : technologies, businee models and risk management*.

[6] V. Carbone, A. Rouquet, and C. Roussat, “The Rise of Crowd Logistics: A New Way to Co-Create Logistics Value,” *Journal of Business Logistics*, vol. 38, no. 4, pp. 238–252, Dec. 2017, doi: 10.1111/jbl.12164.

[7] T. v. Le and S. v. Ukkusuri, “Modeling the willingness to work as crowd-shippers and travel time tolerance in emerging logistics services,” *Travel*

Behaviour and Society, vol. 15, pp. 123–132, Apr. 2019, doi: 10.1016/j.tbs.2019.02.001.

[8] H. Paloheimo, M. Lettenmeier, and H. Waris, "Transport reduction by crowdsourced deliveries – a library case in Finland," *Journal of Cleaner Production*, vol. 132, pp. 240–251, Sep. 2016, doi: 10.1016/j.jclepro.2015.04.103.

[9] Y. Wang, D. Zhang, Q. Liu, F. Shen, and L. H. Lee, "Towards enhancing the last-mile delivery: An effective crowd-tasking model with scalable solutions," *Transportation Research Part E: Logistics and Transportation Review*, vol. 93, pp. 279–293, Sep. 2016, doi: 10.1016/j.tre.2016.06.002.

[10] Z. Yi, C. Xiang, L. Li, and H. Jiang, "Evolutionary game analysis and simulation with system dynamics for behavioral strategies of participants in crowd logistics," *Transportation Letters*, pp. 1–15, 2020, doi: 10.1080/19427867.2020.1783609.

[11] Y. Vakulenko, P. Shams, D. Hellström, and K. Hjort, "Online retail experience and customer satisfaction: the mediating role of last mile delivery," *International Review of Retail, Distribution and Consumer Research*, vol. 29, no. 3, pp. 306–320, May 2019, doi: 10.1080/09593969.2019.1598466.

[12] C. Cordon, P. Garcia-Milà, T. Ferreiro Vilarino, and P. Caballero, "Bikes or Drones to the Consumer: The Logistical Challenge of the Last Mile," 2016, pp. 85–98. doi: 10.1007/978-3-319-31132-6_5.

[13] K. Bi, M. Yang, L. Zahid, and X. Zhou, "A new solution for city distribution to achieve environmental benefits within the trend of green logistics: A case study in China," *Sustainability (Switzerland)*, vol. 12, no. 20, pp. 1–25, Oct. 2020, doi: 10.3390/su12208312.

[14] T. Aized and J. S. Srai, "Hierarchical modelling of Last Mile logistic distribution system," *International Journal of Advanced Manufacturing Technology*, vol. 70, no. 5–8, pp. 1053–1061, Feb. 2014, doi: 10.1007/s00170-013-5349-3.

[15] B. Talbi, "CO2 emissions reduction in road transport sector in Tunisia," *Renewable and Sustainable Energy Reviews*, vol. 69. Elsevier Ltd, pp. 232–238, Mar. 01, 2017. doi: 10.1016/j.rser.2016.11.208.

[16] E. Morganti, L. Dablanc, and F. Fortin, "Final deliveries for online shopping: The deployment of pickup point networks in urban and suburban areas," *Research in Transportation Business and Management*, vol. 11, pp. 23–31, 2014, doi: 10.1016/j.rtbm.2014.03.002.

[17] Z. Zhang and M. A. Figliozzi, "A survey of China's logistics industry and the impacts of transport delays on importers and exporters," *Transport Reviews*, vol. 30, no. 2. pp. 179–194, Mar. 2010. doi: 10.1080/01441640902843232.

[18] K. W. Green, P. J. Zelbst, J. Meacham, and V. S. Bhadauria, "Green supply chain management practices: Impact on performance," *Supply Chain Management*, vol. 17, no. 3, pp. 290–305, Apr. 2012, doi: 10.1108/13598541211227126.

[19] V. Carbone and V. Moatti, "Towards greener supply chains: An institutional perspective," *International Journal of Logistics Research and Applications*, vol. 14, no. 3, pp. 179–197, 2011, doi: 10.1080/13675567.2011.609160.

[20] I. Cardenas, Y. Borbon-Galvez, T. Verlinden, E. van de Voorde, T. Vanelslander, and W. Dewulf, "City logistics, urban goods distribution and last mile delivery and collection," *Competition and Regulation in Network Industries*, vol. 18, no. 1–2, pp. 22–43, Jan. 2017, doi:10.1177/1783591717736505.

[21] E. Aktas, M. Bourlakis, and D. Zissis, "Collaboration in the last mile: evidence from grocery deliveries," *International Journal of Logistics Research and Applications*, vol. 24, no. 3, pp. 227–241, 2021, doi: 10.1080/13675567.2020.1740660.

[22] S. Y. Ko, R. P. Sari, M. Makhmudov, and C. S. Ko, "Collaboration model for service clustering in last-mile delivery," *Sustainability (Switzerland)*, vol. 12, no. 14, Jul. 2020, doi: 10.3390/su12145844.

[23] "Collaboration in last mile food deliveries: a multi-compartment vehicle routing problem."

[24] C. Vanovermeire and K. Sörensen, "Analysis of different cost allocation methods in a collaborative transport setting," 2014.

[25] V. Frehe, J. Mehmann, and F. Teuteberg, "Understanding and assessing crowd logistics business models – using everyday people for last mile delivery," *Journal of Business and Industrial Marketing*, vol. 32, no. 1, pp. 75–97, 2017, doi: 10.1108/JBIM-10-2015-0182.

[26] J. Rześny-Cieplińska and A. Szmelter-Jarosz, "Assessment of the crowd logistics solutions-the stakeholders' analysis approach," *Sustainability (Switzerland)*, vol. 11, no. 19, Oct. 2019, doi: 10.3390/su11195361.