Sustainability analysis in logistics

MANOLACHE Mădălina[1]

1 Titu Maiorescu University, The Faculty of Economic Sciences,
Calea Văcăreşti no.189, Bucharest, Romania, email address: manolache.madalina99@yahoo.com

Abstract

In order to increase overall sustainability throughout supply chain activities, lower operating costs, and improve efficiency, this article explores the optimization of logistic processes using mathematical tools and algorithms. Organizations must use analytical and data-driven techniques to improve decision-making and optimize operations as global supply chains grow more intricate and unpredictable. In order to solve problems with route planning, inventory management, warehouse operations, and risk assessment, mathematical optimization models—such as linear and nonlinear programming, heuristic algorithms, network flow models, and multi-criteria decision analysis—are essential. The increasing demand for robust, flexible, and ecologically conscious logistics systems shapes the study's setting. Digital transformation, automation, and green logistics are examples of emerging trends that emphasize the significance of mathematically based strategies that can produce measurable gains. Businesses can reduce waste, maximize resource allocation, and better predict interruptions by incorporating mathematical algorithms into logistical planning and execution. An analytical summary of these approaches is given in this article, with a focus on their useful uses and quantifiable advantages for contemporary logistics.

Keywords: sustainability, process optimization, green logistics, risk matrix, algorithms

1. Introduction

Logistics activities negatively impact the environment through greenhouse gas (GHG) emissions, with road freight transport having the greatest effect across the entire logistics chain. In the European Union, a significant share of total CO_2 emissions comes from road transport (approximately 15%), primarily generated by trucks and vans. To address this issue, the European Parliament proposed a package called "Fit for 55," aimed at reducing greenhouse gas emissions from vehicles to zero by the year 2035. This package was introduced in 2018 as a set of objectives and policies for lowering CO_2 emissions. The European Green Deal is a comprehensive set of measures meant to support the transition toward a climate-neutral economy. This initiative serves as a key strategy for improving quality of life, protecting the environment, and transforming European society toward a healthier way of living.

The main instrument at the European level used to reduce GHG emissions is the EU Emissions Trading System (EU ETS). Greenhouse gas emission certificates, commonly referred to as CO_2 certificates, are tradable rights representing one metric ton of carbon dioxide not emitted. The trading of these certificates is based on the difference between actual GHG emissions and the EU-established cap. Installations that have a surplus of certificates—meaning they emitted fewer greenhouse gases than the allowed annual quota—may sell these certificates to entities that have a deficit, that is, those that exceeded the European GHG emission limit. In Romania, Government Decision No. 780/2006 [1] transposed this scheme and sets out the obligations regarding the verification and reporting of greenhouse gas emissions.

Additionally, the introduction of a carbon tax has been proposed to encourage the reduction of GHG emissions. The purpose of this measure is to stimulate the choice of cleaner alternatives that rely on low-emission technologies.

DHL Group is one of the largest and most complex logistics and delivery companies in the world, with its headquarters located in Bonn, Germany. DHL invented international express delivery by sending documents ahead of the goods to facilitate customs processing. The company was fully acquired by Deutsche Post in the early 2000s and became part of what is now DHL Group.

As of 2024, DHL employs more than 601,700 people and operates in over 220 countries and territories. The company generates total revenues of 84.2 billion euros, with a net income of 3.3 billion euros and an operating profit of 5.9 billion euros.

As part of a reorganization plan aimed at saving 1 billion euros by 2027, 8,000 employees from the parcel division in Germany will be laid off. Among DHL's ongoing strategic priorities are the digitalization of as many processes as possible, automation, sustainable logistics, and expansion into regions such as Southeast Asia, Latin America, and India, where markets are rapidly growing. The company is investing in development by planning delivery routes using artificial intelligence, implementing smart warehouses, and advancing logistics solutions for the e-commerce sector. [2]

“Connecting people, improving lives” is the mission slogan of DHL. Through objectives such as facilitating international trade and simplifying the use of logistics services for both businesses and individual customers, DHL aims to promote sustainable growth through technological innovation. The company therefore adopts a customer-oriented approach, placing strong emphasis on logistics solutions that meet clients' needs while simultaneously integrating and promoting digital transformation, global accessibility, and the importance of environmental sustainability practices.

In terms of sustainability, DHL has been investing consistently in electric vehicles since 2021. Through these investments—from approximately 15,000 vehicles in 2021 to more than 39,000 in 2024—the company has expanded its fleet and significantly contributed to reducing greenhouse gas emissions. Its global expansion is also reflected in the steady growth of its workforce, which surpassed 601,700 employees in 2024.[2] [3] [4]

The evolutionary fluctuations in DHL Group's operating profit highlight a trajectory shaped by global macroeconomic shifts, as well as the significant challenges faced between 2019 and 2024, including the COVID-19 pandemic [3]

2. Methodology

Modern logistics plays a crucial role in the success of any business, directly influencing costs, delivery times, and customer satisfaction. In this context, optimizing logistics costs has become a strategic priority. An effective mathematical tool for achieving this objective is the Simplex algorithm, which is used to solve linear programming problems.

The proposed algorithm is based on the linear programming model, which analyzes the extreme point of a real-valued function represented by a linear expression, when the variables of this function must satisfy a set of constraints. It is well known that maximum efficiency implies minimizing effort and maximizing results, while simultaneously meeting all technical and economic constraints.

The algorithm developed using the simplex method concludes in two possible scenarios:

1) The optimal solution is obtained, and it is determined that the linear programming problem has a finite optimum — either unique or multiple;
2) The optimal solution is not obtained, because such a solution does not exist, and it is determined that the linear programming problem has no finite optimum.

To solve linear programming problems using the simplex method, we first consider the standard maximization problem:

$$\begin{cases} [max]\, f = \sum_{j=1}^{n} c_j x_j \\ \sum_{j=1}^{n} a_{ij} x_j \leq b, 1 \leq i \leq m \\ x_j \geq 0, 1 \leq j \leq n \end{cases} \tag{1}$$

The stages of developing this algorithm are as follows:

Step 1: Determining the objective function and the constraints

$$\begin{cases} [max]\, f - \sum_{j=1}^{n} c_j x_j + f = 0 \\ \sum_{j=1}^{n} a_{ij} x_j + s_j = b_j, 1 \leq i \leq m \\ b_j > 0, 1 \leq j \leq n \\ x_j \geq 0, 1 \leq j \leq n \end{cases} \tag{2}$$

Step 2: Determining the matrix or the simplex tableau:

We rewrite the linear programming problem by expressing the objective function in standard form and introducing artificial or slack variables s_j that transform the inequalities into equations.

We consider the simplex tableau in the following form:

1)

Table no. 1. Simplex table

Row	x_1	...	x_k	...	x_n	s_1	...	s_t	...	s_n	f	b	Ratio
L_{11}	a_{11}	...	a_{1k}	...	a_{1n}	1	...	0	...	0	0	b_1	
...	...	...	...	...	...	...	...	...	...	...	...	...	
L_{1r}	a_{1r}	...	a_{rk}	...	a_{rn}	0	...	1	...	...	0	b_r	
...	...	...	...	...	...	...	...	...	...	...	...	...	
L_{1m}	a_{1m}	...	a_{mk}	...	a_{mn}	0	...	0	...	1	0	b_m	
$L_{1,m+1}$	$-c_1$	...	$-c_k$	...	$-c_n$	0	...	0	...	0	1	0	

Step 3: Determining the pivot and applying the rectangle rule

Determining the pivot column**:**

The pivot column is identified by selecting the minimum negative value of c_j.

$$c_p = \min\{c_j\}, 1 \leq p \leq n\ . \tag{3}$$

$1 \leq j \leq n$

Determining the pivot row:

First, the ratios in the last column of the simplex tableau are calculated:

$$r_j = \frac{b_1}{a_{1p}}, \ldots\ldots\ldots, r_m = \frac{b_m}{a_{mp}} \tag{4}$$

For the remaining values, Gauss's rule is applied.

Step 4: Continue the iterations until all pivot cells corresponding to the variables of the problem are obtained.

Step 5: If all the values in the last row of the simplex tableau are zero or positive, the optimal solution has been reached.

To apply the Simplex algorithm to the company under analysis, we established the following data to be used as input variables: the road transport fleet, air transport, and rail transport. Each of these three activities emits a certain amount of CO_2.

At present, there are no publicly available data regarding the exact amount of CO_2 emitted by DHL Romania's road, rail, and air transport fleets. However, at a global level, DHL has reported a significant reduction in carbon emissions, partly due to the electrification of its fleet and the use of alternative fuels. For example, in 2022, DHL reduced CO_2 emissions by 1 million metric tons, equivalent to removing 223,000 cars from the road for one year.

To simulate the company's CO_2 reduction activity, we used DHL's website, which provides an online carbon footprint calculator for the activities mentioned above. [5]

The results of the simulations obtained using this calculator are presented in Annex no. 3. The Simplex algorithm will be applied for a shipment of 1,000 kg and the distance between Bucharest and Timișoara (746.35 km for air transport, 542.06 km for freight road transport, and 529.11 km for rail transport). It should be noted that, due to the lack of detailed information for each process, the total amount of CO_2e was entered as the maximum value that must not be exceeded, while the quantity allocated to each process was calculated as follows: 20% of the total CO_2e for processes 1 and 3, and the remaining 60% for process 2.

Therefore, the information obtained for the application of the Simplex algorithm is the following:

Table no. 2. Consolidated data for the Simplex algorithm

Resources/Uses	Process 1	Process 2	Process 1	Constraint total kg CO_2e WtW
Road transport fleet consumption	0	45,85	0	45,85
Rail transport fleet consumption	0,10	7,05	0,25	7,40

Air transport fleet consumption	2	931,83	18,64	952,47
Maximum allowed value	0,7	328,24	6,30	

Source: Own contribution

Through the optimization process, the aim is to obtain the lowest possible total quantity of kilograms.

$$\begin{cases} \text{MAX } 0{,}7x_1 + 328{,}24x_2 + 6{,}30x_3 \\ 0x_1 + 45{,}85x_2 + 0x_3 \leq 45{,}85 \\ 0{,}10x_1 + 7{,}05x_2 + 0{,}25x_3 \leq 7{,}40 \\ 2x_1 + 931{,}83x_2 + 18{,}64x_3 \leq 952{,}47 \end{cases}$$

Table no. 3. Iteration 1 of the SIMPLEX algorithm

Row	x_1	x_2	x_3	S_1	S_2	S_3	**f**	**B**	**Ratio**
L_{11}	0	45,85	0	1	0	0	0	45,85	$\frac{45{,}85}{45{,}85} = 1$
L_{12}	0,10	7,05	0,25	0	1	0	0	7,40	$\frac{7{,}40}{7{,}05} = 1{,}0496$
L_{13}	2	931,83	18,64	0	0	1	0	952,47	$\frac{952{,}47}{931{,}83} = 1{,}0221$
L_{14}	$-0{,}7$	$-328{,}24$	$-6{,}30$	0	0	0	1		

Source: Own contribution

Table no. 4. Iteration 2 of the SIMPLEX algorithm

Row	x_1	x_2	x_3	S_1	S_2	S_3	**f**	**B**	**Ratio**
L_{21}	1	1	0	0,028	0	0	0	1	
L_{22}	0,1	0	0,25	-0,1538	1	0	0	0,35	1,4
L_{23}	2	0	18,64	-20,3234	0	1	0	20,64	1,1073
L_{24}	-0,7	0	$-6{,}30$	7,159	0	0	1		

Source: Own contribution

Table no. 5. Iteration 3 of the SIMPLEX algorithm

Row	x_1	x_2	x_3	S_1	S_2	S_3	**f**	**B**	**Ratio**
L_{31}	1	1	0	0,0218	0	0	0	1	
L_{32}	0,0732	0	0	0,1188	1	-0,0134	0	0,732	1,4
L_{33}	0,1073	0	1	-1,0903	0	0,0536	0	1,1073	1,1073
L_{34}	-0,024	0	0	0,29	0	0,338	1		

Source: Own contribution

Table no. 6. Iteration 4 of the SIMPLEX algorithm

Row	x_1	x_2	x_3	S_1	S_2	S_3	**f**	**B**	**Ratio**
L_{41}	0	1	0	0,0218	0	0	0	1	
L_{42}	1	0	0	1,6237	13.6657	-0,1833	0	1	
L_{43}	0	0	1	-1,2645	-1,4663	0,0733	0	1	
L_{44}	0	0	0	0,329	0,3284	0,3336	1	335,24	

Source: Own contribution

The final values are: x1=1, x2=1, x3=1 and Z=335,24.

In that case, taking into account the initial system:

$$\begin{cases} \text{MAX } 0{,}7x_1 + 328{,}24x_2 + 6{,}30x_3 \\ 0x_1 + 45{,}85x_2 + 0x_3 \leq 45{,}85 \\ 0{,}10x_1 + 7{,}05x_2 + 0{,}25x_3 \leq 7{,}40 \\ 2x_1 + 931{,}83x_2 + 18{,}64x_3 \leq 952{,}47 \end{cases}$$

It can be observed that the value of the objective function *f* is 0,7x1+328,24x1+6,30x1=335,24, which indicates that a total value of 335.24 kg CO_2e can be achieved for the three modes of transport, whereas, according to the previous simulations, the total CO_2e amounted to 1005.72 kg. Considering the values of x_1, x_2, and x_3, an investment strategy can be developed in such a way that CO_2e emissions can be reduced by approximately 33%.

Thus, it can be stated that the use of the Simplex algorithm in logistic optimization processes is widely adopted, as logistics involves numerous decisions related to costs, routes, inventory, and capacities — all of which can be effectively modeled using linear programming. In current practice, the Simplex algorithm is used together with specialized planning software. Among these, we may mention: IBM® ILOG® CPLEX® Optimization Studio, SAP Integrated Business Planning (SAP IBP), Oracle Supply Chain Planning Cloud. Optimization and planning tools are used together to support better decision-making and to manage resources efficiently, in accordance with objectives and constraints. Their interconnection represents a logical approach to activities within well-defined processes, where planning provides the overall framework, while optimization identifies the best possible solution.

As shown in the analysis presented above, the logistics industry market has growth potential; however, this does not mean that it is not influenced by various internal and external factors that may slow down or even reduce this growth trend.

By using the probability/impact matrix and the risk matrix, the aim is to analyze the potential risks associated with this market. For the probability/impact matrix, a five-by-five structure was selected, as it is much more relevant in the current economic context.

Therefore, the probability (P) of risk occurrence and the impact (I) on activities or objectives are estimated using a five-level scale. The assessment grid reflects both the likelihood of risk manifestation and the corresponding level of impact or consequences.

Table no. 7: Assessment of the probability (P) of risk occurrence

Probability level		**Explanation**
1	Rare	It is very unlikely to occur over a long period of time
2	Unlikely	It is unlikely to occur over a long period of time
3	Possible	It is likely to occur over a medium period of time
4	Very likely	It is likely to occur over a short period of time
5	Almost certain	It is very likely to occur over a short period of time

Source: Own contribution adapted from ISO 31000 — Risk Management [6]

Table no. 8: Assessment of the impact/consequences of risks (I)

Consequence/ Impact level		**Explanetion**
1	Insignificant	With a very low impact on the structure’s activities and the achievement of objectives and/or no financial impact
2	Minor	With a low impact on the structure’s activities and the achievement of the objectives and/or a very low financial impact
3	Moderate	With a moderate impact on the structure’s activities and the achivement of objectives and/or a medium financial impact
4	Major	With a major impact on the structure’s activities and the achivement of the objectives and/or a major financial impact
5	Critical	With a major impact on the structure’s activities and the achievement of the objectives and/or a significant financil impact

Source: Own contribution adapted from ISO 31000 — Risk Management [6]

Combining the two estimates on a two-dimensional scale represents the **risk exposure (E)**, an indicator based on which the attitude toward each problem identified as a risk is established.

Table no. 9: Determining risk exposure (E): Probability (P) × Impact (I)

5	**PROBABILITY (P)**	**5**	**10**	**15**	**20**	**25**
4		**4**	**8**	**12**	**16**	**20**
3		**3**	**6**	**9**	**12**	**15**
2		**2**	**4**	**6**	**8**	**10**
1		**1**	**2**	**3**	**4**	**5**
Exposure to Risk= PxI		**IMPACT (I)**				
		1	**2**	**3**	**4**	**5**

Source: Own contribution adapted from ISO 31000 — Risk Management [6]

The risks identified in the risk matrix will be assigned both a probability of occurrence and the impact they may have on companies operating in the logistics industry.

Risk exposure is seen as a consequence that any organization may experience in relation to its predetermined objectives if the risk materializes. Thus, by calculating this indicator, it becomes possible to analyze risk tolerance — the "amount" of risk that the organization is prepared to tolerate or is willing to be exposed to at a given moment.

Table no. 10: Establishing the tolerance level

Score	**Tolerance Level**	**Control measures**
1-4	**Tolerable**	**No control measures required**
5-8	**High tolerability**	**Requires medium and long-term control measures**
9-12	**Low tolerability**	**Requires short-term control measures**
13-25	**Intolerable**	**Requires urgent control measures**

Source: Own contribution adapted from ISO 31000 — Risk Management [6]

The use of the risk matrix in logistics brings multiple advantages, as unpredictable situations frequently occur in the logistics sector (delays, bottlenecks, stock shortages, transportation issues, etc.). Thus, using the matrix helps visualize, classify, and prioritize risks, supporting decision-making and preventing potential negative consequences.

Table no. 11: Risk Matrix

No.	Risks	P	I	E	Responsible for implementing measures	Risk prevention or correction measures	Risk analysis
1.	High costs for the ecological transition	3	3	9	Green Logistics department	Route optimization and improvement of vehicle loading routes	Moderate risk. The investment, together with clear objectives, leads to cost reduction
2.	Failure to achieve the objective of greenhouse gas emission neutrality by 2050	5	5	25	CEO Sustainability officer	Clear technological investments, creation of interim targets (for 2030, 2040)	**Critical risk**, with the possibility of being reduced to major in the long term through careful and periodic monitoring.
3.	Negative impact on public perception	3	4	12	Social Responsibility/ Communication Manager	Transparent communication on progress toward commitments, dedicated sustainability platforms, and social media monitoring	**Moderate to minor risk** if managed through constant communication of real-time progress and by providing evidence.
4.	Climate-related vulnerabilities	5	4	20	Supply Chain department /Risk department	Resilient logistics centers, continuity plans for natural disasters, digitalization, and predictive analytics	**Major risk**, with the possibility of being reduced to moderate through optimization of the logistics process.
5.	High CO2 emissions	2	3	6	Green Logistics department	Investments in clear objectives, fleet modernization, and purchasing of biofuel	**Moderate to minor risk** due to well-defined objectives.
6.	Non-compliance with European regulations	2	2	4	Legal Council	Audits Annual sustainability report	**Minor risk** – The company already has annual reporting and investments in place to meet the objective.
7.	Lack of employee involvement in the strategy	1	2	2	Social Responsibility department/ Green Logistics department	Employee training programs Voluntary involvement in ecological activities	**Minor risk** – Employee training programs exist, and the ecological strategy they will take part in is presented to them.
8.	Social inequalities in the logistics chain	3	4	12	Social Responsibility Department /	Audits Ethical procurement policies	**Moderate to minor risk** – reduces collaboration with suppliers who

					Audit / Procurement Department		do not align with the company's objectives.
9.	Risk of corruption and lack of transparency	2	2	4	General Council / Legal Council	Implementation and monitoring of compliance with a clear code of ethics Occasional external audits	**Minor risk** – The group has a sound and strict governance system
10.	Risk of war	3	5	15	General Management Supply Chain Department /Risk department	Route optimization Ensuring operational continuity	**Major risk**, with significant impact on operations.

Source: Own contribution

3. Conclusion

The analysis demonstrates that in a sector as complex and dynamic as logistics, effective planning, operational optimization, and rigorous risk management constitute essential pillars for achieving high-performance outcomes. Integrating mathematical optimization tools—particularly the Simplex algorithm—with advanced planning software and structured risk-assessment methodologies generates significant strategic value for organizations operating in this field.

The combined use of these tools supports cost-efficient operations, accelerates decision-making processes, enhances delivery reliability, and improves the organizational capacity to respond promptly to disruptions. Moreover, their integration strengthens long-term economic sustainability by ensuring the consistent and efficient allocation of resources.

The adoption of the Simplex algorithm plays a crucial role in mathematical optimization, enabling companies to minimize operational costs while simultaneously reducing resource consumption. This contributes directly to lowering CO_2 emissions through the identification of the most efficient transportation routes and modes, as well as by improving capacity utilization and avoiding operational waste.

Planning software further enhances these outcomes by automating complex decision processes and providing real-time visibility across the logistics chain. Such systems facilitate proactive adjustments that reduce idle times and minimize inefficient multi-stop deliveries, contributing to energy savings and decreased environmental impact. Increasingly, these digital platforms integrate environmental objectives as core decision parameters, ensuring that sustainability becomes a defining element of operational strategy.

Complementing these efforts, risk-analysis tools identify vulnerabilities that may generate resource losses or environmental risks, allowing companies to design alternative operational scenarios that maintain continuity with minimal ecological footprint. By mitigating risks associated with excess emissions or unjustified consumption, organizations reinforce the resilience and adaptability of their logistics networks.

Together, these components form an integrated framework that not only optimizes operations and reduces costs but also contributes meaningfully to environmental responsibility and sustainable economic performance. Through optimization, digitalization, and preventive management, companies can reduce their logistics-related carbon footprint, utilize resources more responsibly, and respond more effectively to emerging challenges—supporting a logistics sector that is sustainable, competitive, and resilient in the long term.

As global trends in digital transformation, sustainability, and customer-centricity intensify, the logistics industry faces increasing pressure to evolve. In this context, adaptability and innovation are no longer optional but fundamental drivers of future competitiveness. The findings of this study underscore the importance of balancing social responsibility with economic performance as a core principle in shaping the logistics systems of tomorrow.

4. References

[1] Government Decision no. 780/14 June 2006 on the establishment of the greenhouse gas emissions trading scheme]. Retrieved May 11, 2025, from https://legislatie.just.ro/Public/DetaliiDocument/72971, 18.11.2025

[2] DHL Group. (2025). *DHL Group annual earnings 2024*. Retrieved May 10, 2025, from https://group.dhl.com/en/media-relations/press-releases/2025/dhl-group-annual-earnings-2024.html

[3] DHL Group. (2024). *DHL Group annual earnings 2023*. Retrieved May 10, 2025, from https://group.dhl.com/en/media-relations/press-releases/2024/dhl-group-annual-earnings-2023.html

[4] DHL Group. (n.d.). *Key figures*. Retrieved May 10, 2025, from https://group.dhl.com/en/investors/key-figures.html

[5] [https://carboncalculator.dhl.com/.]

[6] [https://www.iso.org/standard/65694.html]