SUSTAINABILITY LEVELS ANALYSIS: A STUDY CASE OF GRAIN TRANSPORTATION USING ROADRAILERS

ANÁLISE DOS NÍVEIS DE SUSTENTABILIDADE: UM ESTUDO DE CASO DO TRANSPORTE DE GRÃOS UTILIZANDO RODOTRILHOS

ANÁLISIS DE NIVELES DE SOSTENABILIDAD: UM ESTUDIO DE CASO DE TRANSPORTE DE GRANOS UTILIZANDO CARRETERA-CARRIL

Guilherme Peres dos Santos | UFSC - Universidade Federal de Santa Catarina, Brazil
Ricardo Villarroel Dávalos | UFSC - Universidade Federal de Santa Catarina, Brazil

ABSTRACT
Like any other industrial or service activity, transport sector requires sustainable solutions development. Meeting such demands becomes even more urgent in economies that use road transportation for most of their activities. Aiming to propose possible alternatives to road transportation, so that it doesn't compromise operational performance, this research evaluates potential impacts by adopting RoadRailer intermodal system for low-added value cargo transportation. The study use fuzzy logic, taking as analysis object the sustainability level of individual activities by road and rail for agricultural product movement from countryside to Paraná State's coast, as well as the way how this indicator can be affected by combination of these modes. The results point to more sustainable options through intermodality, also depending on the adopted transport modes sequencing for routing.

KEYWORDS
Sustainability; grain transportation; RoadRailer; Fuzzy System

RESUMO
Assim como qualquer atividade industrial e de serviços, o setor de transporte requer o desenvolvimento de soluções sustentáveis. O atendimento a tais demandas se torna ainda mais urgente em economias que utilizam o transporte rodoviário para a maioria de suas atividades. Visando propor possíveis alternativas ao transporte rodoviário, de modo que não comprometa o desempenho operacional, esta pesquisa avalia os possíveis impactos da adoção de um sistema intermodal de rodotrilhos para o transporte de cargas de baixo valor agregado. O estudo utiliza a lógica difusa, tendo como objeto de análise o nível de sustentabilidade das atividades individuais por rodovias e ferrovias para o transporte de produtos agrícolas do interior ao litoral do estado do Paraná, bem como a maneira como este indicador pode ser afetado pela combinação dessas modalidades. Os resultados apontam para opções mais sustentáveis através da intermodalidade, a depender também do sequenciamento dos modos de transporte adotados na roteirização.

PALAVRAS-CHAVE
Sustentabilidade; transporte de grãos; Rodotrilho; Sistema Nebuloso

http://dx.doi.org/10.29183/2447-3073.MIX2023.v9.n3.147-157
ISSN: 2447-0899 (IMPRESSA) | 2447-3073 (ONLINE)

RESUMEN

Como toda actividad industrial y de servicios, el sector del transporte requiere del desarrollo de soluciones sostenibles. Satisfacer tales demandas se vuelve aún más urgente en economías que utilizan el transporte por carretera para la mayoría de sus actividades. Buscando proponer posibles alternativas a este transporte, de modo que no comprometa el desempeño operativo, esta investigación evalúa los posibles impactos de la adopción de un sistema intermodal vial-ferroviario para el transporte de carga de bajo valor agregado. El estudio utiliza la lógica difusa, teniendo como objeto de análisis el nivel de sostenibilidad de las actividades individuales por carretera y ferrocarril para el transporte de productos agrícolas desde el interior hasta la costa del estado de Paraná, así como la forma en que este indicador puede verse afectada por la combinación de estas modalidades. Los resultados apuntan a opciones más sostenibles a través de la intermodalidad, también en función de la secuencia de modos de transporte adoptados en el enrutamiento.

PALABRAS CLAVE

Sostenibilidad; transporte de granos; Carretera-carril; Sistema Nebuloso

Sustainability levels analysis: A study case of grain transportation using Roadrailers | G. P. dos Santos; R. V. Dávalos.
https://doi.org/10.29183/2447-3073.MIX2023.v9.n3.147-157

1. INTRODUCTION

The more movable, more developed is a country, be it due to the moving of goods for its several regions supply and global trade, or to passenger locomotion, nationally or internationally.

Goods transportation distribution in Brazil concentrates more than half of its activities on roadway transport, which creates a freight dependency on this mode, besides being more expensive and harmful to environment, leading to a need for service relocation by other modalities, like railway and waterway.

The Search for sustainable practices is theme that has been gaining more space within productive sectors. Evidently, this criterion brings constant challenges and concerning in transportation activities, given that, in Brazilian case, roadway mode is used the most, and simultaneously, the biggest greenhouse gas (GHG) generator (HEINOLD; MEISEL, 2018).

Among many alternatives to individual road transportation there's intermodal systems implementation, which consists on integration and better use of positive characteristics that each mode has to provide (LOWE, 2005). The RoadRailer system is an intermodal transport feature that presents a combination of roadway flexibility in initial and final stretches with the bigger capacity by railway haulage (JOHNSTON; MARSHALL, 1993).

This research has the goal to develop a sustainability levels analysis model among different grain transportation alternatives from production area and storage to the shore. For that, it settles a comparison between road or rail individual transportation and RoadRailer system, considering as assessment parameters the time required performance related and GHG emission.

2. LITERATURE REVIEW

Goods transportation in Brazil is made around 60% by trucks (CNT, 2019). However, there is gap this modality cannot individually fulfill in terms of sustainability. It is the low added value products case for long distances, not being this the more suitable transport mode for such service. Besides, this mode responds for over 90% of transport sector pollutant emissions (SOLIANI, 2021).

Railroads, on the other hand, have as main characteristic an inferior operational performance to highways. In addition to lower speed, a lot of time is spent on terminals loading operations (ANTT, 2022). Such condition is directly related to divestments followed by privatizations during the 90s (SILVEIRA, 2002).

2.1. Transport sustainability

According to (BRUNDTLAND, 1987), sustainable development is defined as:

> development that meets the needs of the present without compromising the ability to future generations to meet their own needs.

In addition, sustainable development must achieve a three-win solution, being socially inclusionary, environmentally sustainable and economically viable (SACHS, 2010).

However, despite sustainability and sustainable development are considered important frames to structure policies and debates, it still lacks a clear consensus of what is a sustainable development, its desirability, or how to achieve it. Such issue requires integrating activities over simple pursuing independent list of goals (MANCEBO; SACHS, 2015). Furthermore, the authors quote subsidiary goals which must be achieved, like gender equality, insurance of healthy lives, insurance of food security and good nutrition, quality education and lifelong learning offer, universe access to water and sanitation, secure and sustainable energy, among others

In transportation sector, two main dimensions are highlighted. The first one refers to trip number decreasing, through spatial distribution planning and land use. The second one refers to higher energy efficiency and preference for vehicle supply with renewable power sources (BANISTER, 2018). The highway-railway integrated system in Europe is one positive outcome example of intermodal transportation options (MINÁRIK, 2021).

Rail transportation advantages over roadways, from an environmental point of view, are already broadly grounded. Such indicator can be verified by energy consumption or emitted pollutants amount per transported unit by each mode (BIGAZZI, 2019; PINCHASIK et al., 2020; WINEBRAKE et al., 2008). In face of this fact, the looking for solutions backed to intermodality can lead to benefits, not environmentally only, but economics as well (HAVENGA et al., 2011).

Rajak, Parthiban and Dhanalakshmi (2016) propose an evaluation concerning urban public transportation, in which environment, social, economic and service effective aspects are considered. Under this perspective, cargo transportation might be analyzed as well. Zhao et

al. (2020) address an increasing of scientific researches about sustainability in transport services for the last two decades, including "sustainability", "model" and "carbon emission" as three top keywords.

Finally, given that transportation activities affect directly quality of life, people participation plays an important role on making decisions, settling policies and strategies, considering transport multiple indicators (STEG; GIFFORD, 2005).

2.2. RoadRailer system

The RoadRailer constitutes an interchangeable system of rail traction of semi-trailers. Its main feature is the ability to handle freight compartments both by highways and railways, providing agility to goods transference with no need for transshipment between modes, which can reduce cargo operation and handling time required at yards and terminals (LOWE, 2005).

This system is similar to container operations, with the difference that the transference equipment is less complex. It is required only the semi-trailers, mechanical adapters, so that the semi-trailers can operate as wagons too, transference pneumatic devices and rail bogies support (MINDUR, 2016). Figure 01 indicates the components to operate a RoadRailer system.

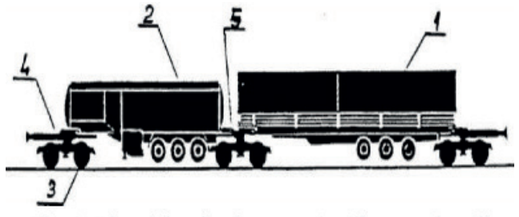

Fig. 1. Bimodal train elements: 1 - Chest road - rail trailer, 2 - tank semi-trailer road and railway, 3 - Standard bogie, 4 - utmost adapter train devices, 5 - middle adapter.

Figure 01: RoadRailer system components.
Source: Mindur (2016).

2.3. Fuzzy sets

Be X a set of points. A fuzzy set *A* in *X* is characterized by the membership function $f_A(x)$, which associates to each element $x \subseteq X$ a membership degree within [0, 1] interval (ZADEH, 1965). The author takes as example the $f_A(x)$ function that represents the "numbers much bigger than 1" set, so that number 5 has a membership degree closer to 0.0 than number 100, in this set. Insofar as x holds off from 1, closer the membership function will be to 1.0 within the settled interval.

Unlike classical logic sets, a fuzzy system is constituted by linguistic variables that may belong to more than one set simultaneously. Temperature is a variable example that might assume "low", "medium" and "high" classifications, depending on beholder (GOMIDE; GUDWIN, 1994). By Figure 02, one can see that insofar as temperature approximates 50 °C, its membership degree to "Medium" function increases and decreases for "Low" function.

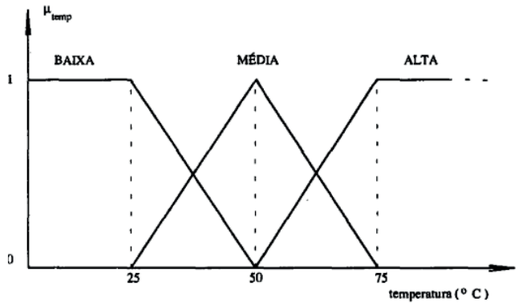

Figure 02: Membership degree of "temperature" variable.
Source: Gomide and Gudwin (1994).

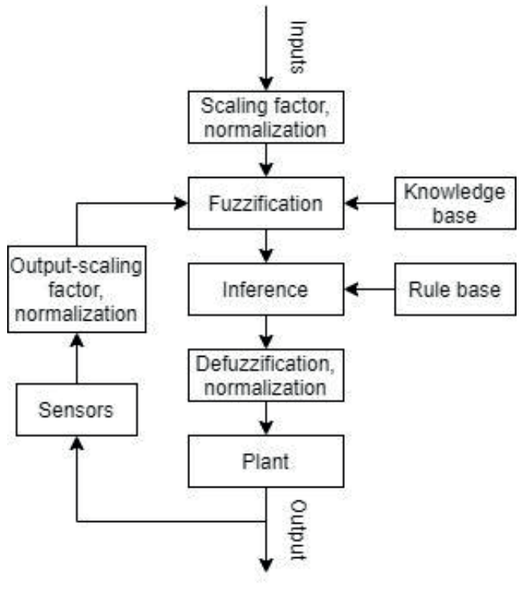

Figure 03: Fuzzy variables assessment structure .
Source: Authors, adapted from Ross (2010).

The assessment process for a given index starts by fuzzification, turning a classical (or crisp) variable into a fuzzy one. At the end, it is generated a response variable by deffuzification process, which consists in making scalar a fuzzy value, in order to provide a general index to support decision making (ROSS, 2010). Figure 03 summarizes an assessment process of fuzzy sets.

Through fuzzy analysis, Dumane, Sarate and Chavan (2018) suggest that an overall sustainability may be divided in: ecological, comprising air, land, water and biodiversity; and human, which includes policy, wealth, health and knowledge.

3. METHODOLOGICAL PROCEDURE

Brazilian railway system presents low operational speeds in most of its network. However, another factor that increases grain transportation spent time are waiting and delays at terminals for cargo shipping from warehouses to wagons.

Aiming to evaluate possible improvements sustainability-related, it was simulated transport performance by RoadRailer intermodality on moving agricultural products from Brazil's southern region countryside to the coast for foreign trade, in order to stablish a comparison with transportation roadway and railway vehicles loaded through transshipment process. RoadRailers operational data were obtained indirectly from registered data by Ferreira and Sigut (1995).

Taking the premise that there's a better operational performance by trucks, and minor environmental impacts by trains given their lower greenhouse gas emissions (GHG), it was taken as reference Seara LLD grain terminal for transport performance and environmental impacts analysis, from Londrina city, in Paraná state, to Dom Pedro II port, in Paranaguá.

Once the RoadRailer intermodality dismisses transshipment, and consequent cargo storage, this alternative has bigger flexibility to operate at intermediate yards along the path, being able to easily transit between road and rail modes. The study case steps to determine the routes sustainability levels across the bounded region are divided in: data collection, fuzzy system modeling and output parametrization to classify the alternatives.

4. STUDY CASE

As options to move the grains from countryside to the coast, there are railway and roadway transportation with transshipment since the origin in Londrina, and roadway movement along initial stretches as well, allowing mode exchange to rail through RoadRailer intermodality at intermediate rail yards, in cities such as Apucarana and Mauá da Serra.

When approaching final destiny by rail, it is also possible to transfer the compartments, using as changing points in Ponta Grossa, São José dos Pinhais and Morretes cities, from which cargo can be transported by road to the final destiny. By this arrangement, 14 different routes were identified, varying among transition possibilities road-to-rail and rail-to-road. It wasn't adopted railway paths shorter than 200 kilometers. Figure 04 describes possible routes to transport the agricultural products.

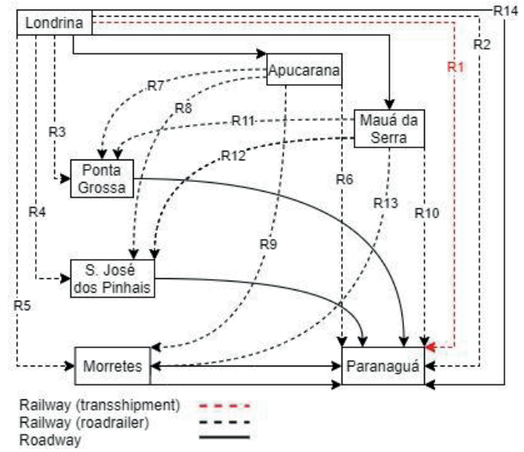

Figure 04: Available routes for grain movement.
Source: Authors.

It was necessary 245 simulation rounds so that the obtained parameters were situated within a 95% confidence interval.

4.1. Data collection

The fuzzy system input data were transport time required and GHG emission rates, to determine performance index and environmental impact, respectively. Table 01 expresses evaluated parameters, softwares used to build the simulation systems, and output data.

For performance data, ARENA Simulation® software was employed to calculate both trains loading/assembly microsimulation and the movement of grains until Dom Pedro II port macrosimulation.

When it comes to pollutants emission simulation processes, it was employed GREET® 2021 software, which simulates the total emission rate for a given activity, including grain production and its transportation to the final destiny. For the aimed evaluation, only transportation emission was considered, since production GHG emissions don't depend on the chosen mode.

Independent variables	Simulation softwares	Simulated data	
		Lower limit	Upper limit
Performance (hours)	ARENA Simulation® • Input Analyzer • Output Analyzer	19.87	50.86
GHG emission (ton/TU)	GREET 2021®	0.0093	0.0262

Table 01: Obtained data.
Source: Authors.

4.2. Fuzzy system modeling

The fuzzy system first step construction consisted in assessment index normalization, by attributing the membership functions according to each linguistic variable classification. The membership functions of independent variables take a triangular shape given by equation (1).

$$\mu(x) = ax + b \qquad (1)$$

Figure 05 illustrates the fuzzification system of normalized values related to independent variables, with scale from 1 to 5, being classified as "very bad" for long term trips or high emission rates and "very good" for short term trips

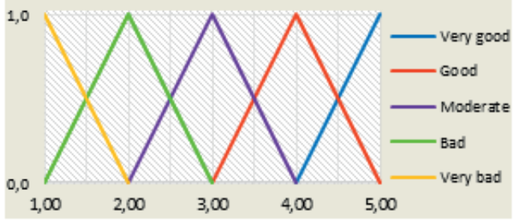

Figure 05: Membership functions of independent variables.
Source: Authors.

and low emission rates.

4.3. Output data parametrization

Defuzzification process involved determining the number of membership functions by association rules and their parameters for final classification of each transportation route.

The bigger is the number of fuzzy sets, the better is the classification accuracy, being recommended practical values between 2 and 7 sets, not providing significative gains for values above this interval. Besides, the recommended superposition of functions is meant be within 0.25 and 0.75 range (SIMÕES; SHAW, 2007).

Equations (2) and (3) define the sustainability levels' membership functions, which assume sigmoid shapes for the extreme classifications (minimum and maximum) and gaussian shapes for intermediate sets, respectively.

$$\mu_1(x) = \frac{1}{1+e^{-\beta x+\tau}} \qquad (2)$$

$$\mu_2(x) = e^{\frac{-(x-\tau)^2}{\beta}} \qquad (3)$$

Table 02 provides the adopted parameters from equations (2) and (3), being a direct reflection from their shapes and positions.

The association rules between independent variables

Fuzzy set	β	τ	Classification
Minimum	-12,00	18,00	1,0
Very low	0,3607	2,00	2,0
Low		3,00	3,0
Moderate		4,00	4,0
High		5,00	5,0
Very high		6,00	6,0
Maximum	12,00	-78,00	7,0

Table 02: Defuzzification parameters.
Source: Authors.

are defined by Table 03, so it determines the membership sets for each predicted alternative.

The membership fuzzy sets subjected to defuzzification process are represented by Figure 06 graphic. The more placed to right, the more sustainable is the alternative.

Sustainability levels are obtained by the Area's Centroid method. Equation (4) expresses the sustainability degree output.

$$x^* = \frac{\sum \mu_i(x)\, x_i}{\sum \mu_i(x)} \qquad (4)$$

Operational performance	GHG emission rates				
	Very high	High	Moderate	Low	Very low
Very slow	Minimum	Minimum	Very low	Low	Moderate
Slow	Minimum	Very low	Low	Moderate	High
Moderate	Very low	Low	Moderate	High	Very high
Fast	Low	Moderate	High	Very high	Maximum
Very fast	Moderate	High	Very high	Maximum	Maximum

Table 03: Association rules of alternatives' sustainability levels.
Source: Authors.

Figure 06: Fuzzy sets for classification of sustainability levels.
Source: Authors.

5. RESULTS AND DISCUSSION

Roadway individual transportation presented the highest operational performance, given its higher speed compared to any other alternative. Yet, its low energy efficiency made it the worst environmental performance. About individual railway transshipment mode, it was observed the opposite phenomenon to roadway. Hence, the centroid areas for individual modes routes alternatives are placed exactly where horizontal axis marks 4.00.

The output data that concerning about travel time performance and emission rates are expressed by Table 04.

Based on Ross (2010) proposed fuzzy structure, and Dumane, Sarate and Chavan (2018) guidelines, the current procedure has led to the following sustainability defuzzification parameters. Figure 07 represents x* value from Equation (4) related to each route. Appendix A's Figure 08 illustrates the respective areas for centroid calculation in each available alternative.

Based on the obtained results, it is verified that intermodal routes R2, R6, R8 and R10 presented superior sustainability levels to individual transport mode alternatives. On the other hand, intermodality presented the worst results for routes R3, R7 and R11, which are belong to "Moderate", "Low", "Very low", and "Minimum" set levels, even if in low degree in the last group. It stands out that operational performance and environmental impact had the same importance degree on sustainability analysis structuring.

Alternative	Performance (h)	Emission (Ton/TU)
Route 1	50.86	9.30E-03
Route 2	41.40	9.30E-03
Route 3	45.42	1.72E-02
Route 4	48.54	1.25E-02
Route 5	50.18	1.09E-02
Route 6	39.87	1.12E-02
Route 7	43.37	1.91E-02
Route 8	47.14	1.09E-02
Route 9	49.35	1.29E-02
Route 10	37.29	1.20E-02
Route 11	40.93	2.00E-02
Route 12	45.25	1.53E-02
Route 13	47.78	1.37E-02
Route 14	19.87	2.62E-02

Table 04: Alternatives sustainability level.
Source: Authors.

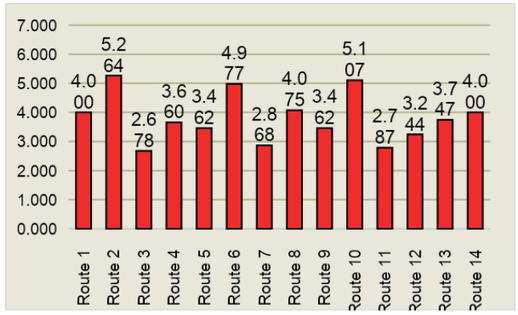

Figure 07: Defuzzification outputs.
Source: Authors.

6. FINAL CONSIDERATIONS

The present work focused on the possibility to implement a cargo intermodal transport system as an alternative to accomplish higher sustainability indexes in this service sector. Given the necessity of continuous search for less harmful practices to the environment, it is always effectual to understand alternatives that make possible this goal without big losses to operational feasibility. The research identified four alternatives with better sustainability levels for goods transportation in relation to the movement by a unique mode. That reinforces Minárik (2021) and Havenga et al. (2011) statements about intermodal transportation's potential advantages.

The methodological procedures had similar aspects to Hemdi, Saman and Sharif (2013) case study, in which resorts to fuzzy analysis to settle sustainability levels on electric power generation. The authors use Equation (4) in order to determine the best alternative considering parameters like pollution, technology, cost, safety, among other. It is important to quote that the authors consider environmental, economic and social aspects for sustainability assessment.

Rajak, Parthiban and Dhanalakshmi (2016) also evaluate sustainability indexes by fuzzy system logic. Besides method similarity with the present article, the authors attribute different weights to each parameter, providing good data precision related service users perception.

For future research, it is suggested to assess other independent variables and their implications to transport sustainability levels, such as cost, reliability, frequence, safety, and others. It is also recommended variables assessment under different importance weights, once shippers might not consider the indicators as equally prioritizeable.

REFERENCES

AGÊNCIA NACIONAL DE TRANSPORTES TERRESTRES. **Declaração de rede.** Disponível em: <https://portal.antt.gov.br/declaracao-de-rede-2022>. Acesso em: 20 out. 2022.

BANISTER, D. Policy on sustainable transport in England: the case of high speed 2. **European Journal of Transport and Infrastructure Research**, v. 18, n. 3, p. 262–275, 2018.

BIGAZZI, A. Comparison of marginal and average emission factors for passenger transportation modes. **Applied Energy**, v. 242, p. 1460–1466, 2019.

BRUNDTLAND, G. H. **Report of the world commission on environment and development**. United Nations, 1987.

CONFEDERAÇÃO NACIONAL DOS TRANSPORTES. **Pesquisa CNT de rodovias 2019: 23**. Brasília: [s.n.]. Disponível em: <https://pesquisarodovias.cnt.org.br/downloads/ultimaversao/gerencial.pdf>.

DUMANE, P. R.; SARATE, A. D.; CHAVAN, S. S. Sustainability assessment by use of fuzzy logic—a review. [s.l.] **Springer Singapore**, 2018. v. 810

FERREIRA, L.; SIGUT, J. Modelling Intermodal Freight Terminal Operations. **Road and Transport Research Journal**, v. 4, n. 4, p. 4–16, 1995.

GOMIDE, F. A. C.; GUDWIN, R. R. Modelagem, controle, sistemas e lógica fuzzy. **SBA Controle & Automação**, v. 4, n. 3, p. 97–115, 1994.

HAVENGA, J. H. et al. Sustainable freight transport in South Africa: domestic intermodal solutions. **Journal of Transport and Supply Chain Management**, v. 5, n. 1, p. 149–169, 2011.

HEINOLD, A.; MEISEL, F. Emission rates of intermodal rail/road and road-only transportation in Europe: A comprehensive simulation study. **Transportation Research Part D: Transport and Environment**, v. 65, p. 421–437, 2018.

Sustainability levels analysis: A study case of grain transportation using Roadrailers | G. P. dos Santos; R. V. Dávalos.
https://doi.org/10.29183/2447-3073.MIX2023.v9.n3.147-157

HEMDI, A. R.; SAMAN, M. Z. M.; SHARIF, S. Sustainability evaluation using fuzzy inference methods. **International Journal of Sustainable Energy**, v. 32, n. 3, p. 169–185, 2013.

JOHNSTON, M. L.; MARSHALL, S. Shipper perceptions of intermodal equipment. **Transportation Journal**, v. 33, n. 1, p. 6–9, 1993.

LOWE, D. **Intermodal Freight Transport.** 1. ed. Oxford: Elsevier, 2005.

MANCEBO, F.; SACHS, I. **Transitions to sustainability**. 1. ed. Dordrecht: Springer, 2015.

MINÁRIK, M. Sustainable Transport of Goods Using Combined Transport Solutions: The Case of EU. **Naše gospodarstvo/Our economy**, v. 67, n. 2, p. 29–39, 2021.

MINDUR, L. Concept of Freight Road-Railing Transport in Bimodal. **Logistics and Transport**, v. 2, n. 30, p. 67–72, 2016.

PINCHASIK, D. R. et al. Crossing borders and expanding modal shift measures : effects on mode choice and emissions from freight transport in the Nordics. **Sustainability**, v. 12, n. 3, p. 1–23, 2020.

RAJAK, S.; PARTHIBAN, P.; DHANALAKSHMI, R. Sustainable transportation systems performance evaluation using fuzzy logic. **Ecological Indicators**, v. 71, p. 503–513, 2016.

ROSS, T. J. **Fuzzy logic with engineering applications**. 3. ed. Chichester: John Wiley & Sons, Ltd, 2010.

SACHS, I. In search of three-win solutions: the challenges of the 2012 UN conference on environment and sustainable development. **Sustentabilidade em Debate**, v. 1, n. 2, p. 25–29, 2010.

SILVEIRA, M. R. Transporte e Logística: as Ferrovias no Brasil. **Geosul**, v. 17, n. 34, p. 63–86, 2002.

SIMÕES, M. G.; SHAW, I. S. **Controle e modelagem fuzzy**. 2. ed. São Paulo: Blucher, 2007.

SOLIANI, R. D. Brazilian road freight transportation sector: the challenge of sustainability. **Journal of Traffic and Logistics Engineering**, v. 9, n. 2, p. 32–41, 2021.

STEG, L.; GIFFORD, R. Sustainable transportation and quality of life. **Journal of Transport Geography**, v. 13, p. 59–69, 2005.

WINEBRAKE, J. J. et al. Assessing energy, environmental, and economic tradeoffs in intermodal freight transportation. **Journal of the Air & Waste Management Association**, v. 58, n. 8, p. 1004–1013, 2008.

ZADEH, L. A. Fuzzy sets*. **Information and Control**, v. 8, n. 3, p. 338–353, 1965.

ZHAO, X. et al. Evaluation of sustainable transport research in 2000-2019. **Journal of Cleaner Production**, v. 256, p. 1–16, 2020.

Mix Sustentável | Florianópolis | v.9 | n.3 | p.147-157 | JUL. | 2023

APPENDIX A

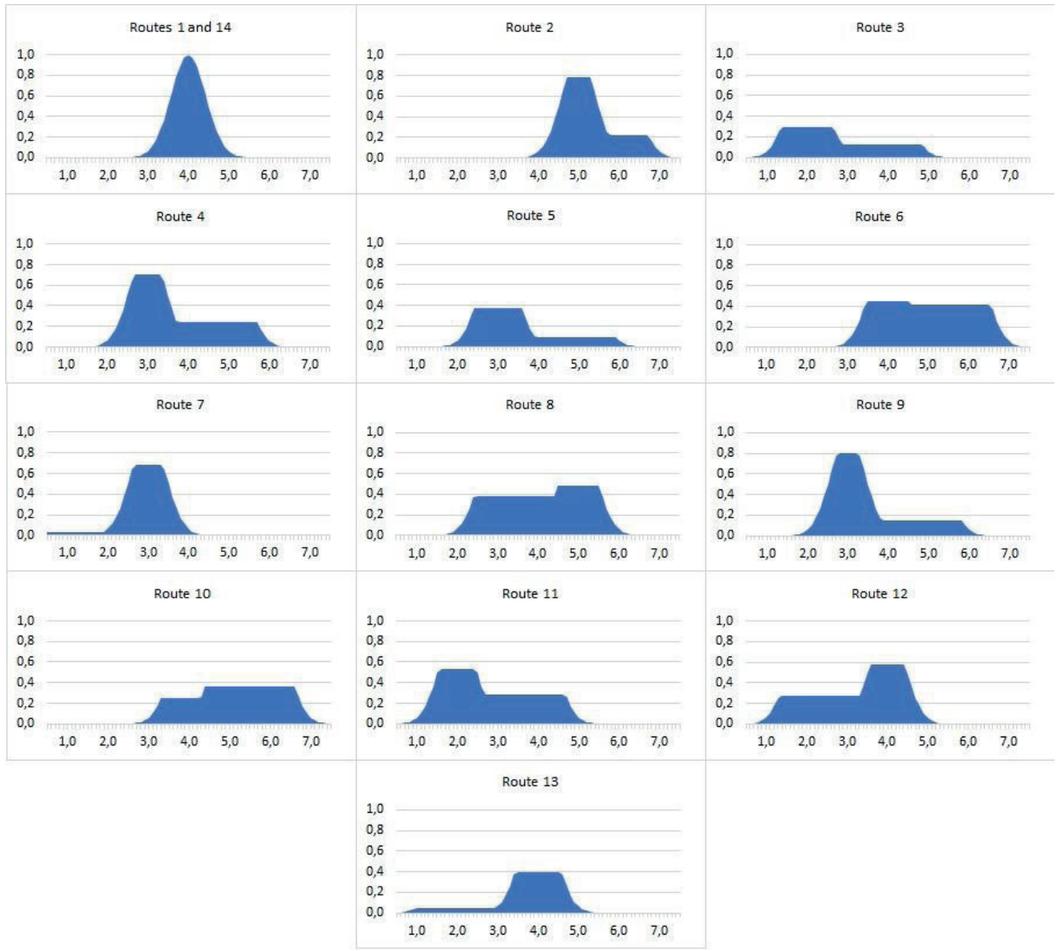

Figure 07: Defuzzification outputs.
Source: Authors.

AUTHORS

ORCID: https://orcid.org/0000-0002-8964-2899
GUILHERME PERES DOS SANTOS, Mestrado. | Universidade Federal de Santa Catarina | Transport Engineering and Territorial Management | Florianópolis, SC) - Brazil | E-mail: guilherme77peres@gmail.com

ORCID: https://orcid.org/0000-0001-9747-4453
RICARDO VILLARROEL DÁVALOS, Doutorado. | Universidade Federal de Santa Catarina | Production and Systems Engineering | Florianópolis, SC) - Brazil | E-mail: ricardo.davalos@ufsc.br

HOW TO CITE THIS ARTICLE

SANTOS, Guilherme Peres dos; DÁVALOS, Ricardo Villarroel. MIX Sustentável, v. 9, n. 3, p. 147-157, 2023. ISSN 2447-3073. Available at: <http://www.nexos.ufsc.br/index.php/mixsustentavel>. Accessed at: _/_/_. doi: <https://doi.org/10.29183/2447-3073.MIX2023.v9.n3.147-157>.

SUBMITTED AT: 25/11/2022
ACCEPTED AT: 04/05/2023

Sustainability levels analysis: A study case of grain transportation using Roadrailers | G. P. dos Santos; R. V. Dávalos.
https://doi.org/10.29183/2447-3073.MIX2023.v9.n3.147-157

PUBLISHED AT: 30/07/2023
RESPONSIBLE EDITORS: Paulo Cesar Machado Ferroli and Lisiane Ilha Librelotto.

Record of authorship contribution:
CRediT Taxonomy (http://credit.niso.org/)

GPS: Conceptualization, data curation, formal analysis, investigation, methodology, resources, visualization, writing – original draft, and writing – review & editing.
RVD: Conceptualization, formal analysis, methodology,supervision, validation, visualization, and writing – review & editing.

Declaration of conflict: nothing was declared.

Mix Sustentável | Florianópolis | v.9 | n.3 | p.147-157 | JUL. | 2023