Optimising Supply Chain Logistics System Using Data Analytics Techniques

Eleni Mangina[1,2(✉)], Pranav Kashyap Narasimhan[1], Mohammad Saffari[2,3], and Ilias Vlachos[4]

[1] School of Computer Science, University College Dublin, Dublin, Ireland
{eleni.mangina,mohammad.saffari}@ucd.ie
[2] UCD Energy Institute, University College Dublin, Dublin, Ireland
[3] School of Mechanical and Materials Engineering, University College Dublin, Dublin, Ireland
pranavkashyap2006@gmail.com
[4] La Rochelle Business School, Excelia Group, La Rochelle, France
ivlachos@gmail.com

Abstract. The transport sector's share of global energy-related carbon emissions is about 23%. Transportation and logistics can improve the economic growth of nations and profitability in businesses, and if efficiently designed and managed their carbon footprints will be reduced. Important progresses have been made to enhance the efficiency of logistics supply chain using mathematical optimisation techniques. However, recent needs in collaborative supply chain on one hand, and advancements in data science have heightened the need for optimisation techniques based on big data analytics. This paper studies and evaluates models for European freight transport logistics actions utilising advanced data analytics solutions. Three new supply chain algorithms of horizontal collaboration, pooling, and physical internet have been developed using historical data of European road freight transport. Then, two indicators of sustainability and efficiency were used to evaluate each developed strategy. The results have shown that there is substantial potential in pursuing these strategies and encourages future research into logistic supply chain and data analytic methods for designing sustainable transport systems.

Keywords: Supply chain strategies · Transport optimisation · Carbon emissions reduction

1 Introduction

The European Union (EU) road freight industry is one of the largest consumers of energy [1]. Since 2014, GHG emissions from the EU-28 transport sector have been increasing. Road transport and aviation caused 3% rise in greenhouse gas emissions in 2016, compared to its levels in 2015. In 2016, transport contributed

Supported by University College Dublin and University of Leeds.

A. L. Martins et al. (Eds.): INTSYS 2019, LNICST 310, pp. 77–91, 2020.
https://doi.org/10.1007/978-3-030-38822-5_6

27% of total GHG emissions in the EU-28, of which road transport was responsible for almost 72% of total greenhouse gas emissions from transport (including international aviation and international shipping) [2]. For this reason, the EU countries adopted the objective to cut down emissions by 80–95% by the year 2050 in comparison to the 1990 levels [3].

Figure 1 shows CO_2 emissions per mode of transport in Europe [4] from 2000 to 2014. It can be observed that the amount of carbon emissions in maritime and road transport had been the highest among other modes of transport, and since 2013 onward road freight transport had the highest rate of CO_2 emissions.

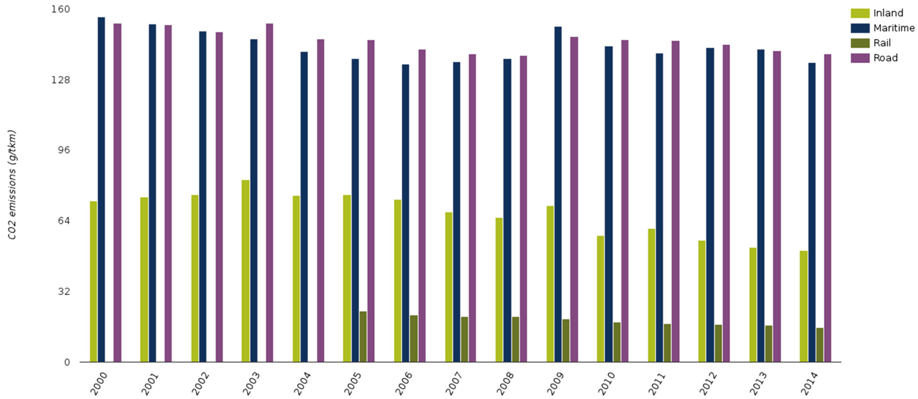

Fig. 1. Specific CO_2 emissions per tonne-km by freight transport mode in Europe [4]

Logistics network design and sustainable logistics management policies are two essential aspects for developing a low-carbon regional logistics system [5]. There has been an increasing emphasis on the necessity for efficient supply chains worldwide. There are several factors which influence the efficiency and effectiveness of transport systems such as traffic congestion problems, carbon emissions, road user charges, regulatory directives and skill shortages [6]. These inefficiencies lead to poor asset utilisation, unnecessary administration, excessive waiting time and inventory management, increased emissions and more importantly an increase in costs [7].

A large and growing body of literature has investigated the supply change efficiency improvement [8], as well as simulation and optimisation methods [9]. For example, in a recent study, Muñoz-Villamizar et al. [10] proposed a new methodology for assessing the environmental performance of logistics systems to improve the sustainability of urban freight transport systems. In another study, Andrés and Padilla [11] evaluated the most influential factors that have affected the energy consumption and carbon emissions trends of road freight transport in Spain from 1996 to 2012. Additionally, Mrazovik et al. [12] presented a routing optimisation method based on data analytics to improve the circulation of vehicles and utilisation of urban parking spaces.

Recent developments in data analytics have heightened the need for methods and tools to make data-driven supply change management [13]. Recent evidence shows that significant progresses have taken place in the field of logistics for reducing carbon emissions and improving the supply chain efficiency, such as Horizontal Collaboration [14], Pooling [15], and Physical Internet [16]. This is an important multidisciplinary and interdisciplinary research topic, nevertheless, there has been little quantitative analysis of data-driven techniques for sustainable supply chain [17] which makes this field of study an excellent opportunity for the development of new techniques and methods.

The main objective of this study is to develop data-driven optimisation algorithms for three popular supply chain methods of Pooling, Horizontal Collaboration, and Physical Internet and performing data analysis on the European road freight transport operations to improve the vehicle usage efficiency, and decrease carbon dioxide emissions per journey.

2 Background Study

2.1 The Sustainable Global Supply Chain

The world economy is likely to grow rapidly and a feature of this growth would be increased demand for transport and logistics. Correspondingly, this requires governments and other stakeholders to plan carefully to cope with the environmental, social and economic needs of a rapidly-growing supply chain network [18]. It is essential to invest further in infrastructure of logistics operations and intelligent transport systems for empowering efficient planning and better coordination of logistics operations [19].

There have been several studies to demonstrate the link between an increase in demand for transport operations and the rise in economic indicators [20]. Governments have realised the impact of free and easy trade and have responded by deregulating transport which has helped in removing unnecessary barriers to competition and has helped in making markets more competitive and ensured that prices come down and the services improve. However, as the supply chains are fast growing, it is essential that they are sustainable [21].

For this, previous studies have investigated the use of optimisation based on heuristic methods for logistics supply chain. For example, Wei and Dong [22] proposed a new multi-objective optimisation solution using adaptive-weight Genetic Algorithm method to optimise freight costs and transport time in new dry-port-based cross-border logistics networks in Chinese inland regions. In another recent study, Liu et al. [23] proposed a real-time information-driven dynamic optimisation method for smart vehicles and logistics operations to achieve green logistics. They showed that, by using internet-of-things (IoT) technology, vehicles utilisation rate can be improved, and by providing the optimal routing with ensured efficiency of logistics services, fuel consumption, number of vehicles used, and costs can be reduced. In addition, and in lines with previous researches reviewed in this paragraph, Abbbassi et al. [24] and Masson et al. [25] used different mathematical optimisation methodologies to improve the logistics transportation system.

However, the use of big data and data analytics for supply chain management and logistics has recently gained prominence [26,27]. The recent trends in supply chain logistics and data analytics suggest that there is a need to shift from heuristics methods to data-driven decision making techniques [28]. This is a step change towards more sustainable logistics supply chain which is addressed in current study. Three important supply chain logistics strategies are horizontal collaborations, pooling, and physical internet which are explained further in next sections.

2.2 Horizontal Collaborations

Horizontal collaborations are characterised by companies sharing supply chain services for common interests which can increase the efficiency and competitiveness of the participating companies [29]. Nevertheless, in the field of supply chain and logistics, more research is required to be done in the domain of horizontal collaboration or swap operations. Several benefits are associated with horizontal collaboration. For example, costs could be shared between participating organisations. Moreover, better production flexibility can be attained. Also, the involved businesses can use the capability of their partners to access new customers and markets. However, the cost of establishing coordination among the different partners is quite high and it requires significant capital investments which is a drawback. The quality of offered products could also be reversely affected by choosing the wrong partner, where losing reputation among customers could be a threat for the company and project.

2.3 Pooling

In supply chain logistics pooling means grouping of shipments that are bound to the same region and are centralised onto trailers for the entire or part of the journey. Pooling, in order to be successful needs that the demands to be met are similar and compatible. When third party logistics (3PL) provider is used for pooling, there is a higher security risk since customers require their products to be always detectable and prefer routine updates about the condition of their product. Moreover, combining hazardous products with inflammable products as they may affect the safety of the journey could be a risk [30].

2.4 Physical Internet

Internet has strongly influenced and changed the manner of information exchange and flows globally. Today, the internet is not about data and information anymore but there is a strong tie between internet and physical world. In other words, the physical internet is using the basics of the internet to logistics. The physical internet encases physical goods into green and modular containers which are usually made from environment friendly materials. This needs minimum packaging in which the so-called smart packets are tagged with sensors to facilitate proper routing and maintenance. This has been brought through progresses in the 'Internet of Things' technology and the application of sensors and radio-frequency identification (RFID) [31].

Based on the literature review, there is a great potential for improving the efficiency of logistics systems and shifting from traditional to integrated logistics systems such as collaborative logistics [32]. The important advantages of such collaborative logistics are: lower prices due to aggregated purchasing quantities, reduction of supply risk and administration cost due to centralised purchasing activities, reduction of inventory and transportation costs, logistics facilities through a rationalisation of equipment and improved sharing of data and manpower [33]. The basis of these methods is 'coopetition' or 'collaborative competition' where direct rivals collaborate on those parts of the supply chain where they do not have a specific advantage, instead of competing [34].

The current literature on big data analytics for supply chain logistics up to now has been descriptive with recent examples of applying data analytics into practice for improving the supply chain [35]. In addition, no research has been found that developed horizontal collaboration, pooling, and physical internet optimisation algorithms based on big data analytics, which is the main scope of this study.

3 Methodology

3.1 Overview

The data used in this study was obtained from the European Road Freight Transport (ERFT) survey, which consisted of road freight operations information of 27 European nations and European Free Trade Association (EFTA) countries between 2011 and 2014. The dataset contained over 11 million journeys with vehicle-related variables, journey-related variables, and goods-related variables. IBM SPSS Modeller [36] and Python [37] data analysis and programming software were used to develop pooling, horizontal collaboration, and physical internet supply chain logistics algorithms.

Anomaly detection and data preparation models of IBM were used. Then outliers were removed and the data was normalised. The data used in the survey did not include details about the efficiency of each journey neither the carbon emissions per journey which are the two indicators utilised to analyse journeys. The dataset did not include data on return journey and the distance covered on empty load, neither handling costs. So that, it was not possible to perform reverse logistics. The journeys of dataset were mainly categorised in 3 distinct classes; 1. intra-regional journeys, 2. inter-regional journeys belonging to the same country, and 3. international journeys between two different countries. The formula and steps used to calculate these variables are explained herein. The efficiency of the journeys can be calculated using Eq. 1, which also could be called the ratio of load factor [38].

$$\eta = (\phi/\chi) \times 100 \tag{1}$$

where η stands for Efficiency in percentage, ϕ for Load, and χ for Capacity. To calculate the total emissions, a simplified formula proposed by the European Association for Forwarding, Transport, Logistics and Customs Services (CLECAT) [39] was used. Then, the overall greenhouse gas emissions per tonne kilometre is calculated using Eqs. 2 and 3:

$$G_T = T_{cap} \times g_t \tag{2}$$

$$T_{cap} = \frac{(W_g - \phi + \chi) \times d}{1000} \tag{3}$$

where G_t is the total greenhouse gas emissions per tonne kilometres (g CO_2/t-km), T_{cap} is transport capacity, g_t is emissions factor depending on the vehicle weighting, W_g is gross weight, and d is distance.

Analysing the influence of the supply chain strategies on the efficiency and sustainability of Journeys was the most important step in this study.

To do this, the concepts available in literature on logistics in supply chain management had to be converted to executable code. These algorithms were written and developed in Python v2.7. The Python scripts were developed to read in journeys from a .csv or .sav file and save them as objects and modify them based on the supply chain strategy.

3.2 Supply Chain Logistics Strategies

Horizontal Collaboration. The main aim of Horizontal Collaboration algorithm was to find a similar journey with same destination and type of goods but with shorter distance travels to approach the destination and swap these journeys. Then, to enhance the analysis efficiency of the algorithm, a nested dictionary which was of the form: journeys [“*year*”] [“*quarter*”] [“*destination*”] was used in Python environment. This was utilised to decrease the computational complexity of the algorithm and decrease the number of comparisons. Nevertheless, there is a restriction placed on the relevant period which needs to be taken into account for the swap actions and by default, for this analysis, this period was set to 4 quarters (including the current quarter). It should be noted that this algorithm only swaps the categories of goods but it can be improve further by considering the product's name or type. Figure 2 represents the flowchart for horizontal collaboration algorithm developed in this study.

In this method the execution time is linear, and browse the candidate list to find the first journey which meets the condition for swapping, which is another journey that covers a shorter distance to the same destination when compared to the original journey. The candidate list is classified in increasing order of time (year and quarter) so priority is given to the first journey which meets this condition and not certainly the best journey. There is a method switch as a part of the Journey class which takes in two arguments, the journey to be swapped and the original journey. Afterwards, the algorithm builds a new journey with

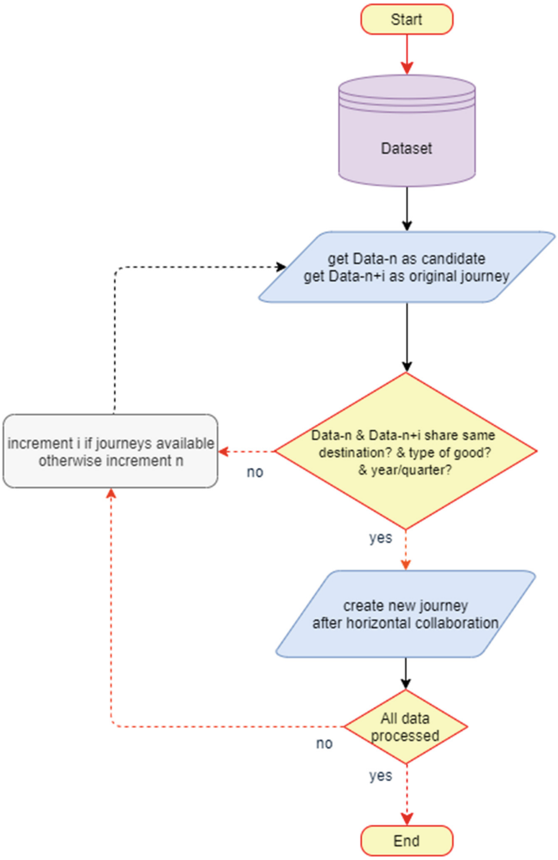

Fig. 2. Flowchart for Horizontal Collaboration algorithm

the same vehicle variables and origin as the journey for swapping and the load and the item weights from the original journey.

Pooling. Pooling means uniting two journeys which are less than complete capacity to enhance the total efficiency and decrease the total hazardous emissions.

Pooling, in order to take place successfully, requires the two journeys to take place in the same time frame, and follow the same route. Additionally, the objects contained in these journeys have to be compatible with each other. The algorithm developed for the analysis only considered journeys which had the same origin and destination, but, it is possible that this can be improved to allow for pooling of partial journeys and the creation of hubs along the way which would also serve as co-ordination centres. The nested dictionary utilised for the Pooling algorithm is similar to the dictionary utilised for Horizontal Collaboration, however the origin of each journey was also considered: journeys [“*year*”]

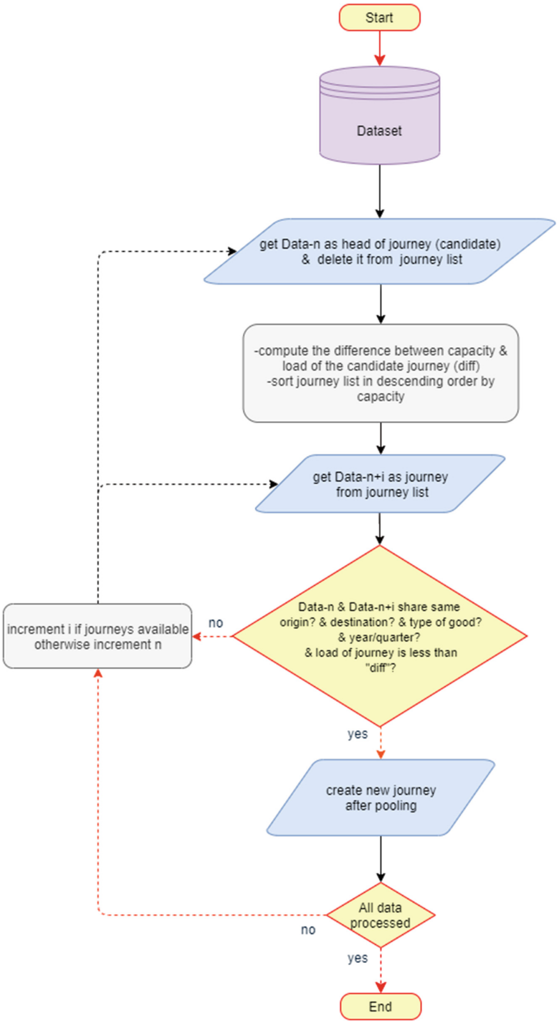

Fig. 3. Flowchart for Pooling algorithm

[“*quarter*”] [“*origin*”] [“*destination*”]. Figure 3 demonstrates the flowchart of Pooling algorithm developed in this study.

In this method, the journey list is taken as an input and returns a list of result with the final journeys after pooling has taken place. The first element of the journey list is initialised as head and removed from the list and the difference between the capacity and the load is calculated. The journeys in the journey list are then placed in descending order according to their capacity and the head is then compared with all the other journeys in the journey list and two conditions need to be fulfilled before the journeys can be pooled; first, the items present in the head and the journey being compared do not violate the blacklist, and second, the load of the journey being compared is less than the difference between the head capacity and the load. This method is iterated until all journeys are pooled.

Physical Internet. The algorithm for the Physical Internet only took into account 'port to port' logistics and optimising of partial journeys because of the lack of clear information on exact locations in the data was not taken into account. This algorithm was an extension of the Pooling Algorithm with some design changes including the creation of a new class named PI-Container which contained information about the individual Physical Internet container, type, origin, and destination of goods, vehicle registration number, and weight of each container. The Journey Class was also modified to store the information about all the Containers in that journey and a dictionary was used to store all the containers in circulation for easy searching and tracking. There containers were created dynamically at run time based on a user-selected set of weights for the Physical Internet containers which only contained one type of goods. A Greedy Approach was followed with respect to creating these containers with the preference being given to the bigger weighted containers first. This algorithm only performs pooling based on the Physical Internet containers, nevertheless, the Physical Internet is more than just a horizontal collaboration strategy since it aims to change the way physical objects are handled in the supply chain.

3.3 Data Visualisation

Since the study involved geographic data, it was important that a GIS tool be used to visualise the routes taken during the period. The journey visualisation was carried out using ArcGIS [40] which is a popular GIS developed by ESRI and widely used in several research projects. The advantage of using ArcGIS over several other JavaScript libraries which can visualise GIS data is that ArcGIS has greater support for regions outside the US and was easy to embed into a website or view online. Another advantage was that ArcGIS supported Python 2.7 so it could be easily adapted to build a Spatial Decision Support System in the future using some of the algorithms developed in this project in the future. Apart from ArcGIS, Tableau [41] was also used to visualise the routes and provide other information such as the efficiency of regions or the volume of goods. Tableau is a popular Business Intelligence software that can be used to build interactive dashboards to allow decision makers to quickly analyse the data and make decisions. It should be mentioned that, it was not possible to do a simulation of the journeys using agent-based software or other open source libraries due to the high degree of generality in the data.

4 Results

4.1 Assessment of Supply Chain Logistic Strategies

Horizontal Collaboration. The results of efficiency improvement in percentage, emissions reduction in $g\,CO_2/t.km$, and distance reduction in km after applying Horizontal Collaboration strategy are presented in this section. The optimisation algorithm developed for Horizontal Collaboration used big dataset of European road freight transportation. Table 1 shows the results after applying Horizontal Collaboration by different Journey IDs. It can be observed that distance reductions from 9 to 160 km achieved. In addition, a maximum CO_2 reduction of 0.282 $g\,CO_2/t.km$ was observed. Because the covered distance is short, the overall carbon emissions are negligible. Also, it can be seen that in some cases negative efficiencies are achieved when swapping was used with a high-capacity vehicle.

Furthermore, 42.29% of efficiency improvement was achieved only in case of Journey C. From the analyses performed on five randomly chosen journeys (Journeys A to E), Horizontal Collaboration has demonstrated to be a suitable strategy to decrease carbon emissions. This could be a good strategy for small-size manufacturers since the reduction in the distance covered can also lead to reduction in overall costs and offer better profitability.

Table 1. Comparison of efficiency, distance, and emissions after Horizontal Collaboration

Journey ID	Efficiency improvement	Distance reduction	Emissions reduction (g CO_2/t-km)
A	−0.08%	9 km	0.282
B	−4.91%	29 km	0.039
C	42.29%	8 km	0.013
D	0.00%	95 km	0.157
E	−66.19%	160 km	0.163

Pooling. From data analyses and optimisation performed, it was shown that Pooling can improve both the efficiency and reduce the carbon emissions in road fright transport. Figures 4 and 5 compare emissions reduction and efficiency improvement by using Pooling strategy in different years in some selected EU countries including Germany, France, Spain, Netherlands, Austria, United Kingdom, and Ireland, respectively. It can be seen that in the selected EU countries freight transport efficiency improved substantially, and the CO_2 emissions decreased in all years. For greenhouse gas emissions a maximum reduction of 12% (350000 $g\,CO_2/t-km$) was recorded from 2011 to 2014 (see Fig. 4), and in terms of overall efficiency an improvement of 23% was observed considering all countries (see Fig. 5).

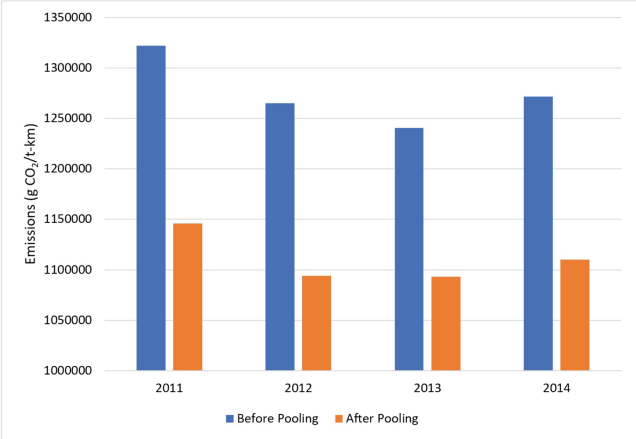

Fig. 4. Comparison of total emissions before and after Pooling by year

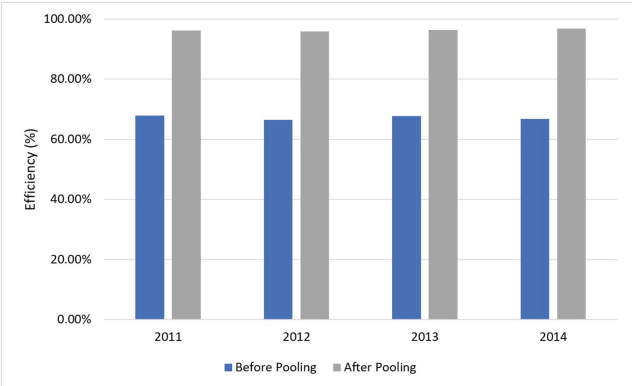

Fig. 5. Comparison of efficiency before and after Pooling by year

4.2 Data Visualisation

The last phase of the Analysis was Data Visualisation is a very important phase of the Knowledge Discovery Process as it helps to convey the findings of the Analysis and good analysis would be incomplete without good visualisation to convey the story or message from the results. Since the study involved Geographic data, it was important that a GIS tool be used to visualise the routes taken during the period. A brief description is given on how the visualisations were created.

Tableau is probably the most popular Business Intelligence software and is widely used by data analysts in industry to create interactive dashboards which can be used to represent a wide variety of information quickly. The interactive nature of Tableau makes it a popular choice for managers and decision makers. For example, in the interactive dashboard created for this study shown in Fig. 6, clicking on a country will display the emissions per year as well as the most popular goods in that country. For example, in case of Ireland it can be seen that the efficiency before Pooling was 52.50%, the trend of carbon emissions from 2011 to 2014 can be seen, and also it shows which products and goods were transported the most.

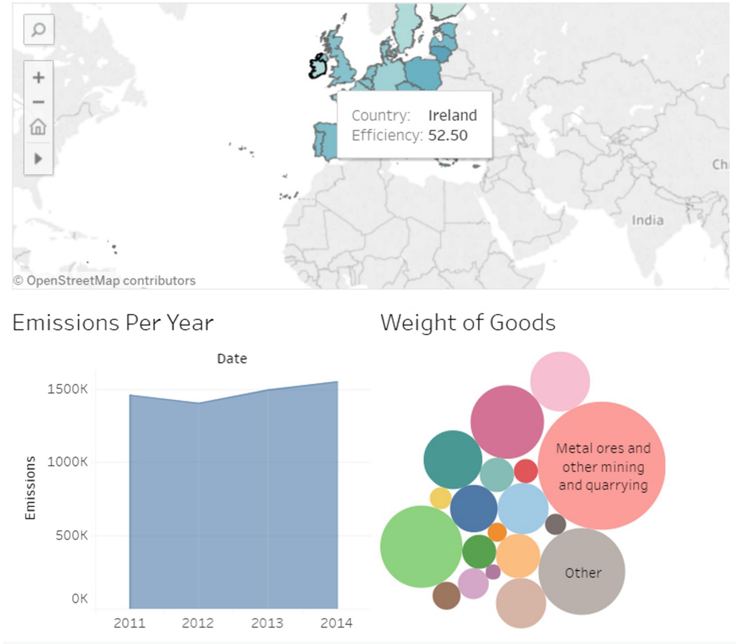

Fig. 6. Tableau dashboard representing data on countries

5 Conclusions

The main objective of this study was to develop three supply chain algorithms of Horizontal Collaboration, Pooling, and Physical Internet. Then, data from the European Road Freight Transport survey was used to assess the effectiveness of these three supply chain strategies to improve the efficiency and the sustainability of European road freight operations. The results were very impressive and there was as much as a 12% reductions in road freight transport emissions and a 23% increase in the overall efficiency, using Pooling strategy. The results of the present study would vary depending on the dataset used and the approach, however, the study has demonstrated that there are benefits to coopetition and horizontal collaboration in Logistics and this can be an area for future work and research in the field of supply chain management. The future work would also involve combining Horizontal Collaboration and Pooling and allow for pooling of swapped goods from different suppliers, in which more information about the location and the types of products involved will be required.

Acknowledgements. This publication has emanated from research conducted between School of Computer Science (UCD) and Business School (University of Leeds) as part of the collaborative/network project "Big Data Analytics for Sustainable Global Supply Chains" and data provided by the Commission (Eurostat) in the framework of the above mentioned collaborative/network project (Research entity identification number:2014/219/UK).

References

1. Nowakowska-Grunt, J., Strzelczyk, M.: The current situation and the directions of changes in road freight transport in the European Union. Transp. Res. Procedia **39**, 350–359 (2019)
2. European Environment Agency: Progress of EU transport sector towards its environment and climate objectives, pp. 1–13 (2017)
3. European Commission: EU Reference Scenario 2016 energy, transport and GHG emissions Trends to 2050, pp. 1–220 (2016)
4. European Environment Agency. https://www.eea.europa.eu/data-and-maps/figures/specific-co2-emissions-per-tonne-2. Accessed 12 June 2019
5. Jie, L., Chunhui, Y., Muhammad, H., Qiuyan, Y.: The relationship between environment and logistics performance: evidence from Asian countries. J. Clean. Prod. **204**, 282–291 (2018)
6. Marufuzzaman, M., Ekşioğlu, S.D.: Managing congestion in supply chains via dynamic freight routing: an application in the biomass supply chain. Transp. Res. Part E: Logist. Transp. Rev. **99**, 54–76 (2017)
7. Managan, J., Lalwani, C., Jadavpur, R., Butcher, T.: Global Logistics and Supply Chain Management. Wiley, Hoboken (2012)
8. Nikfarjam, H., Rostamy-Malkhalifeh, M., Mamizadeh-Chatghayeh, S.: Measuring supply chain efficiency based on a hybrid approach. Transp. Res. Part D: Transp. Environ. **39**, 141–150 (2015)
9. Hajian Heidary, M., Aghaie, A.: Risk averse sourcing in a stochastic supply chain: a simulation-optimization approach. Comput. Ind. Eng. **130**, 62–74 (2019)
10. Muñoz-Villamizar, A., Santos, J., Montoya-Torres, J., Velázquez-Martínez, J.: Measuring environmental performance of urban freight transport systems: a case study. Sustain. Cities Soc. **52**, 101844 (2020)
11. Andrés, L., Padilla, E.: Energy intensity in road freight transport of heavy goods vehicles in Spain. Energy Policy **85**, 101844 (2015)
12. Mrazovic, P., Eser, E., Ferhatosmanoglu, H., Larriba-Pey, J.L., Matskin, M.: Multi-vehicle route planning for efficient urban freight transport. In: 2018 International Conference on Intelligent Systems (IS), pp. 744–753 (2018)
13. Zhong, R.Y., Newman, S.T., Huang, G.Q., Lan, S.: Big Data for supply chain management in the service and manufacturing sectors: challenges, opportunities, and future perspectives. Comput. Ind. Eng. **101**, 572–591 (2016)

14. Cruijssen, F., Cools, M., Dullaert, W.: Horizontal cooperation in logistics: opportunities and impediments. Transp. Res. Part E: Logist. Transp. Rev. **43**, 129–142 (2007)
15. Pan, S., Ballot, E., Fontane, F.: The reduction of greenhouse gas emissions from freight transport by pooling supply chains. Int. J. Prod. Econ. **143**, 86–94 (2013)
16. Yang, Y., Pan, S., Ballot, E.: Freight transportation resilience enabled by physical internet. IFAC-PapersOnLine **50**, 2278–2283 (2017)
17. Govindan, K., Cheng, T.C.E., Mishra, N., Shukla, N.: Big data analytics and application for logistics and supply chain management. Transp. Res. Part E: Logist. Transp. Rev. **114**, 343–349 (2018)
18. Sdoukopoulos, A., Pitsiava-Latinopoulou, M., Basbas, S., Papaioannou, P.: Measuring progress towards transport sustainability through indicators: analysis and metrics of the main indicator initiatives. Transp. Res. Part D: Transp. Environ. **67**, 316–333 (2019)
19. Sun, S.C., Duan, Z.Y., Chen, C.: Energy overview for globalized world economy: source, supply chain and sink. Renew. Sustain. Energy Rev. **69**, 735–749 (2017)
20. Koberg, E., Longoni, A.: Freight transport impacts from the economic crisis in Greece. Transp. Policy **57**, 51–58 (2017)
21. Koberg, E., Longoni, A.: A systematic review of sustainable supply chain management in global supply chains. J. Clean. Prod. **207**, 1084–1098 (2019)
22. Wei, H., Dong, M.: Import-export freight organization and optimization in the dry-port-based cross-border logistics network under the Belt and Road Initiative. Comput. Ind. Eng. **130**, 472–484 (2019)
23. Liu, S., Zhang, Y., Liu, Y., Wang, L., Wang, X.V.: An 'Internet of Things' enabled dynamic optimization method for smart vehicles and logistics tasks. J. Clean. Prod. **215**, 806–820 (2019)
24. Abbassi, A., El hilali Alaoui, A., Boukachour, J.: Robust optimisation of the intermodal freight transport problem: modeling and solving with an efficient hybrid approach. J. Comput. Sci. **30**, 127–142 (2019)
25. Masson, R., Trentini, A., Lehuédé, F., Malhéné, N., Péton, O., Tlahig, H.: Optimization of a city logistics transportation system with mixed passengers and goods. EURO J. Transp. Logist. **6**, 81–109 (2017)
26. Wang, G., Gunasekaran, A., Ngai, E.W.T., Papadopoulos, T.: Big data analytics in logistics and supply chain management: certain investigations for research and applications. Int. J. Prod. Econ. **176**, 98–110 (2016)
27. Kamble, S.S., Gunasekaran, A., Gawankar, S.A.: Achieving sustainable performance in a data-driven agriculture supply chain: a review for research and applications. Int. J. Prod. Econ. **219**, 179–194 (2020)
28. Arunachalam, D., Kumar, N., Kawalek, J.P.: Understanding big data analytics capabilities in supply chain management: unravelling the issues, challenges and implications for practice. Transp. Res. Part E: Logist. Transp. Rev. **114**, 416–436 (2018)
29. Soysal, M., Bloemhof-Ruwaard, J.M., Haijema, R., van der Vorst, J.G.A.J.: Modeling a green inventory routing problem for perishable products with horizontal collaboration. Comput. Oper. Res. **89**, 168–182 (2018)
30. Bachmann, F., Hanimann, A., Artho, J., Jonas, K.: What drives people to carpool? Explaining carpooling intention from the perspectives of carpooling passengers and drivers. Transp. Res. Part F: Traffic Psychol. Behav. **59**, 260–268 (2018)
31. Lee, C.C., Chen, S.D., Li, C.T., Cheng, C.L., Lai, Y.M.: Security enhancement on an RFID ownership transfer protocol based on cloud. Future Gener. Comput. Syst. **93**, 266–277 (2019)

32. Moutaoukil, A., Derrouiche, R., Neubert, G.: Pooling supply chain: literature review of collaborative strategies. In: Camarinha-Matos, L.M., Xu, L., Afsarmanesh, H. (eds.) PRO-VE 2012. IAICT, vol. 380, pp. 513–525. Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-32775-9_52
33. Bahinipati, B.K., Kanda, A., Deshmukh, S.G.: Horizontal collaboration in semiconductor manufacturing industry supply chain: an evaluation of collaboration intensity index. Comput. Ind. Eng. **57**, 880–895 (2009)
34. Li, X.: Operations management of logistics and supply chain: issues and directions. Discrete Dyn. Nat. Soc. **2014**, 7 (2014)
35. Mujica Mota, M., El Makhloufi, A., Scala, P.: On the logistics of cocoa supply chain in Côte d'Ivoire: simulation-based analysis. Comput. Ind. Eng. **137**, 106034 (2019)
36. SPSS Modeler. https://www.ibm.com/products/spss-modeler. Accessed 30 Jan 2019
37. Python. https://www.python.org. Accessed 30 Jan 2019
38. Load factors for freight transport, European Environment Agency. https://www.eea.europa.eu/downloads/064091f718cd81fb2042d01de9965765/1492593883/load-factors-for-freight-transport.pdf. Accessed 25 Sept 2019
39. Schmied, M., Knörr, K.: Calculating GHG emissions for freight forwarding and logistics services in accordance with EN 16258 Calculating GHG emissions for freight forwarding and logistics services. European Association for Forwarding, Transport, Logistics and Customs Services (CLECAT), Brussels (2012)
40. LNCS Homepage. https://www.arcgis.com/index.html. Accessed 30 Jan 2019
41. Tableau. https://www.tableau.com. Accessed 30 Jan 2019