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An unstructured big data approach for country logistics performance assessment in global supply chains

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Abstract

Purpose – The purpose of this study is to explore the potential for the development of a country logistics performance assessment approach based upon textual big data analytics.

Design/methodology/approach – The study employs design science principles. Data were collected using the Global Perspectives text corpus that describes the logistics systems of 20 countries from 2006–2014. The extracted texts were processed and analysed using text analytic techniques, and domain experts were employed for training and developing the approach.

Findings – The developed approach is able to generate results in the form of logistics performance assessments. It contributes towards the development of more informed weights of the different country logistics performance categories. That said, a larger text corpus and iterative classifier training is required to produce a more robust approach for benchmarking and ranking.

Practical implications – When successfully developed and implemented, the developed approach can be used by managers and government bodies, such as the World Bank and its stakeholders, to complement the Logistics Performance Index (LPI).

Originality/value – A new and unconventional approach for logistics system performance assessment is explored. A new potential for textual big data analytic applications in supply chain management is demonstrated. A contribution to performance management in operations and supply chain management is made by demonstrating how domain-specific text corpora can be transformed into an important source of performance information.

Keywords Design science, Global supply chains, Big data and machine learning, CSCMP global perspectives, Logistics performance index (LPI), Trade facilitation, Neo-institutional economics, Public policy

Paper type Research paper

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1. Introduction

Global supply chain management involves the cross-border movement of goods, international logistics and operations management by firms and its executives (Bowersox and Calantone, 1998; Klassen and Whybark, 1994). The costs of cross-border logistics remain high (Oum and Park, 2004) due to spatial differences and the geographical frictions that impede freight flows (Hausman *et al.*, 2013). The performance of national logistics systems thereby plays a central role in the global supply chain location decisions of firms, and it is against this backdrop that the need for assessing the performance of country logistics systems arises for operations management decision-making (Kinra and Kotzab, 2008a, b). Research already suggests that logistics capabilities at the country level have an impact on firm-level supply chain management and bears implications for firms' global supply chain location decisions (Wiengarten *et al.*, 2014).

In relation to the literature on the assessment of country logistics systems, a select, but also still rather small, group of literature has emerged over the past two decades. The mainstream literature largely treats the performance assessment of country logistics as a stable and predictable process, where a more or less fixed set of quantitative, trade facilitation measures are updated on a regular and continuous basis to enable benchmarking over time between countries (e.g. Bowersox *et al.*, 2003; Bookbinder and Tan, 2003). This is, thus, a type of performance assessment that seeks to work within the boundaries of present definitions and within a pre-set performance measurement framework, and its potential weakness is that it is less adaptable to specific decision-making situations. The World Bank's Logistics Performance Index (LPI) is a well-known practical tool for the logistics performance measurement of countries that is available for policy-makers (Arvis *et al.*, 2018). With its exclusive policy focus, limitations regarding its particular types of performance measures (Memedovic *et al.*, 2008) and its lacking information basis in terms of industry and business specificity (Kent, 2010), it is insufficient to deal with the complexity of global supply chain decisions that require a deeper capability and institutional analysis.

Cross-border manufacturing and trading processes are complex and need information-rich performance management solutions. Logistics frictions can be a significant source of supply chain complexity and thus require innovative, information technology (IT)-enabled approaches in the management of global supply chains (Hausman *et al.*, 2010). Both environmental and information factors drive complexity in global supply chain decision-making (Kinra, 2015), and upgrading the information system, e.g. with richer communication media (Stringfellow *et al.*, 2008), remains a valid alternative to ease the challenges of coping with this complexity (Flynn and Flynn, 1999; Galbraith, 1973).

One opportunity that needs to be explored further is the leveraging of the information for performance assessment and benchmarking that is already available in the form of rich communication media such as country reports, wikis and other such unstructured textual big data sources that specifically contain country logistics assessments. This type of already available information may provide a robust but also adaptable supplement to the other forms of country logistics assessment available in the literature, hereby making the global and local decision-making support stronger.

The ability of software to analyse text has been claimed to remain rather limited (Chen *et al.*, 2012). The main challenge remains in extracting meaning (Dimaggio *et al.*, 2013), though recent techniques and opportunities within the field of big data and predictive analytics may allow the development of such an approach (Matthias *et al.*, 2017). Based on these considerations, the purpose of this study is to explore the potential for the development of an automated textual big data analytics approach that can provide country logistics performance assessments in relation to global supply chain complexity. We formulate the following research questions:

RQ1. How can global supply chain complexity communication in country reports be used to design an automated textual big data approach for country logistics performance assessment?

RQ2. To what extent can the developed approach provide a good complement to existing assessments of country logistics performance?

We adopt design science principles to explain the need for and to develop the automated text analytic approach for country logistics performance assessment. The study employs varied text analytic approaches and machine learning techniques to develop, train and evaluate the assessment tool. This is done using a text corpus of country logistics complexity assessments made in the context of global supply chains in the periodical, *Global Perspectives*. The results illustrate how our approach tackles the task with reasonable accuracy and generates useful assessments from a managerial and policy-making perspective. Furthermore, the results illustrate how big data techniques, such as text analysis, have the potential to be an important supplement to other performance assessment approaches.

Our approach is novel and adds with an important innovation to the existing big data approaches for country logistics performance assessment (Bowersox *et al.*, 2003; Rodrigues *et al.*, 2005). It also contributes with the development of country performance measures for the emerging big data-driven supply chain (BDDSC) organisation (Kamble and Gunasekaran, 2020) and holds implications for research on logistics performance measurement more generally. Our findings show that the developed approach can be adjusted to the logistics performance information that is extracted. The approach, thus, has the potential to be better aligned to the information needs of managers or policy-makers and to the specific logistics decision-making problem at hand (Griffis *et al.*, 2004).

The rest of the paper is structured as follows. We begin with a discussion about the importance of country logistics performance assessment in global supply chain decision-making, the existing approaches and the theoretical gaps. This is followed by a presentation of the adopted theoretical framework and research methodology. Next, the performance assessment approach is applied on the text corpus and the results are presented, including a critical evaluation of the approach. Finally, the paper concludes with implications, limitations and directions for future research.

2. Theory

2.1 Why country logistics performance assessment matters?

Logistics management includes all activities in the planning, implementation and control of the forward and reverse flows and storage of goods, services and related information between the point of origin and the point of consumption (CSCMP: Council of Supply Chain Management Professionals). Logistics costs are the combined costs associated with these activities and represent more than just transportation costs because logistics also includes the activities of warehousing, packaging and materials handling and inventory control. These costs of logistics can thereby comprise between 10 and 25 percent of the total costs of a firm's international sales, and these are expected to rise with rises in cross-border activity (Oum and Park, 2004).

Country logistics performance matters because of these time and distance costs that arise in cross-border operations, and this calls for public–private partnerships for the control of these costs (Hausman *et al.*, 2013). Trade facilitation offers a macroeconomic perspective on how policy-makers can positively influence the global supply chain capabilities and performance of firm operations in a country or an economic region. Policy reforms at a country level can lead to significant performance benefits in the upgrading of supply chain capabilities of its firms (Mann, 2012; Fugate *et al.*, 2019). Country logistics performance is, therefore, closely related and defined in terms of logistics capability, which is the "…. capacity of a country (location) to provide modern, reliable and dense infrastructures, business-friendly environment, high quality of logistic services, and trade facilitation, to respond to contemporary business needs of efficient delivery of raw materials to producers and products from producers to final consumers" (Memedovic *et al.*, 2008, p. 367).

Research on the importance of country logistics performance is scarce. Wiengarten *et al.* (2014) finds that firms with global supply chains in countries with superior logistics capabilities adopt significantly lower levels of supply chain integration, in contrast with countries with lower capabilities, where there can be performance benefits related with higher levels of supply chain integration. One instance where performance assessment and benchmarking of national logistics systems can become relevant is during the global supply chain location decision of firms, e.g. warehouse site selection decisions (Kinra and Kotzab, 2008a). Wiengarten *et al.* (2014) find support for this, though there is a lack of work that links country logistics performance assessment to managerial decision-making. Similarly, there are not many normative assessments in academic research that can demonstrate country logistics assessments from a global supply chain decision-making point of view (see Mann, 2012).

2.2 The main analytical approach for country logistics performance assessment in global supply chains

Currently, there are different approaches for country logistics performance assessment, depending on the way each conceptualises the spatial variation of logistics costs (Kinra, 2015). Perhaps, the most adopted are the ones that are offered under the economics and trade facilitation rubric, and we focus our attention on these as they have been recommended in the context of global supply chains (Mann, 2012). The economics and trade facilitation literature generally adopt the stance that spatial variation is generated by the structure of national resource endowments and (bilateral) trading patterns between countries. For example, the extensive deployment of the *gravity model* (Anderson, 1979) embodies the adoption of this perspective in the literature (Hausman *et al.*, 2013; Roy *et al.*, 2018). The performance assessments are either generated in terms of known quantitative data that are readily available (Bowersox *et al.*, 2003; Bookbinder and Tan, 2003) or through the collection of perceptions of logistics managers on country-level trade facilitation performance dimensions (Memedovic *et al.*, 2008). A common limitation in the literature is the missing aspect about organisational goals, decision-making complexity and the role of information in global supply chains and the performance assessment. As Hesse and Rodrigue (2004) state, we need a better understanding about the relevant spatial impedance factors and measures related to decision-maker complexity from logistics systems.

For example, the LPI, which has consistently measured the logistics performance of countries on a biennial basis since 2007, is conceivably the most important tool that has arisen out of the trade facilitation rubric. It essentially focusses on (international) trade logistics and measures the logistics connectivity of countries around six performance dimensions: customs, infrastructure, tracking and tracing, ease of international shipments, logistics service quality and timeliness. Although it has considerably evolved since its inception, its large focus on public policy (Arvis *et al.*, 2018) and poor industrial application (Kent, 2010) render it incomplete for an assessment from the point of view of the complexity of global supply chains.

In relation to the shortcomings of the LPI, first, there is an equal treatment and assignment of weights to its input and output performance categories and dimensions, which is highly improbable, given the geography and complexity of country logistics systems (Kashiha *et al.*, 2016; Rezaei *et al.*, 2018). Second, global supply chain management involves more than just port-to-port movement of goods, and country logistics performance assessment should involve measuring a host of other distances that arise in global supply chains (Halaszovich and Kinra, 2018; Lorentz *et al.*, 2018). Third, global supply chain complexity assessment requires more media richness and synchronous systems (Stringfellow *et al.*, 2008). Last but not least, with its overreliance on "soft data" and fixed set of transport and information infrastructure performance measures, the LPI provides an incomplete assessment and what is needed is a deeper logistics capability assessment (Memedovic *et al.*, 2008) around complexity in global supply chain operations (Kinra and Kotzab, 2008a, b).

2.3 Global supply chain complexity and alternative big data approaches for country logistics performance assessment

Country logistics performance assessment solves a spatial transactions cost problem for the border-crossing firm and its decision-maker and requires a performance assessment of the complexity of the country environment (Kinra, 2015). This is because the firm needs to assess the transaction costs of operating or locating across country borders, and consequentially, the degree to which its communication and physical infrastructure need to be internalised (McCann and Mudambi, 2004). Stated differently, the firm needs to constantly address the "*market vs hierarchy*" dilemma under conditions of uncertainty and information asymmetry (Williamson, 1975). This uncertainty relates to the variation in spatial transactions costs over distance, namely, the transportation, communication and institutional costs that vary across countries (McCann, 2008). These costs are directly related to the logistics costs of the firm and lead it to experience country logistics environmental complexity (Kinra and Kotzab, 2008a), which can be assessed through a host of country logistics attributes or decision factors, and their corresponding information measures (Kinra, 2015) illustrated through Figure 1. Research has also shown how this complexity combined with other forms of upstream and downstream supply chain complexity can have a negative impact on manufacturing plant performance (Bozarth *et al.*, 2009; Ferdows, 2018). The challenges from cross-border operations require the firm to develop flexibility and a unique set of performance standards and decision support systems that are needed to manage this complexity (Manuj and Mentzer, 2008; Ivanov and Dolgui, 2020).

Both, differences in the logistics environment and the quantity and variety of the information required to assess the environment drive this complexity. The informational and computational requirements can be significant in the context of global supply chain management (Kinra, 2015). Investing in a better information system is a viable strategy for coping with this complexity (Flynn and Flynn, 1999), and it is recommended to improve the richness of the information and communication system to reduce the interaction distance that directly impacts the invisible costs in global supply chains (Stringfellow *et al.*, 2008). The importance of using big data and richer communication media, as a part of country logistics performance assessment, is, thus, emphasised.

Big data and predictive analytics have already gained ground in logistics and supply chain management (Schoenherr and Speier-Pero, 2015). Application of big data can have a significant impact on supply chain performance and calls for new approaches for performance measurement (Kamble and Gunasekaran, 2020). Bowersox *et al.* (2003) have already suggested the application of an artificial intelligence (AI) and machine learning approach for the assessment of country logistics performance. However, their approach is based on structured, quantitative data. Almost 80 per cent of all data possessed by organisations are in the form of "unstructured", textual data (Wenzel and Quaquebeke, 2018), and there are data such as country reports that specifically contain country logistics assessments (Kinra, 2015). The main challenge for researchers is how to manage and extract meaning from these large volumes of text, and recent advances in topic modelling (Dimaggio *et al.*, 2013) and related text mining techniques can aid in this challenge (Bhattacharjya *et al.*, 2018).

Based upon these considerations, Figure 1 presents the framework for an alternative big data approach for country logistics performance assessment that can better aid in coping with the complexity in global supply chain decision-making. The different types of the highlighted factors and information measures that aid in the country logistics performance assessment around global supply chain complexity have already been identified (Kinra, 2015). We build on this and term these factors as the performance measurement categories and measures and couple them with automated big data techniques. These techniques are capable of extracting the measures as part of the performance assessment, but they are also

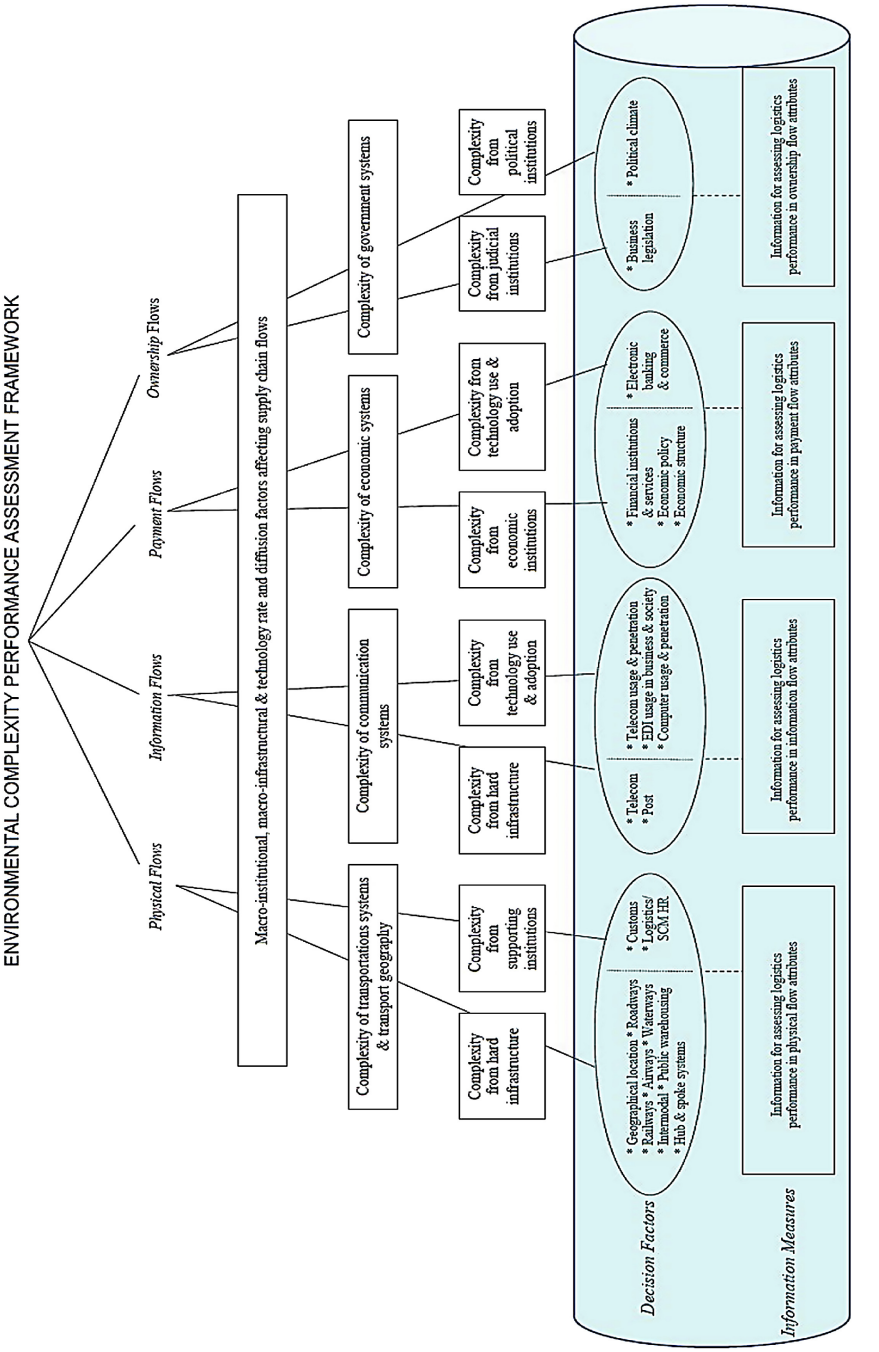

Figure 1.
A framework for country logistics performance assessment (adapted from Kinra, 2015)

capable of classification and ranking based upon the extracted information. The measures are identified, extracted and classified for a range of countries, and the performance assessment design artefact is developed and trained using a mix of text mining techniques and data sources that are described next.

3. Research methodology

3.1 Applied design science principles

The study employs design science principles to develop the approach for country logistics performance assessment. The purpose of design science research is both descriptive and explanatory, and it aims to provide solutions to practical problems involving socio-technical systems (Van Aken *et al.*, 2016). The design to be developed in our study is a socio-technical system consisting of the domain expert who represents the domain problem, the text analyst who is the data scientist and a range of big data techniques.

Design science is a young paradigm that is applicable to the creation of scientific knowledge in management (Van Aken *et al.*, 2016). The design science approach seeks a solution to a class of problems in a series of steps that require solution incubation and development of the initial solution design, followed by a series of iterations that may be required to refine the solution (Holmström *et al.*, 2009).

The problem to be resolved in our study concerns a class of global supply chain management decision support situations where country logistics performance assessment is required (e.g. warehouse site location). The existing solutions such as the LPI can only provide partial decision support. The problem has already been established in literature (see Kinra and Kotzab, 2008a; Kinra, 2015), and a resolution is sought for better decision support using a set of different approaches that are now emerging (e.g. Rezaei *et al.*, 2018). The approach that is explored in this study is based upon textual big data, and we attempt to propose a suitable solution using the techniques and methods of this approach. The research process adopted in our study paper is, thus, coherent with the *problem identification – design evaluation* design science research process (Peffers *et al.*, 2007). Based upon this process and its principles, we have first reviewed the existing literature on country logistics performance assessment, explained the need for the development of a textual big data-based technical advance and have initiated and demonstrated the design of the new approach. At the same time, we are aware that the full design potential might not be achieved within the confines of the present study. Thus, just like Reinerth *et al.* (2018), our study is also concerned with design initiation and solution incubation. The design artefact is a text-based information processing system for country logistics performance assessment, and the relevant principles for design development for such information systems (Abbasi and Chen, 2008) are adopted.

3.2 Design of the suggested approach

The design of the suggested approach rests upon a mix of text mining and machine learning techniques. The protocol for development was made in line with the principles described by Kobayashi *et al.* (2018a). Given the research questions and theoretical foundation, the design of the approach contains two different types of big data analytic tools that, when used in combination, should be able to provide assessments. These are now described in more detail.

The first tool should be able to provide an overview analysis of the different performance categories and measures (referred to as the decision factors and information measures) that drive complexity in the global supply chain and have been employed in a text corpus. As performance assessment criteria are unstable and can change, this tool should also be able to detect the emerging categories and measures of assessment. It should be able to content analyse the entire text corpus in terms of the performance keywords, word frequencies and

collocations. Thus, the tool is founded on a mix of supervised (*keyword analysis*) and unsupervised (*word frequency analysis* and *collocation analysis*) learning approaches. Text extraction and preprocessing are done using the natural language toolkit (NLTK) and Python programming language. As with Dimaggio *et al.* (2013), topic modelling could have been employed as an alternative method to figure out key topics in the text corpus. But because the primary goal of the first tool is to provide the overview analysis of the text corpus, the *keyword, word frequency* and *collocation analysis* are suitable methods.

The second tool should be able to assist in the classification of the text taking into account the domain-specific attributes of country logistics systems assessments and ideally, be able to create an automated classification and ranking system that may help in performance assessment and benchmarking. It is, thus, founded on multi-label text classification principles (Kobayashi *et al.*, 2018b), and out of the several approaches available in text classification domain, a simple text classification method was chosen (Zhang and Li, 2007) based on the Bayes rule that relies on a simple representation of documents using the bag of words approach. Even though there are other available text classification methods such as logistic regression, we have employed the naïve Bayes classifier and methods (McCallum and Nigam, 1998; Chen *et al.*, 2009), as these perform very well in the case of relatively small training corpora.

Feature selection was considered. Our text classification is based on unigrams, and therefore, each word/token is a feature in identifying the suitable label for a given text document. However, to increase the accuracy of text classification, we have implemented a feature section scheme where we sorted the features according to their term frequency and inverse document frequency (TF-IDF) scores and used the top 200 features in the classification task.

3.3 Data and processing

The *word frequency analysis* and *collocation analysis* are unsupervised, and these did not require any prior keywords. But, keyword analysis is a supervised approach as suitable keywords for the decision factors were provided based on the framework for country logistics performance assessment (Figure 1).

The performance analysis is conducted through a text corpus containing rich communication in *Global Perspectives*, which is the flagship periodical of CSCMP. It was chosen because it is highly representative of the problem domain and is dedicated towards the managerial understanding of the logistics and supply chain environmental complexity at a country level (CSCMP, 2014a, b). An alternative source could have been the use of country *wikis*, which almost always contain (or link to) sections on transport, communication and economy. However, because of concerns about information quality, reliability and representativeness, [1] we opted against the use of this source for the present research. In the case of *Global Perspectives*, this problem is eliminated because the council formally sets up an expert committee in each instance, which then creates and conveys the message to its members through the professional media texts. It then conveys information and expert assessments on country logistics performance in the context of global supply chain management, for each country that is profiled.

The data for the classification tool have originated in the use of human coders for training and developing the design artefact in a way that can enable it to automatically classify and benchmark the logistics performance of different countries. In this instance, we used seven domain experts as coders, who provided us with expert coding of text pertaining to country logistics performance, around the various performance assessment dimensions represented by the decision factors in Figure 1 (labelling the training set in the parlance of text analytics). The coding exercise was undertaken in an intensive one-day workshop, using a Web-based

classification instrument that entailed classifying text portions from *Global Perspectives* (see Appendix 1). An example of a text string is provided in Figure 2. The human coders were first familiarised with the overall model and text classes and were then asked to perform the classifications. Each expert coder managed to undertake between 30 and 100 classifications that were then used to train and build the automated text classifier. Finally, the automated text classifier was executed on the *Global Perspectives* text corpus for the generation of results. Figure 3 provides a graphic representation of the overall approach that was developed and employed.

The overall scope of the analysis included 20 different countries/regions (Figure 4) and a text corpus of 22 text documents that cover their logistics performance over the period 2006–2014. We, thus, account for longitudinal data that are important from the point of view of tracking how different performance categories evolve.

4. Results and discussion

The developed approach was applied on the Global Perspectives corpus to see how it performed in textual extraction, information retrieval and in the performance assessment task. A selection of the results is presented below.

4.1 Results from the keyword, word frequency and collocation analysis

As part of keyword analysis, the most predominant performance categories (Figure 1) could be investigated in the text corpus. Each of the 21 decision factors (e.g. Waterways) adopted was supplemented with suitable search words (port, water, sea, shipping, etc.) that are representative of that factor. The occurrence counts of search terms are summed up to find out the keyword occurrence count for a decision factor. Based on the keyword occurrence

> "The logistics infrastructure enables fast and reliable movement of goods either by road rail sea inland waterway air or pipelines. The combination of multimodal hinterland network connections is unique in the world. Due to the high volume of goods being handled competition is high resulting in attractive price-quality ratios for logistics and logistics-related services"

Figure 2.
An example of a text string

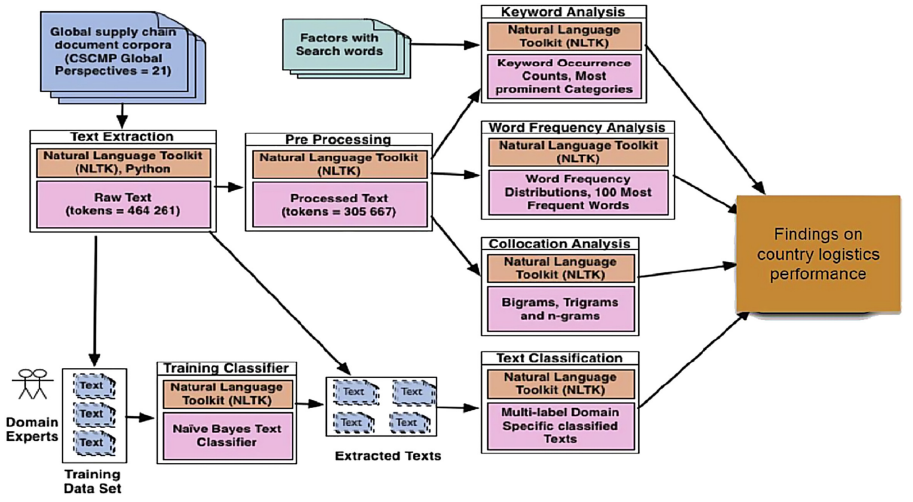

Figure 3.
Approach for an unstructured big data approach for country logistics performance assessment

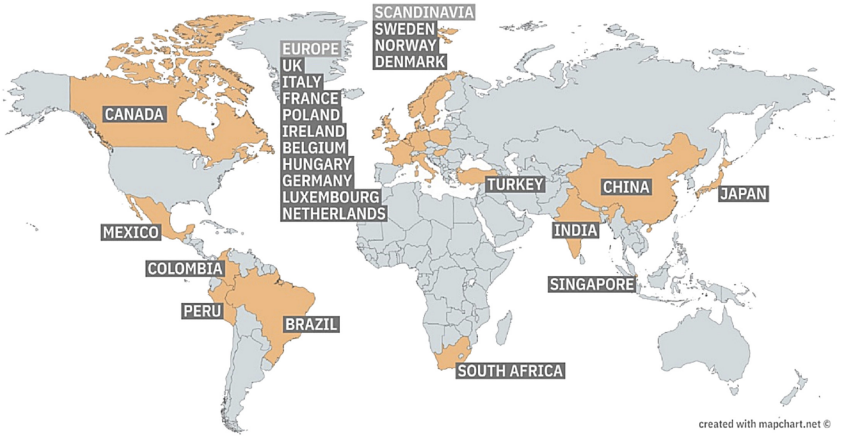

Figure 4.
Current scope of country analysis through *Global Perspectives*

counts of decision factors, it was possible to compare which categories are predominant in the entire corpus as well as in each country descriptions. In addition to that, it was possible to compare categories across the countries such that the most prominent countries for any given category could be identified.

Figure 5 shows the most frequent categories and measures for the whole data set. As the complexity assessments are related to global supply chains, we were also able to segregate the performance category analysis along different globalisation periods based on data from UNCTAD (UN Conference for Trade and Development), in an attempt to understand the driver categories of global supply chain complexity. Table 1 presents the category analysis of the text corpus. It is evident from these results that waterways, which is an infrastructural category and capability, stands out as the most important in the analysis, though the economic structure and economic policy factors also drive the assessments. Moreover, it is notable that most assessments were driven by macro infrastructural, institutional and finally communication and IT rate and diffusion performance categories, in that order.

As part of the word frequency analysis, it was found that it is possible to perform a more in-grained country performance analysis through the generation of useful word clouds for each country, as well as a word cloud for the whole text corpus. This was made possible by computation of the term-document matrix for the whole corpus as a single document and for each individual *Global Perspectives* document as well. Word frequency analysis and word clouds enabled us to get a visual overview of the major performance topics, in addition to the established performance categories and measures that were assessed in the documents. We

Figure 5.
Top categories and measures for whole data set

found that the results from this analysis in conjunction with the collocation analysis provided an intuitive assessment and visibility over different topics and concepts that were assessed in the country descriptions. It, thus, helped us notice the emerging performance dimensions like "sustainability" and "security" that can play an important role in global supply chain assessments. We searched further for these emerging performance dimensions and found that these figured noticeably in the assessments, measured by their respective keyword counts in the data corpus that are presented in Figure 6.

4.2 Results from the machine learning and text classification

The results from the machine learning and text classification show that the text classifier is able to generate consistent results with some reasonable accuracy and can provide a performance assessment. Table 2 presents the classification reports. In the sentiment analysis, the classifier performs well, especially for the prediction of the *positive* and *negative* labels, with performance measures in the range of 0.60–0.90. In the case of the *unsure* label, the number of documents in this class were not many, and therefore, the classifier was not able to predict correctly. However, the performance of the classifier for the logistics performance categories (decision factors) is quite low. Though, when compared with the baseline accuracy, e.g. by choosing a random class out of all classes, most of the classifier performance measures (precision, recall, F1-score and accuracy) for the categories performed much better than the baseline accuracy. This is a reasonable result, keeping in mind the focus of our study, which was the exploration and methodological demonstration of the text classification techniques rather than the achievement of perfect classifier performance measures.

Consequently, we were able to apply and demonstrate classifier for a comparative benchmarking of the different countries. Figure 7 shows the selected results from the

Categories	2004–2007	2008–2009	2010–2013	2014
Waterways	1,361	2,232	2,965	1,117
Intermodal	668	701	1,119	424
Economic structure	396	464	917	225
Railways	363	486	677	337
Economic policy	321	239	581	124
Airways	185	674	849	299
Geographical location	108	548	649	120

Table 1.
Category analysis of global supply chain perspectives

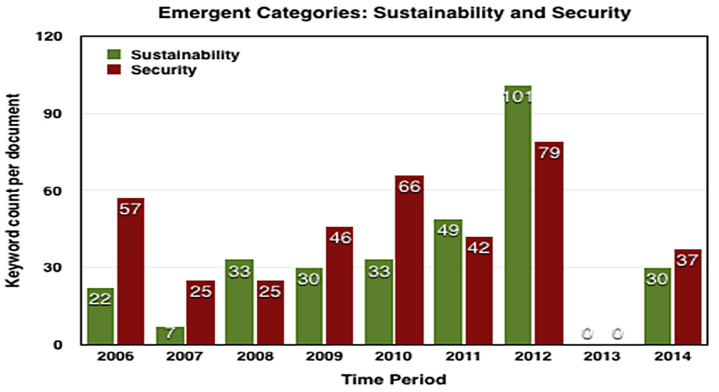

Figure 6.
Emergent categories of sustainability and security

Class label	Precision	Recall	f1-score	Support
Algorithm: naive Bayes classifier, model: decision factors				
Geographical location	00.36	00.18	00.24	44
Railways	00.33	00.27	00.30	37
Intermodal	00.10	00.06	00.07	33
Logistics/SCM HR	00.21	00.28	00.24	25
Public warehousing	00.11	00.33	00.16	9
Economic structure	00.38	00.41	00.40	49
No decision factor	00.35	00.55	00.42	33
Customs	00.24	00.25	00.24	16
Business legislation	00.00	00.00	00.00	12
Roadways	00.48	00.28	00.35	50
Economic policy	00.08	00.12	00.10	16
Political climate	00.17	00.12	00.14	16
Waterways	00.42	00.44	00.43	50
Airways	00.27	00.35	00.30	23
Algorithm: naive Bayes classifier, model: sentiment				
Positive	0.69	0.89	0.78	113
Neutral	0.59	0.36	0.44	56
Negative	0.88	0.54	0.67	26
Unsure	0.00	0.00	0.00	5

Table 2.
Classification report for performance category analysis and for sentiment analysis

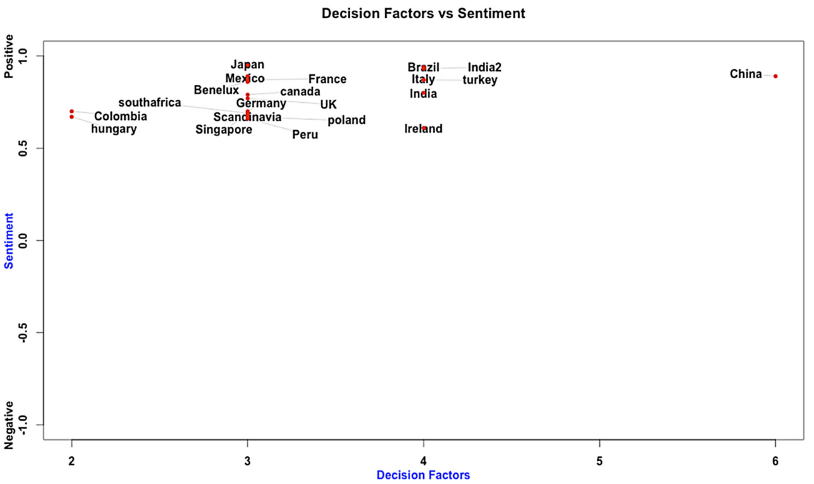

Figure 7.
Country-level classification and assessment ability of the classifier

classification exercise, showing the ability of the classifier to classify and rank the logistics performance of all the countries in the data set. As we can see from the figure, all the countries are ranked high on the sentiment dimension, i.e. have a positive sentiment value greater than 0.5. The second dimension shows the number of prominent country logistics performance categories. The highest number of performance categories exists in the assessments for China, which are: waterways, electronic banking and commerce, economic structure, geographical location, roadways and logistics/supply chain management human resource (SCM HR). However, most of the countries deal with four or less prominent performance categories, and the other categories

appear less significantly in the assessments. The most dominant categories are: electronic banking and commerce, waterways and economic structure.

Similar results were also found in the ability of the classifier to assess performance with regard to the environmental complexity of the analysed countries.

In the following section, we provide a reflection on these findings and considerations for the further design and development of the presented approach.

4.3 Discussion of results and theoretical implications

To address the second research question, we critically reflect on the developed approach by comparing it to the LPI approach, and more generally how our approach can aid in generating complexity-based performance assessments.

It is evident from our findings that some performance categories such as *waterways*, *intermodal* and *economic structure* are more frequently assessed than others such as *customs*. As the LPI assigns equal weights to all performance categories, this result may help in creating more informed weights for the performance categories in country logistics performance assessment, depending on the local decision-making situation. Similarly, in relation to the LPI, it might be possible to do a more in-grained analysis on the evolution of each performance category over time. From Table 1, it can be evident that barring a few exceptions such as *airways*, the importance of each performance criterion remains relatively stable across the different analysed periods. The results may then help in arguing for the use of the chosen performance categories for country logistics assessment and, furthermore, in assigning relative weights to the criteria. Our results on the derivation of weights were checked against similar results from other studies (Rezaei *et al.*, 2018; Ulutaş and Karakoöy, 2019) and are found to be robust. We also found a limited rank reversal possibility that can occur in the LPI from this result though this needs further investigation. This implies that there is no negative implication for empirical studies that employ LPI ranks (e.g. Wiengarten *et al.*, 2014), though there is a positive practical implication for policy decision-making, and this is discussed further on.

Our approach also includes a large set of performance categories and aids in eradicating the problem of the fixed set of performance dimensions and categories that are associated with the LPI. In line with the main purpose and design parameters behind Tool 1, the approach is able to perform well on the standard information retrieval and extraction tasks and can provide a good overall representation and assessment of the different categories that drive environmental complexity in the global supply chain. We are able to detect some emerging performance dimensions, notably *sustainability* (Figure 6), which has recently generated interest in the evaluation of country supply chain performance (e.g. Reinerth *et al.*, 2018). The trend towards sustainability is also visible by looking at Table 1, where there is a general movement towards the assessment of more sustainable modes of transport such as waterways and rail. An interesting theoretical implication is, thus, how environmental disbenefits should be measured in relation to the existing spatial transaction cost categories for country logistics performance assessment in global supply chains (McCann, 1998, 2008).

In line with the ambitions behind the design of Tool 2, the approach has been able to some extent to classify complexity and benchmark with some reasonable accuracy, though there have been some challenges that need resolution. It is evident from Figure 7 that all the countries emerge highly in their ranking on the sentiment dimension, i.e. positive sentiment values greater than 0.5. Here, it is evident that the classifier could only detect a positive sentiment. This might be because of a few reasons, which are now discussed. First, the document size for the consideration of our expert coders might be too large. Related to this issue, the classification categories derived out of the theoretical framework might also have been too many and may have resulted in an overburden for our expert coders. Consequently, at what stage should the theoretically oriented researcher enter the design phase with domain

expertise (Holmström *et al.*, 2009)? In our study, this entry took place at a very early stage and helped steer the design in a way that conformed to theoretical requirements. This was done by applying the construct of environmental complexity in conformance with theory, as it is important to develop domain-specific data science for big data knowledge production (Waller and Fawcett, 2013). In hindsight, this feature could also have been a limitation in the design reaching its optimal potential because the human classifiers employed for design development displayed signs of confusion and duress, from the stringency in applying the theoretical constructs during the classification exercise. An implication could, thus, be that the theoretically oriented researcher either does not participate in the development phase or enters in a different role. However, this needs to be further analysed in the context of operations and supply chain management research, alongside the aspects about whether the design should contribute towards theory, artefact or both (Baskerville *et al.*, 2018).

Second, *Global Perspectives* is a text corpus that largely contains positive, descriptive assessments that have an emphasis on future development plans, which are indeed suitable to understand and assess the institutional dynamism from a policy-making point of view. Whereas if the text corpus had been user-generated content such as social media data (e.g. Twitter, Facebook, etc.), which contains the opinions and expression from consumers, then it would more likely contain not only the positive sentiments but also negative sentiments (Bhattacharjya *et al.*, 2018). However, these social media text corpora may not be ideal for country logistics performance assessment from a policy-making point of view, and the dilemma, thus, needs to be resolved in future work, e.g. using the media richness lens (Lengel and Daft, 1988).

Similar challenges also emerged in the classification of complexity, where it was experienced that the text classification rendered itself into ambiguity for the experts. For example, there were divergent classifications between the domain experts about the interpretation of, and level of complexity, for the same text portions. Our approach has, thus, not been able to produce any significant differentiation between the countries, and the ranking and benchmarking are yet unstable in comparison to the LPI. Dimaggio *et al.* (2013) point out this type of emergence of meaning as a central tenet in textual analysis and therefore suggest "topic modelling" as an appropriate approach. However, as our aim was broader and included deriving assessments using pre-defined classes, the plausibility of these reasons and strategies needs to be scrutinised further. A common approach to deal with this challenge is more extensive classifier training (Kobayashi *et al.*, 2018b), and this could also be explored further in combination with the media richness perspective (Daft *et al.*, 1987).

As a final word, caution should be exerted in overinterpreting the results presented here, as there might be institutional factors, such as the profession and culture of the involved experts, in the expert commentaries found in the analysed text corpus (Stringfellow *et al.*, 2008). Although larger text corpora may aid in normalising these factors, more research is needed on these aspects for the decision-maker to feel confident about the generated results.

5. Contribution and practical implications

The study has contributed in many ways. First, a novel contribution to the literature on country logistics performance assessment is made. Our approach adds to the research of Bowersox *et al.* (2003) that at a very early stage (see also Rodrigues *et al.*, 2005) suggested the employment of machine learning approaches based on quantitative country data. Our approach goes a step forward and is one of the first that attempts the use of country reports, which are inherently unstructured, complex and difficult to process for extracting meaningful facts and actionable insights. By employing a more comprehensive set of input performance categories and richer communication data, our approach provides a much deeper country logistics capability analysis (Memedovic *et al.*, 2008). Additionally, it helps in developing more

informed weights for the different performance categories using existing textual big data in comparison to other more resource demanding data approaches (Rezai *et al.*, 2018).

Another central contribution of the presented research is its implications for research on logistics performance measurement. Our findings show that the developed approach can be adjusted in relation to the logistics performance information that is extracted. The developed approach, thus, addresses a call to design performance measurement systems and performance measures that can detect performance consistent with the logistics organisation's specific mission, goals and environment (Griffis *et al.*, 2004).

Finally, a more general contribution is also made through the adoption of the country perspective, which is a growing theme in the international operations management literature (e.g. Schoenherr, 2009; Wiengarten *et al.*, 2015; Gupta and Gupta, 2019) from the point of view of understanding and measuring the "macro-level" institutional context for operations and supply chain management (Kinra and Kotzab, 2008b; Tokar and Swink, 2019). Similarly, it is one of the few studies that have attempted to link supply chain risk, complexity and performance and digital systems in the context of global supply chains (Ivanov and Dolgui, 2020; Reinerth *et al.*, 2018).

There are some important practical implications too. From a managerial perspective, the application of big data methods, and freely available text documents, exemplifies one of the first applications of this new technology to the field of supply chain performance measurement. As the access to important data on supply chain performance may be considered sparse because of data ownership issue (Hald and Mouritsen, 2018), this may be an extremely important innovation for practitioners seeking to grasp supply chain performance and will open many opportunities. For example, there is abundant information about the logistics performance available in the form of user-generated content such as blogs, online forums, Wikipedia corpus, etc., which contains valuable information and that could help companies to mine, estimate and predict performance.

From a policy-making perspective, the approach explored here suggests a better incorporation of the concept of generalised costs of transport into country logistics assessments. Although the concept is fairly well used in the marketing and pricing of logistics services (Mangan and Lalwani, 2016), its adoption in the use for policy decisions is not always straightforward (Rothengatter, 2017), and this also reflects in the limited performance categories and measures that are employed in the LPI. The approach suggested here is more comprehensive and will be able to incorporate a wider range of benefits that national or regional policy-making should consider when investing in capabilities. Similarly, our approach suggests the measurement of country logistics performance against output indicators such as "complexity" and "sustainability", which represent the negative externalities of the global logistics system. Finally, as policy-making is the main tool for institutional change and development, and institutions are dynamic and develop over time (Cantwell *et al.*, 2010; Lundan and Li, 2019), our approach suggests the use of richer communication media, which have the ability to provide a deeper institutional analysis in relation to capturing the country logistics performance. Although the LPI is established and durable, our approach can be a valuable complement under conditions where the LPI provides incomplete assessments with regard to individual country-oriented decision-making and where the (LPI) survey is resource-constraining or not possible (see Kobayashi *et al.*, 2018b).

Finally, there are related implications for the industry associations, CSCMP in particular. As our approach works together with the rich communication and assessments that are found in *Global Perspectives*, the implication for the council is to continue with the production of this periodical. The council has not produced assessments on any new countries, or updates on the existing ones, since 2015. Based upon the analysis presented in the paper, we also call for more nuanced complexity assessments in the future, perhaps involving a wider stakeholder group, and with a larger representation of managers. Similarly, there could be future implications in terms of how the communication should be written and structured in a way that reduces equivocality and ambiguity and lends itself into an easier analysis.

6. Conclusion

The purpose of this paper was to explore the development of an automated textual big data approach that can provide country logistics performance assessments in relation to global supply chain complexity. Keeping in mind the nature of our study, the unstructured big data approach explored in this paper is found useful, in that it can both aid in automating the generation of text-based assessments and can improve the country logistics assessments in relation to global supply chain complexity. The paper has been able to do so by adopting design science principles, using an organisation environmental complexity performance assessment framework and a mix of textual big data analytic approaches and machine learning techniques. The approach is, thus, able to cope better with complexity, provide a more balanced assessment, help in the creation of weights for the different performance categories and, to some extent, is also able to generate rankings and allow benchmarking.

However, as in any other study, there are limitations. The design requires more iterations before the approach can produce reliable results. First, the accuracy and ability of the approach to generate practically valid results will need more training set data and further iterations and perhaps also a modification of the design to move forward. The quality of the existing text corpus could require enhancement using supplementary textual data sources that provide more balanced assessments than only the positive, descriptive assessments that were found in *Global Perspectives*. Second, further training work with domain experts will be required to generate more accuracy. Finally, there are some technical text extraction challenges that need resolution before the approach can be fully functional. An improvement around these limitations will be able to generate additional practically useful information for decision-makers. In addition to the range of further research areas presented earlier, future work should also seek to develop the logistics performance assessment methodology empirically within a policy-making and a managerial decision-making scenario.

Note

1. https://www.sciencedirect.com/topics/psychology/wikis

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Appendix 1: Web-based multidimensional classifier training tool